IUFRO Research Group 3.08 Small-scale Forestry Conference

Small-scale and Community Forestry and the Changing Nature of Forest Landscapes

11 – 15 October 2015

Sunshine Coast, Australia

Conference Proceedings

Edited by John Meadows, Stephen Harrison and John Herbohn

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Brief note on the booklet

Welcome! This Proceedings booklet contains selected papers from the IUFRO Research Group 3.08 2015 Conference on Small-scale and Community Forestry and the Changing Nature of Forest Landscapes. The conference was organised by members of the Tropical Forests and People Research Centre at the University of the Sunshine Coast, with financial and logistical support from the University of the Sunshine Coast (USC), the Australian Centre for International Agricultural Research (ACIAR) and IUFRO including through the organisation's Special Program for Developing Capacities (SPDC).

The conference was a great success and the largest ever hosted by the IUFRO Small-scale Forestry Research Group. Over 95 presentations were made in the plenary sessions and topically themed concurrent sessions held over four days. The presentations explored in detail many of the complex socioeconomic and environmental issues, challenges and opportunities for the management of small-scale and community forests across the world. Over 100 delegates came from 21 countries from throughout Europe, Asia, the Pacific and the Americas. The resulting mix of people provided an exciting opportunity to explore different ideas and draw from a diverse range of experiences and perspectives.

This booklet includes the full papers from a small sample of the presentations given at the conference. The 16 papers comprise a range of topics covered in the themed presentation sessions, including Agroforestry Systems, Community Forestry, Forest Planting Stock, Timber Harvesting and Marketing, Forest Ownership, Extension and Incentive Programs, and Forest Governance.

Note that minimal review and editing of these papers has been undertaken. As with the abstracts published in the Conference Book of Abstracts, editing of these papers has been largely restricted to formatting for their presentation in a consistent style. While some editing of text has been undertaken, the final content rests solely with the authors.

We thank all of the delegates, including members of the Organising Committee, the Scientific Panel and the volunteers for contributing to the success of the conference. We also gratefully acknowledge the support provided by IUFRO, ACIAR and USC.

The Editorial Team – Dr John Meadows, Professor Steve Harrison and Professor John Herbohn.

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Cover photograph: View from Mt Coolum to Mt Ninderry and Yandina Station. (Photo: John Herbohn)

Contents

Removing Barriers to the Commercialisation of Agroforestry Trees in Nepal

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Abstract

Agroforestry has evolved as a part of the traditional subsistence farming systems in the mid-hills of Nepal. These farming systems are undergoing major changes brought about by the outmigration of male labour and resulting feminisation of the rural labour force. There has been inadequate agronomic development and serious food insecurity is a problem in Nepal. Of 75 districts, 42 have a food deficit. Most of these districts are in the mid-hills and mountain region of Nepal. Fortunately, the productive functions of trees in these agroforestry systems perform important subsistence functions of supplying firewood and fodder, and also present a resource that can be utilised to redress the trade imbalance of Nepal's timber products. However, there are many barriers to getting these trees into the market. This paper presents two agroforestry case studies of differing situations with respect to market integration of agroforestry products. It then analyses the barriers for advancing agroforestry, and draws practical policy implications for promoting commercial agroforestry, in Nepal. The first case study describes subsistence-level agroforestry systems including: fuel and fodder trees on terrace risers sustaining a few livestock; agropastoral systems on fallow land; and silvo-fishery, apiculture and sericulture. In most areas of Nepal agroforestry has not made major advances and all these practices by and large provide productive services at subsistence level only. There are however instances where agroforestry trees are well linked into industrial wood flows. The Government of Nepal is promoting small-scale woodlots or private forests as part of an agroforestry system. Adoption of private forestry in Nepal remains very low with only about 2458 registered private forests covering an area of 2333 ha. Despite this low registration, volume of timber extracted from private land is twice that from other sources (community forest and government forest). The second case study describes a situation where trees from private land are well linked into commercial wood flows and highlights the specific institutional arrangements that have facilitated this development.

Keywords: private forestry, food security, act and policies, innovative agroforestry practices.

1. Introduction

Agroforestry has been recognized as one of the important systems for supporting livelihoods in the middle hill population of Nepal. Agroforestry integrates existing farming systems along with innovations such as silvo-fishery and sericulture, and it is important for its productive, protective and regulatory functions. In Nepal, there has been inadequate agronomic development and serious food insecurity is a problem. The total number of food insecure people across Nepal is estimated to be 3.7 million. Of 75 districts, 42 have a food deficit, and 40% of the families have started to skip or reduce their meals (FAO, 2010).

The food deficit situation is extremely alarming in the Far- and Mid-Western Mountains. Additionally, there is an increasing trend of people migrating temporarily and permanently outside of their home country in search of a better life (Bhadra, 2007). A report suggests that more than 50% of Nepalese households have at least one member outside of household living in another district or abroad for various purposes (CBS 2011). Male migration has resulted in a significant level of land abandonment. Consequently, there is decreased food production at a local level and massive import of food (Adhikari and Hobley, 2011; Paudel et al. 2014).

There is however ample scope for agroforestry systems to be practiced in the country which can address the problem of food security to some extent. In this context, the Government of Nepal has taken steps in developing forestry for economic prosperity. The development of agroforestry science in Nepal literally began with the Fifth Five-year Plan period (1975-1980). It has stressed the contribution of forests to the economic, social and industrial development of the country. The Three Year Approach Paper (2013/14 -2015/16) currently in operation has also aimed to identify high value medicinal and aromatic plants, sustainable harvest, technology development, commercialization and marketing for economic development, environment protection and enhancing rural livelihood among others (NPC, 2013). The interim constitution of Nepal (2007) and Forest Policy (2015) have acknowledged the role of private forests and emphasized the private public partnership in developing forest entrepreneurship.

For management purposes, the Government of Nepal has classified forests into two main categories: National Forests and Private Forests. The ownership and control of National Forests lies with the government and that of Private Forests with the individual private tree owner. National Forests include all non-private demarcated or non-demarcated forest lands, paths, ponds, lakes or streams and river-beds inside such forests, and waste or uncultivated or unregistered lands surrounded by forest or situated near adjoining forests. For the management purpose, the National Forest is further divided into five categories:

1. Government Managed Forests
2. Protected Forests
3. Community Forests
4. Leasehold Forests and
5. Religious Forests

Although the policy, rules and regulations are in place private individuals are reluctant to plant trees on farmland. This is mainly because of the lengthy and cumbersome bureaucratic process that needs to be followed up, right from planting of tree seedlings to their harvesting and transportation. Similar is the case with non-timber forest products. At times, the government does place bans on the collection and selling of tree and herb species. Currently the timber species, Sal (*Shorea robusta*), Satisaal (*Dalbergia latifolia*), Okhhar (*Juglans regia*) and Bijayasal (*Pterocarpus marsupium*) have been banned for collection and trading (Report of the District Forest Office (DFO's) workshop, Kathmandu, 2015). Therefore, despite the potential of earning high income for the farmers and improving their livelihoods, most of the high value timber species that could grow on private land are not planted because of the complexity in following the rules and regulations. Nonetheless, private forests are contributing significantly to timber production and its flow in the country is quite substantial. Sawmills, plywood factories and other forest based enterprises are using timber obtained from private forests but no study has been undertaken in connection with the constraints of timber flow from private forests to sawmills and other wood-based enterprises. Hence, a case study has been undertaken to examine the contribution of private forests to timber flow in three districts of the country, and to explore the existing barriers that are hindering the commercialisation of agroforestry trees in Nepal.

2. The Study Site

This research was carried out in three middle hill districts (Kavre, Sindhupalchok and Lamjung) of Nepal. In Kavre and Lamjung districts, a joint project of Government of Nepal and Australia entitled "Enhancing Livelihoods and Food Security through Agroforestry and Community Forestry (EnLiFT) has been in operation since 2013 whereas Sindhupalchok is identified as satellite area for extension activities. Both Kavre and Sindhupalchok districts were the sites of the then Nepal Australia Community Forestry Project (Figure 1).

Figure 1: Location of research sites.

3. Research Method

Policy and regulatory documents including the periodic plans and recent forest policy of the government were reviewed. A total of 4 saw mills and 8 other wood-based entrepreneurs that are using logs from private and community forests including plywood, parquet and furniture were visited during the month of July 2015 (Table 1).

Table 1: Types of wood based entrepreneurs visited in three districts.

TYPES OF WOOD BASED ENTERPRISES	DISTRICTS		
	KAVRE	LAMJUNG	SINDHUPALCHOWK
• Sawmills	3	1	Not available
• Parquet/ Furniture	1	2	4

• Plywood	1	Not available	Not available

Source: field visit, 2015

These saw mills and factories were selected based on the type and their operating capacities. Detailed interviews with the sawmill owners were carried out following a semi-structured checklist (provided in Appendix 1). The mechanism of timber flows in these saw mills and wood-based entrepreneurs and factories from various sources (government forest, community forests and private forests) were observed and recorded. Discussions with respective factory owners have been carried out. One sawmill and two privately owned forest-based enterprises (one each in three districts) did not provide any important information except that they would procure timber from private forests. The study was carried out just after the massive earthquake in the country. Therefore, the presence of labour in some of the wood-based entrepreneurs was very minimal (only two persons).

4. Results and Discussions

4.1 Major Timber Species

Pinus species especially Salla (*Pinus roxburghii*) and other hardwood species such as Katus (*Castonopsis indica),* Chilaune *(Schima wallichii*) and the softwood Uttis (*Alnus nepalensis)* are the major tree species that sawmills procure as raw materials. Bhuwan sawmill located in Lamjung also procure Sal (*Shorea robusta*) trees as major raw materials.

Normally sawmills pay cash to the contractors who bring logs to the mill gate. The price varies with the species. Sal (*Shorea robusta*) fetches the maximum price followed by Champ (*Michelia champaka*) in comparisons to the other species. Details of the prices that sawmills and other forest-based enterprises are paying for the different species are provided in Table 2.

Table 2: Price of round logs varies with the type of timber species

	KAVRE DISTRICT		**SINDHUPALCHOWK DISTRICT**				**LAMJUNG DISTRICT**			
	Farm gate price for round logs (NRs)		**Farm gate price for round logs (NRs)**				**Farm gate price for round logs (NRs)**			
Name of forest based enterprise	**Uttis**	**Salla**	**Name of forest based enterprise**	**Uttis**	**Salla**	**Chilaune**	**Name of forest based enterprise**	**Sal**	**Chilaune**	**Chap**
Anilsunil	360-370	550-570	Jugal furniture	-	200-300	200-300	Bhuwan sawmill	2800	300-350	600-700
Araniko	350-410	550-600	Gaurati Bhimsen	500	500	400-500	Ramasa	2400-2500	1000	-
Triupati	300-400	500-600								
Shikar	400	560-600								

4.2 Timber Flow Mechanism

It has been found that almost all sawmills and forest-based entrepreneurs procure round logs from private forests (both registered and unregistered) (Figure 2). Only one factory located in Lamjung district procures round logs from Community Forests through a bidding process, but the volume is very small.

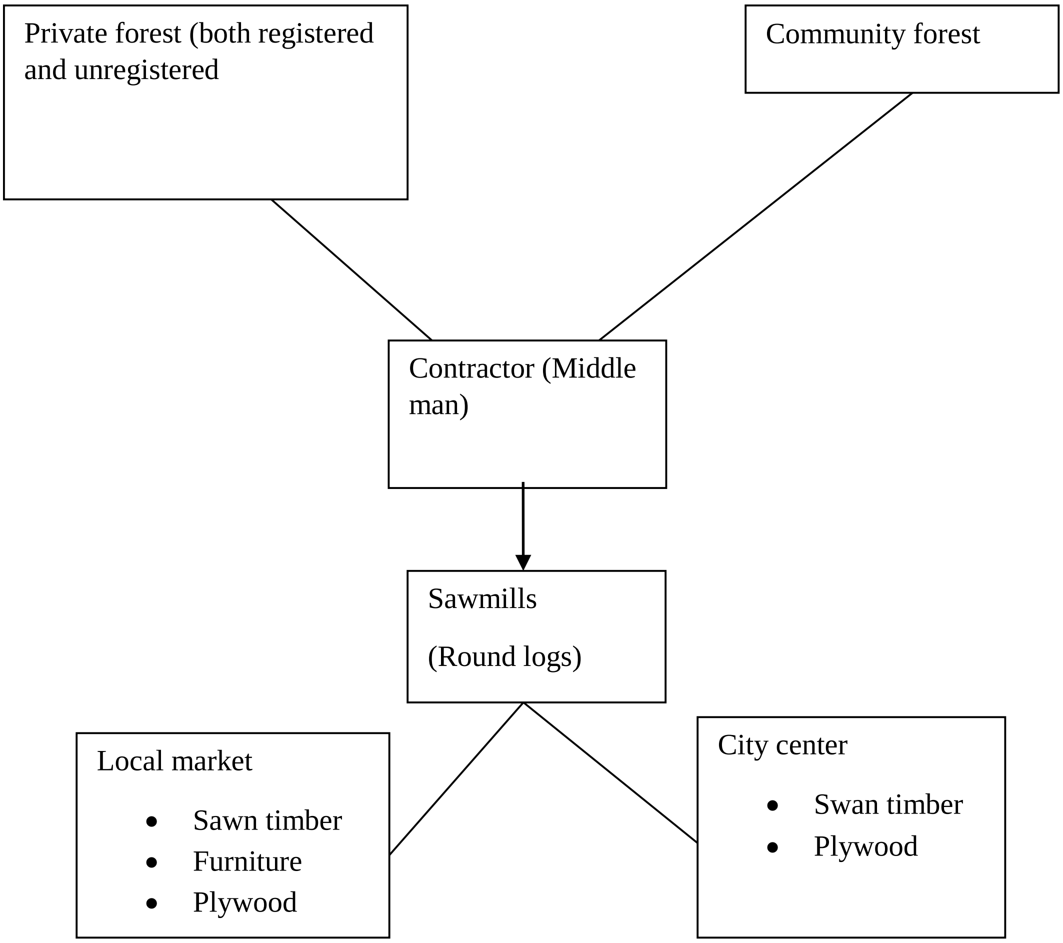

Figure 2: Timber supply mechanism

4.3 Use of Timber in Sawmills and Their Capacities

Most of the sawmills saw round logs in their mill using circular saws. The end product however varies. Some produce laminates and flitching for recutting, and others produce furniture as well (Figures 3-5). But Shikar plywood factory located in Kavre district uses timber exclusively for making plywood. The plywoods produced at this mill are distributed throughout the country under the brand name of ‘Shikhar’.

Figures 3-5: Various end products from sawmills (Lamjung, Kavre and Sindhupalchok).

4.4 Capacity of Sawmills and Wood-based Enterprises

Most of the sawmills have records of log productions for the current year only. It is very interesting that they don't have the records of previous years. However, all of the sawmills reported they were currently running below their production capacity. They are obtaining less quantity of timber as against their annual requirement (Table 3). This is mainly because of an unavailability of raw materials (round wood), inadequate supply of electricity and a shortage of labour. The labour shortage was because of the earthquake as labourers have left for their homes in India. It was reported during the interview that it is very hard to find skilled Nepali labourer for this kind of job. It is mainly because of out-migration of youth, and youths are interested in this type of work. Market demand for timber is very high and mill capacity is also good but due to the unavailability of adequate timber logs there is a limit on the annual production.

Table 3: Capacity of Sawmills and Wood-based enterprises

Name of the Sawmills	**Full capacity '000 cft.)**	**Current capacity ('000 cft.)**
1 AnilSunil (Kavre)	50-60	30-40
2 Araniko (Kavre)	60-70	20-25
3 Tirupati (Kavre)	50-55	15-20
4 Bhuwan (Lamjung)	5	4-5
Name of the Parquet /Furniture Enterprises		
1 Parquet production house (Kavre)	Not available	Not available
2 Jugal furniture (Sindhupalchowk)	10-15	10
3 Gaurti Bhimsen (Sindhupalchowk)	0.2-0.3	0.2-0.3
4 New Jugal (Sindhupalchowk)	Not available	Not available
5 Prabu (Sindhupalchowk)	5-7	0.8-0.9
6 Ramasa (Lamjung)	0.5	0.5
7 Basnet (Lamjung)	Not available	Not available
Name of the Plywood Enterprises		
1 Shikar (Kavre)	300-400	50-60

Source: Field visit, 2015.

4.5 The Role of Middlemen (contractors)

A middleman or contractor plays the vital role in procuring timber from private forests and community forests. Normally contractors act as a local agent but without any institutional identity. Private individuals do not support each other while supplying the timber. It is the contractor who performs all of the jobs for them. Generally, mill owners contact the local contractor. It has been revealed that all the paperwork such as tax paid receipt, approval letter from DFOs etc. required to procure logs from private and community forests is done by the contractor himself. The contractor has to satisfy the civil servant concerned and invest a large amount of money by themselves. The mill owner pays the price to the contractor and the contractor in turn pays the concerned farmer or private individuals according to the nature of the species and estimates of the timber volume.

The process of procuring timber from private individuals is through informal meetings and they estimate the volume of the tree by ocular estimation. The middleman, on an average, depending on the species and distance, pays the individuals. For example, they would pay NRs 1000 to 5000 per Utis tree (100-150 per cubic feet) whereas NRs 250-300 per cubic feet for Pine species. These middlemen receive almost double the price for timber from sawmill owners and capture 40-50 % of the timber market price.

4.6 The Role of Private Individuals

The role of private farmers has not been found very crucial in timber flow as private individuals are not involved directly in timber business. It is the middlemen or the contractors who deal with the sawmill owners and carry out all official formalities for them. However, individual farmers do call these middlemen if they think of harvesting some trees growing in and around their farm lands. There is no formal contract (on paper) between the contractors and, or, middlemen and an individual farmer. It is a verbal only agreement. The contractors pay the price to an individual farmer for his/her standing tree on an ad-hoc basis. The price varies with the type of species: pine species fetching about NRs 275-300 per cubic feet. *Alnus nepalensis* gets the lowest price (150-200) per cubic feet in comparisons to other species *Schima walichii* (200 NRs/ cubic feet). Individuals with trees on difficult terrain to work on would get less amount of money than at road heads. As farmers' estimation of timber volume varies it is likely that in most of the cases they did not get a 'good' price for their product.

Observation on farmers' field sites show that these trees are naturally grown. They don't seem planted and farmers also say that they haven't planted these trees but have come naturally on their own private but unregistered farmland. These farmers also do not know the age of the tree that they would harvest. They just estimate the girth that would give some economic return for them. It is the contractor that fells the tree and transports it to the mills. The cost of transporting timber to the mill gate depends on the distance of the farm to the mill gate and seasons of the year.

Farmers can cut their trees at any month of the year if they wish so but they are not supposed to sell the timber at sawmills or any other wood-based enterprise (even within the same district) during the four months of June 15 - October 16. Forest Regulations 1995 says that "*Timber and Firewood may be collected and taken out from the Forest area during the period between Kartik (October 17) to Jestha (June 14)"*. It does not however say from private forests, yet private individuals are not allowed to bring their logs/timber within this four months period as well. The cost of regulatory compliance is very high for the private individuals both in terms of their time and resources. They have to show various types of paperwork to the DFOs before they can get the permission of transporting the timber for sale.

A glimpse of the steps involved for selling and distribution process of private forest product is presented below (Figure 6). That being the case the private individual agrees to sell their timber produce at much lower rate to the middle man (the contractor) which could be more if they sell their products by themselves at the mill gate.

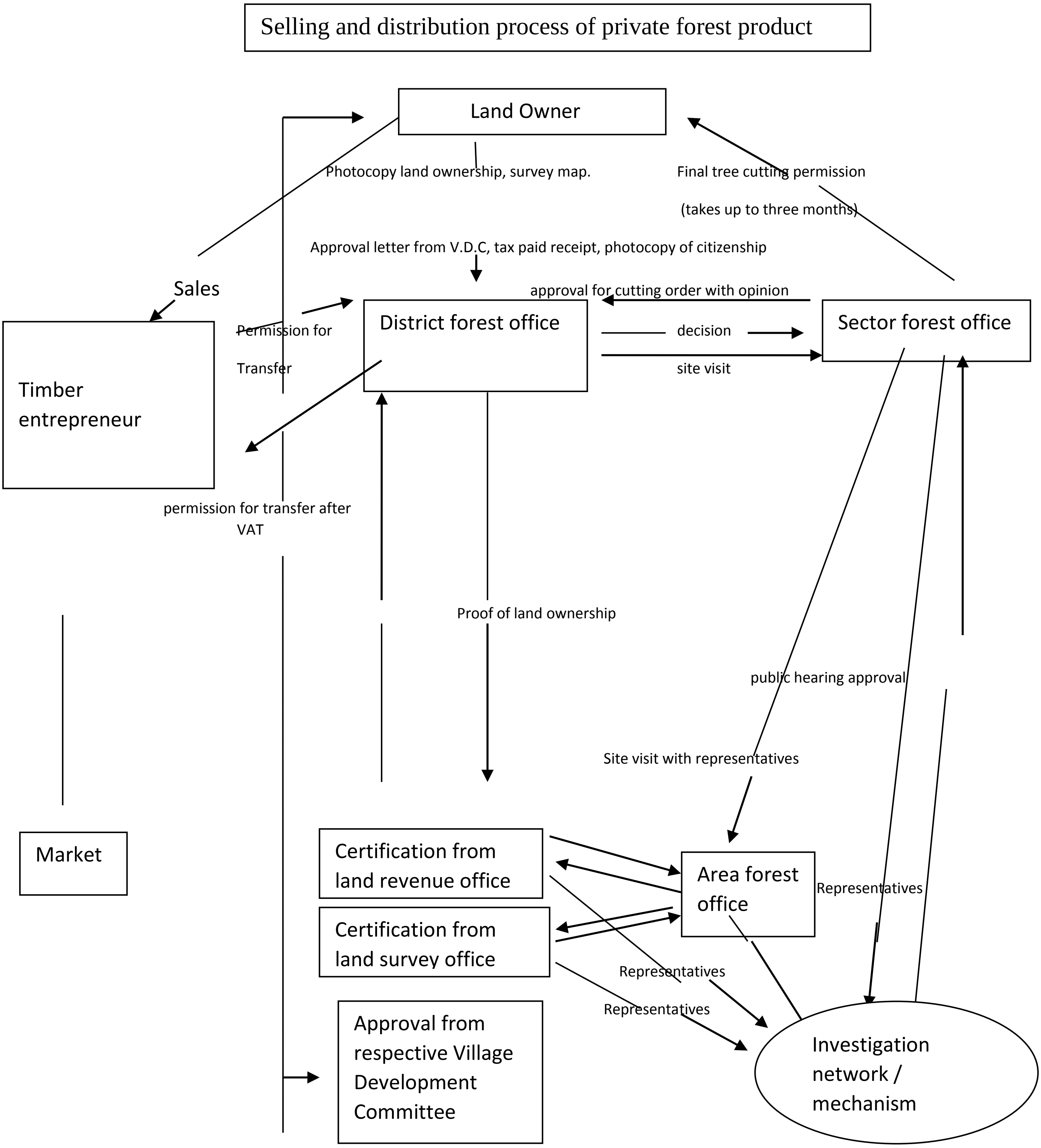

Figure 6: Selling and distribution process of timber from private forest

4.7 Management of Sawmills and Use of Sawn Timber

Most of the mills are managed by a single person and a few sawmills are partnership based. In most of the sawmills, local customers come to the mill to buy the sawn timber for their work. The parquet house located in Kavre district purchase timbers having very short length (less than 50 cm). They use these short sawn timbers for joinery purposes. Some sawmills have wholesale and retail shops. For most sawmills the final products are mainly furniture items (table, dining table, chair, bed, sofa sets) and other wooden structures. A very few sawn timber (logs) are sold within and outside the districts but most of the products go to city centres like Kathmandu, Dang, Butwal, Nepalgunj, Bhairawa, Biratnagar, Narayanghat and Jhapa.

5. Conclusions and Policy Implications

The lengthy administration process of harvesting and transportation of timber to sawmills is the most hindering factors for timber flow in the study area. People are not interested in planting trees on their private farmlands but they don't mind raising trees naturally on their unregistered land. That is why the number of registered private forest in the country is low, at around 2333 hectares only (DFO Workshop, 2015), but the flow of timber in local markets from private land is large (93073.9 m3) in comparison to other categories.

It has been observed that Pine species (mainly *Pinus roxburghii*) and other trees such as *Alnus nepalensis* and *Schima wallichi* are the main species that contribute to the running of sawmills in three districts of Nepal. However, in Lamjung district *Shorea robusta* is one of the prime species that help run sawmills. Almost all sample sawmills in Kavre district procure timber from Kavre, Dholakha, Sindhupalchowk and Ramechhap districts of the country. Interestingly, in Lamjung district most sawmills procure timber from community forests through a bidding process. It was revealed that procuring *Shorea robusta* is not an easy job for contractors. They have to pay a great deal of money to the local youth engaged in these types of jobs.

In private forests tree selection and felling is done by contractors and farmers whereas in community forests the decision is made by a community forest member. Contractors (i.e. the middle man) transport round logs to the mills and these contractors are paid on a per cubic feet basis depending on the tree species. Some sawmills have advanced technology. They have their own saws (band and circular) and other machines for peeling and flitching. Most of the sawmills are managed by single person: the owner. They normally sell their finished product in the large cities within Nepal. The market demand for sawn timber is very high but sawmills are not running to their full capacity. It is mainly because the unavailability of round logs and labour, and frequent power cuts. The administrative process for procuring logs especially from private forests have been found to be one of the major causes of sawmills running below their full capacity.

The Forest Act 1993 and Regulations 1995 are the legal instruments to translate the policy vision into practice. Forest Act 1993 categorizes national and private forests on the basis of ownership. Private Forest represents the forests or trees planted, nurtured or conserved in any private land that belongs to an individual as defined by the prevailing law. Two types of private forest are in operation in Nepal. One is the registered and the other is unregistered. And the framework of private forests is very different. A total of 10 different private forests types have been identified based on timber utilization (DFO Workshop, 2014).

Private forests are actually contributing to the national economy providing employment opportunities and raw materials for various types of wood-based industries. Their contribution to the national economy in terms of Value Added Tax (VAT) only is also very large (Table 4). Private individuals have to pay 13% royalty to the government while selling their timber products. The quantity of timber sold from private forests and the collection of tax in different fiscal years is shown in Table 4.

Table 4: Quantity of timber sold by private forest and collection of tax in different fiscal year

Fiscal Year	Timber sold (m^3)	Revenue collected by the Gov. through Value Added Tax (U.S $)
2065/66	70126.17	752645.93
2066/67	76776.	777159.25
2067/68	73004.8	527253.74
2068/69	88160.9	833435.22
2069/70	93073.9	1232136.22

Source: *Hamro Ban*, 2069/70, Department of Forests, Babar Mahal.

The quantity of timber sold from government forests, community forests and private forests, and the collection of revenue in the fiscal year 2069/70 is very high in comparisons to other type of forests (Table 5).

Table 5: Glimpse of timber sold by forest management type

Types of forest	Quantity of Timber sold (m^3)	Revenue obtained (U.S $)
Government forest	22532.8	6988983.15
Community forest	10509.2	718168.94
Private forest	93073..9	1232136.21

Source: *Hamro Ban,* 2069/70, Department of Forests, Babar Mahal.

Private Forest Development Directives 2011 (the directives) published by the Department of Forests in the year 2013 (with amendment) has provisioned the private forest registration procedure. These procedures are lengthy and difficult to abide by in practice. Individuals wishing to register private forests have to abide by the following important steps.

Step 1: Submission of application to the office of the District Forest Office, or Ilaka Forest Office or Range Post.

Each application must include the following documents:

- Area covered by private forest,
- Type of tree species planted,
- Age of planted trees,
- Number of trees planted,
- For Non-Timber Forest Products and Medicinal and Aromatic Plants, the area covered by it,
- Land ownership certificate,
- Receipt of payment of previous year's land tax, and
- Photocopies showing the land registration number and land map.

Step 2: Investigation procedure.

- Intensive investigation process over the application by the office of the District Forest Office,
- Inviting individuals, institutions and local-level government agencies as appropriate to find out the fact,
- Investigation process could lead to field verification and inquiry with a representative of the Village Development Committee and Municipality as deemed necessary,
- For private forests adjoining national forests and government land, authorities will have to inspect the land and the cost involved for these activities has to be borne by the private individuals,

- For the entire investigation process 52 days have been allocated but in practice it may take longer than that.

The most hindering factors in private forestry are the provision of permission for tree harvesting and transportation. Some of them are:

- If an individual wishes to harvest trees planted on their own private land they must inform, at least one day before commencing, the concerned DFO office/ Illak Forest office or Range post with the recommendation from the concerned Village Development Committee and Municipality,
- In the case of trees felled for commercial purposes, the private individual must provide details of the number of felled trees, their type and volume to the concerned DFO office/ Illaka Forest office and or Range post,
- In the case of private unregistered forest and those adjoining the national forest, an investigation from Range post is necessary before felling and if deemed necessary land survey authorities must be invited and private individuals have to pay for the entire service charge incurred for those activities,
- If the private individuals wish to transport trees outside the district of the tree's origin, then permission has to be obtained from the District Forest Office,
- Individual has to give priority to 26 types of tree species to plant on their private land.

Farmers have limited access to improved tree seeds, new technologies and market opportunities. Hence these elements should be addressed. A DFO's workshop held in 2015 in Kathmandu also identified the following points as constraints to developing and commercialising agroforestry trees in the country:

- long process for private forest registration,
- irrelevance of whether the forest is registered or not,
- a lack of supportive technological and financial systems,
- due to government circular, cutting different species of trees and restriction on transporting,
- difficulties collecting, selling and transferring of forest product from private forest,
- difficulties in transferring the forest product due to the collection of illegal donations from local club, different group, jerks and government unit,
- expenses in gaining approvals from the village development committees for tree cutting,
- limitations of fragmented forest
- farmers receiving low returns due to the due presence of marketing middlemen,
- limited knowledge of suitable species
- unavailability of planting stock (to meet demands),
- no effective law and protection policy for private forests,
- no insurance and finance service,
- no union of owners of private forest,
- lack of suitable development program and support for private forest growers,
- some single industrialist and businessman have price monopoly, and
- lack of geographical and climatic investigations into species suitability.

Agroforestry practices can embrace a wide variety of plants. Pandit et al (2014) has recorded a total of 145 different species including 56 species of medicinal and non-timber plants in their study sites. There is much scope for increasing productivity of both agriculture and forestry for increased benefits to the farming communities. Hence, the government of Nepal should focus on growing of agroforestry species on private land and removing or minimizing the practical difficulties cited above.

Because of the barriers mentioned above farmers are reluctant to raise trees on their farmland and implement agroforestry systems. Hence, its potential contribution has not been analysed in detail. There could be a great deal of contribution in terms of Gross Domestic Product from private forests. Planting trees on private land including fallow lands could be a turning point for generating employment opportunities, checking out-migration, enhancing food security and improving an ecological balance including minimizing the effect of climate change.

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Appendix 1: Questionnaire check list

1. **A typology of mill technology**: i.e. are they peeling for laminates, flitching for re-cutting to smaller sizes elsewhere, milling boards to specification sizes;

2. **Details on tree production.** Collect species data, and if possible good to whether trees are from naturally regenerated stands, intentionally planted in woodlots / private forests; from farmland (terrace risers).

3. **Details on mill production capacity.** How much does the annual production vary from year to year? How much does production vary across seasons of the year?

4. **Supply-demand dynamics.** Is the limit on the annual production caused by supply of timber from farms, or mills technical capacity or market demand?

5. **Contracts with farmers.** How is the relationship between farmer and mill established? Does grower approach mill or other way around? What formal contracts are made? How is price determined? How is farmer paid?

6. **Regulations.** What paperwork and payments does the farmer and the miller have to make to the DFO or other agencies? What is cost of regulatory compliance?

7. **Supply chain responsibilities.** Who selects trees for felling? Who fells the trees? Who transports trees to mill? Who transports mill products to customers? What is cost of transport relative to stump price of tree?

8. **Mill ownership.** Who are owners? Are they owner-operator companies, or are the owners wealthy investors in KTM or India or China etc. Do owners have more than one mill in other areas?

9. **Customers.** Who are the customers? What arrangements exist between mill and customer? Does the owner of the mill also own the wholesale & /or retail steps in the supply chain? What are the final end products and the destination of the timber from these mills?

10. **Formal and informal institutions.** Do farmers collaborate in helping each other supply timber? Are there formal cooperatives? What is relationship between this flow of timber from private land and that from community forests? E.g. Are CFUG member's also supplying private trees and using CFUG facilities, institutional connections etc.?

Forest Extension in the Eastern Highlands of Papua New Guinea.

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Abstract

The Eastern Highlands of Papua New Guinea are experiencing a severe shortage of firewood. Residual native forest and some plantation forestry are insufficient to supply this need. In response, in October 2014, the Papua New Guinea Forest Authority (PNG-FA) undertook a three-day training program in the township of Goroka. Farmers received training in nursery techniques including seed collection, preparing nursery beds, germinating seedlings and out-planting seedlings. Farmers were supplied with seed, shade-cloth and polybags to start their own home nurseries. Follow-up interviews found that nine of thirteen participants had raised seedlings. However, for those farmers living outside of the Goroka environs, problems have emerged. A severe shortage of seed has resulted in farmers using inappropriate *Pinus* species. In PNG, land is often community-owned but managed by individual farmers. Long-term tenure is therefore subject to negotiation between clan members. Technology sharing is also not common between clans. In the grasslands, fire is always a problem. These findings indicate a need for an approach to forest extension which accommodates a low rate of technology diffusion between clans and in which farmers in remote locations receive almost one-to-one follow-up extension assistance and access to seed, and guidance to inter-crop planting patterns which provide protection from fire.

Introduction

There is a critical shortage of firewood in the Eastern Highlands of Papua New Guinea. Small bundles of firewood (approximately 5 pieces by 60 cm long and 5 cm wide) sell for five kina (K5) at the local markets. The Eastern Highlands landscape is dominated by imperata grassland due to deforestation which is causing local rainforest to retreat to mountain slopes. Winters in the highlands are cold and many families are in need of firewood for heating. The problem is exacerbated by a demographic shift in the highlands in which people who live in remote locations are moving to town centres in search of work (Paul, 2012). Typically these people live with their extended families, resulting in increased local requirements for firewood. Many local people have no option but to use firewood as their basic source of heating and cooking. Purchasing firewood is a major expense for many people. Several aid programs have tried to address people's fuel-wood needs through community-based nurseries (Gio, 2011). However, the short duration of most aid programs has resulted in many project nurseries closing once funding ceases. The infrastructure costs required to set up these nurseries can be several thousands of kina. This amount is far beyond the financial capability of many rural farmers.

In response to this problem the Papua New Guinea Forest Authority (PNG-FA) currently distributes seedlings to farmers (and churches, schools, individuals and Non-Government Organisations) whenever seedlings are available. However, seedling distributions do not result in nursery technology transfer to farmers in a manner which will make them self-reliable (Harnath, 1989). To remedy the situation, the PNG-FA (Goroka) decided to undertake research to investigate whether small home nurseries may be viable for individuals and communities. The underlying premise of extension activities was to train farmers in nursery techniques so that they could establish their own home nurseries themselves or pass the training on to others. The second requirement was that no finance and very little material would be supplied, thus avoiding the possibility that participants may join the training program purely in the hope of material gain.

In this paper we present the results of research that was undertaken to investigate the usefulness of small home-based family nurseries as a means of assisting farmers to grow timber trees for domestic use. In the next section we present the methods we used to train farmers in basic nursery techniques. We then present the results of the training program and an analysis of our results in terms of the socio-economic context of small-scale farmers of the Eastern Highlands of PNG. Finally, we discuss implications of our work for nursery extension in PNG.

Research Methods

In November 2014, PNG-FA staff provided a three-day live-in nursery extension training program in Goroka Township. Participants were recruited from PNG-FA records of people who had approached the FA for timber tree seedlings. Fifteen participants were invited to attend the program at the house of a local tree farmer. These fifteen farmers were representative of the types of farmers found in all the six districts of the province. During the course, participants received formal training delivered by foresters. A key aspect of the training was hands-on practical exercises which resulted in demonstrated competence of the skills being imparted. The training covered the following topics:

Seed collection, extraction and storage - the three common tree species planted in the PNG highlands (i.e. *Eucalyptus grandis*, *Pinus strobus* and *Casuarina papuana*) were used. Seed collection and extraction methods for each of the species is demonstrated and seed is stored in small containers;

- Preparing seedling trays;
- Germinating and transplanting seedlings;
- Watering and fertilizing;
- Weeding and hardening;
- Out-planting and management; and
- Constructing a nursery from materials that can be commonly found in rural communities.

At the conclusion of the course, the participants were given seed of the three tree species, poly-bags and a 50cm sieving wire. Follow-up site visits, interviews and phone calls were undertaken to record participants' progress, problems and their plans for further reforestation.

Results

It was found that four participants had established large nurseries capable of growing several thousands of seedlings per year. These participants have become actively involved in distributing seedlings to their wantok[1] and have told FA staff that spreading tree growing technology becomes a social obligation. Apart from the free will of the distribution of seedlings to wantoks, three thousand seedlings were sold to local schools and the public during the World Environment Day.

Subsistence farmers

Phone interviews also indicated two subsistence farmers had grown seedlings and distributed them freely to community members. These 51 community members are affiliated to their village cooperative group and were given twenty seedlings each.

Of the 15 participants, 14 had initiated nurseries in their home gardens (see Table 1). The common feature of the participants is that they had all successfully raised tree seedlings and had transferred the skills and knowledge acquired during the nursery training. Generally, the farmers with large nurseries wanted to plant everything but constraints such as transportation of seedlings and limited finance for labour employment are setbacks in establishment. For example, one participant wanted to transport nine thousand seedlings for a 200-hectare landmass establishment but transportation has been a constraint. Furthermore, to sustain their nursery production, some of their seedlings were sold to partner organizations and the public. On the contrary, subsistence farmers had planted almost every seedling and also have distributed seedlings to their siblings and extended families.

The only secondary school involved had commenced teaching forestry as an instructional course with the help of FA staff giving supplementary notes on all aspects of forest silviculture. A permanent nursery is now planned because a forestry course is now a full time course unit, but this nursery is yet to be established.

Table 1. Characteristics of Fourteen of the Nursery Training Participants

Participant	District	Driving time from Goroka township	Occupation	Number of seedlings raised / planted
A1/ A2	Daulo	70 minutes	Teacher/house wife	2000 / 2000
B	Asaroka	15 minutes	Businessman	600 / 400
C	Asaroka	15 minutes	Secondary school	NA
D	Goroka	10 minutes	Retired Teacher	3000 / 1000
E	Goroka	10 minutes	Church-employee	9000 / 200
F	Goroka	25 minutes	Pastor	3500 / NA
G	Goroka	25 minutes	Activist	3000 / 1000
H	Unggai	45 minutes	Politician	6000 / 2000
I	Ungai	20 minutes	Student	300 / 200
J	Ungai	20 minutes	Subsistence farmer	1000 / 700
K	Ungai	20 minutes	Subsistence farmer	500 / 200
L	Okapa	120 minutes	Subsistence farmer	800 / 800
M	Okapa	120 minutes	Subsistence farmer	700 / 700
N	Benna	35 minutes	Retired Soldier	NA deceased

[1] Wantok in *Pidgin* refers to close relatives but also extended family and friends.

Participant's acceptance of nursery technology

A follow-up visit in April 2015, 6-months after the training, found that the average number of seedlings raised was 2040. The smallest number was 300 and the largest was 9000. The species planted were Pine, Casuarina and Eucalyptus. Typical reasons for planting were for firewood, for future generation, reforestation, timber and poles, boundary demarcation and combatting global warming. Some farmers passed on skills to others and gave some seedlings to their community members. Of the 15 participants, 14 proceeded to germinating seedlings and accepted the training and established their small home nurseries.

Problems in raising and transplanting seedlings

The subsistence farmers, especially those who live in remote locations were faced with a number of challenges:

- Seeds; farmers cannot access Pine seed. This has been especially problematic for farmers from grassland areas where they know the pine trees will perform very well.
- Material; the cost of purchasing basic materials like poly bags and shade cloth.
- Limited finance; PNG today is a cash society where money will drive community forestry activities.
- Fire; is a main setback for grassland communities for establishment of woodlots.

Participant demographic characteristics

We found that participants could be described as either wealthy farmers or subsistence farmers who live in remote areas and close to Goroka Township. The first group began tree growing out of a passion or a business interest and had possessed available finance, manpower and materials to continue extension. The training had encouraged all participants to construct the same scale of nursery; however, we found two cohorts of people. The first cohort consisted of farmers who had constructed nurseries which were typically capable of growing several thousand seedlings, for planting as a hobby or for sale. They are innovative and creative, persistent in order to continue their nursery production regardless of any setbacks. The second cohort were those farmers that did not have enough money to continue their nursery, in terms of material purchases and access to seeds. Accessibility to services is difficult due to remoteness of their locality, poor road condition, and an inability to access seed trees. Because the second group are highly vulnerable in PNG society, they have been identified as targets for future extension work.

Discussion and Conclusions

Our findings indicate that formal instruction delivered in a three-day live-in course, including competency training, is an appropriate instructional method for PNG farmers. The high percentage of farmers who accepted the training (growing their own seedlings) also indicates the farmers are ready and willing to accept new techniques and interventions. In particular, our findings indicate the farmers have the motivation to construct small home nurseries themselves. In contrast to the failure of some larger community-based nurseries when funding eased, our research indicates that farmers have the motivation to grow their own seedlings. However, a lack of materials particularly seeds would appear to be a major constraint. For subsistence farmers living in remote areas, the cost of accessing government services (i.e. seeds or tree seedlings) from the PNG-FA may require a trip to a local town at a cost of an average weekly income. If these people are to be engaged with new technology, our research indicates that it must be taken to them. The implication of this research for the current situation in PNG is that frequent visits and mentoring will substantially help farmers. Small inputs of targeted assistance to help the farmers overcome problems and constraints are essential to maintain their motivation and enthusiasm.

In conclusion, we found that farmers were willing to solve most of their problems. One of the interesting findings is that extended family members or in a wider context the clan system, imposes mutual obligation on its members. In PNG culture, sharing is restricted to extended family members and people in close social proximity. Generally speaking, clans are competitive in natural resource management. However, in this instance, clan-based obligations have resulted in diffusion of the seedling nursery technology to other locations. Technology diffusion occurred both in their communities as well as other neighbouring villages where a relationship has been established through inter-marriages, family ties, and a mutual brother-sister relationship. An unexpected finding was that our research found two examples of cross-clan cooperation – one of an activist local leader cooperating with all her neighbouring clans, and another of a keen tree farmer diffusing the nursery and woodlot establishment technology to another province. These communities have large areas of unused grassland and afforestation is a real need for them. The challenge is to facilitate this process

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EnLiFT Model 1.0: A Livelihood and Food Security Model of a Forest-Farm System

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Abstract

This paper presents the concept, specification and calibration of a systems model for temporal simulation of a forest-farm livelihood system. The model has been developed to examine the level of food security of the forest-farm livelihood system in Nepal and to identify interventions to increase household income and food security. The model framework consists of five modules: annual crops, tree and understorey, livestock, community forest and Food Security Index. The household activities are categorized into the four aspects of food security: availability, access, use, and stability of supply. The model can be applied over 6 household types based on caste and wealth. This typology was derived from cluster analysis of data from a survey of 668 households in 6 villages in 2 mid-hill districts. An example is presented from simulation runs of one type of household – a capital-rich Janajati household for four selected agroforestry production scenarios. The simulation experiment reveals strong relative significance of the tree-understory module on household food security and the crucial importance of off-farm income and remittances from overseas.

Keywords: agroforestry, community forestry, forest and farm linkages, systems modelling

Introduction

The role of integrated forest-farm systems in ecological sustainability and food security has long been recognised (Swaminathan 1984). Initial research on agroforestry had focused on biophysical aspects of agroforestry systems particularly soil improvement, fertility management and crop yield (Nair 1998). The scope however of agroforestry research has broadened over the past two decades to cover economic and social aspects (Montambault and Alavalapati 2005) due to realisation of imperatives of social and economic aspects in advancing agroforestry adoption (Nair 1998; Rochelau 1998) to deliver the promise of eradicating poverty and hunger in developing countries (El-lakany 2004; Garrity 2004). Agroforestry as a science has become an inter- and multi-disciplinary endeavour integrating ecological/biophysical and social/economic/policy aspects to address livelihood and environmental issues (World Agroforestry Centre 2013).

Agroforestry has traditionally been the science and practice of incorporating trees, agricultural crops and livestock either simultaneously and sequentially on the same piece of land. With the increasing body of knowledge arising from agroforestry research, agroforestry is now described as a “dynamic, ecologically-based, natural resource management system that, through integration of trees on farms and in the agriculture landscape diversifies and sustains production and builds institutions" (World Agroforestry Centre 2013, p. 7). With this definition, agroforestry researchers are not only looking at systems where trees are integrated into agricultural cropping systems but are now looking at the interactions and interplay of 'off-farm trees' and forests with integrated tree-crop-livestock systems and the general livelihood and food security implications. Analysing agroforestry as a linked forest-farm system is indispensable because of the immense role of trees and forests on individual households livelihoods (McNeely 2004) as well as the environmental services trees and forests provide at the landscape level (Mbow et al. 2014a). For agroforestry to contribute to food security, social wealth and climate change mitigation, understanding the components and process flows in changing agriculture landscape is essential (Mbow et al. 2014b).

The crucial role played by linked forest-farm systems on livelihoods is prominent in Nepal. Nepalese agroforestry exhibits a heavy reliance of livestock on fodder trees as feed and on manure and forest litter for maintaining soil fertility (Amatya and Newman 1993; Garforth et al. 1999; Palikhe and Fujimoto 2010). Farmers cultivate maize, wheat and millet on their farms that are commonly terraced and bounded with fodder trees. Fodder trees stabilise the terrace risers and provide a major source of feed for livestock (Pandey et al. 2009; Amatya, 1990) constituting up to 70% of dry matter intake for large part of the year (Degen et al. 2010). The economic and ecological benefits of agroforestry are well documented in Nepal, (e.g. Amatya and Newman 1993; Gilmour and Nurse 1991; Malla 2000; Nuepane et al. 2002; Nuepane and Thapa 2001; Pandit and Thapa 2004; Acharya 2006; Regmi and Garforth 2010; Baral et al. 2013; Pandit et al. 2014). But these studies consider Nepali agroforestry systems as rather independent and self-sustaining systems of the landscape.

While the role of trees on farming and livelihoods is widely documented, the interplay of farm trees and tree resources outside farms (i.e. community forests in the context of household agroforestry system and stability) is understudied. The contribution of tree biomass from community forests to household needs is substantial. For example, Balla et al (2014) estimated an average of 528 kg to 2162 kg of forest litter per year is collected by a household in Mustang and Kaski districts in Nepal, respectively. Most of this forest litter is used as bedding material for livestock and later combined with manure to produce compost for application to field crops, while some forest litter is directly applied on field crops. The amount of fuelwood collected from community forests is estimated at 44% of the total household demand while fodder and grass is 27% (Adhikari et al. 2007). Timber demand by rural households in Nepal is generally met from community forests. Lamichhane (2009) identified the major domestic uses of timber in the midhills are (i) construction of house, for the households affected from natural hazards (flood, landslide and fire); (ii) making agricultural tools (plough, yoke, and handles of various tools); (iii) building new houses in the case of separation within families; (iv) repairing houses; (v) building and repairing cattle sheds; and (vi) public construction and developmental activities. Moreover, the availability and access of forest products from community forests has been found by Oli et al. (2014) to strongly dictate households' agroforestry practices in Nepal mid-hills.

Despite the inextricable link of forest and farm systems in most landscapes, most studies to date analyse agroforestry and community forestry separately, and the focus has been on tree and crop interactions. Some well-known examples of these early models include WaNuLCAS (van Noordwijk and Lusiana 1999) and APSIM (Keating et al. 2003; Huth et al. 2003).The FALLOW Model developed by ICRAF/World Agroforestry Centre simulates land-use decisions made by households where the system's performance is measured by carbon stocks, food security and biodiversity (van Noordwijk 2002). These models are all great tools for evaluating agroforestry systems productivity using economic and ecological function indicators but do not capture the subtleties of livelihood processes in the forest-farm systems.

Inspired by WaNULCAS and FALLOW models, EnLiFT Model - a model of a linked forest-farm system, has been developed to explore agroforestry and community forestry technical and policy interventions that might improve livelihood and food security at household and landscape level. This paper presents the concepts and specifications of the EnLIFT Model and provides an example of the model calibrated for a typical household in the Nepal mid-hills. The next section provides an overview of the forest-farm system. Description and specification of the EnLiFT Model constitute the remaining portion of this paper. A short section is provided to conclude the paper with a brief outline on what the model has achieved and a short note of further modelling work.

Overview of the Forest-Farm System in Nepal and Choice of Modelling Platform

Livelihood and food security improvements are the major driving forces for development programs over the last few decades. The concept of livelihood is understood as comprised of capabilities and assets (material and social) required for a means of living (Chambers and Conway 1992). The first aim of any household's livelihood strategy is to achieve food security which the World Food Summit (FAO 1996) described as having access to sufficient, safe and nutritious food to maintain a healthy and active life at all times. Two general dimensions in understanding of 'livelihood' have emerged from the plethora of livelihood studies – these being 'materialist' and 'group centred' (Upreti et al. 2012). A 'materialist' understanding of poverty is concerned mainly with understanding poverty, development, vulnerability and coping strategies while a 'group-centred' approach is concerned with identity and exclusion/inclusion. The EnLiFT Model falls within the 'materialist' understanding of livelihood such that, it is concerned with examining allocation and management of resources of a farm-forest system that would provide the best livelihood outcome. The version of the model reported herewith is a household-level model but it is envisaged that a community-level model will be developed as a project sequel.

The forest-farm system in the Nepal mid-hills is idealised in Figure 1. The farm-forest system is generally comprised of the food production system in private land and forest production on public land being aggregated at household level. While trees are common on private lands, availability of tree products varies between seasons and among household socio-economic status. At times when on-farm tree products are scarce, households make up the deficit from community forests creating the indispensable link of the farm and forest systems. As represented in Figure 1, community forestry contributes to food security through enhancing livelihood capital which is translated as 'purchasing power' in a strict economic sense. Figure 1 is a generic representation of the farm-forest system of a household in a community in the mid-hills of Nepal indicating the key components and areas for improvement. The text beside the arrows and boxes are issues of concern in analysing the flows and relationships. The model is implemented in Stella® software because of its capability as both a modelling too and a communication tool. The section that follows describes the concepts and formulation of the EnLiFT Model.

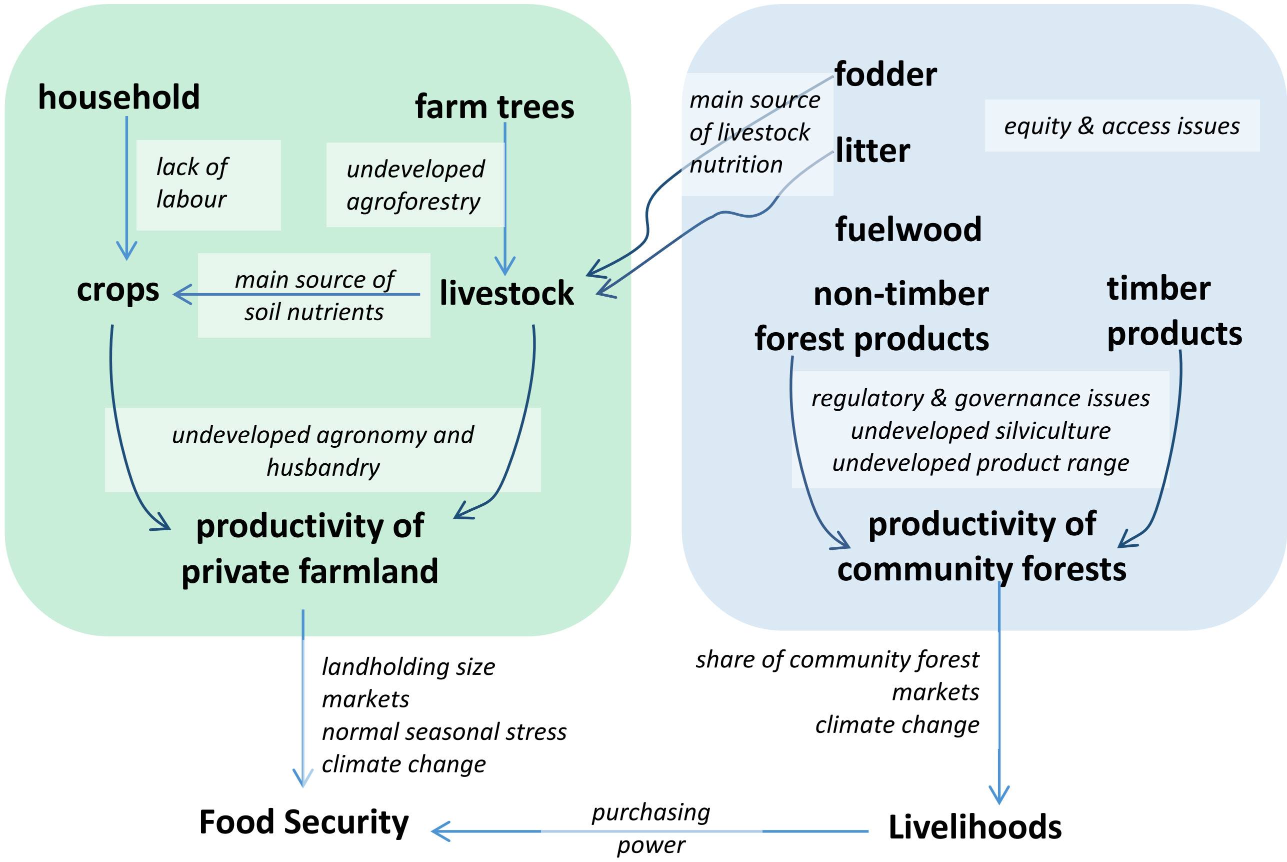


Figure 1. Idealised representation of the forest-farm system in the Nepal mid-hills including identification of areas for improvement.

Description and Specification of EnLiFT Model

Food security in the model

EnLiFT version 1.0 is a model designed with Stella® programming language that aims to simulate food security at the household level in agricultural landscape of the mid-hills of Nepal. The main aim of the model is to simulate resource allocation by farmers at the household and landscape levels with regards to their farming components, i.e. bhari (rainfed terrace), khet (irrigated terrace), kharbari (rainfed upland grazing area) as well as community forest. Thus, operating at a yearly basis was deemed to be more practical compared to simulating agricultural productions at a daily level. Household activities include:

- Cultivating annual crops with a maximum 4 different plots and 3 seasons per plot per year. Annual crop types can be different between seasons.
- Cultivating trees and understorey or adjacent crops in a maximum of 3 different plots and with a maximum 3 different kinds of tree species within the plot namely that for timber, fodder or non-tree forest product (NTFP, e.g. banana and broom grass), and 2 different types of understorey or adjacent crops (e.g. ginger and turmeric).
- Raising a maximum of 4 different types of livestock namely poultry, goat, cattle or buffalo and by sex type, and deriving income from selling the livestock into the market or their products such as milk, processed milk products, or eggs.
- Collecting products from community forests such as fodder and bedding materials for livestock, firewood for processing milk products or household activity (e.g. cooking), and buying trees for the timber.

- Obtaining income from other resource such as under-utilized land (UUL), remittance, pension, or skilled jobs and spending this money on food, non-food, education or health.

The model thus consists of five modules: annual crops, tree and understorey (agroforestry system), livestock, community forest and saving (Fig. 2). The household decisions can be categorized into the four aspects of food security:

- *Availability*: cultivation of annual crops, trees and understorey species and raising livestock to get yield and product;
- *Access*: part of the yield of annual crops and agroforestry systems (e.g. fruits), and livestock products such as milk and eggs are allocated for the household private consumption. In case of shortage, they can buy in the market;
- *Use*: the allocated product and those purchased from the market are used for private consumption;
- *Stability*: the model calculates the agricultural yields, livestock products, and the amount of savings every year along simulation time and the trend in the outputs can describe the stability of the household food security.

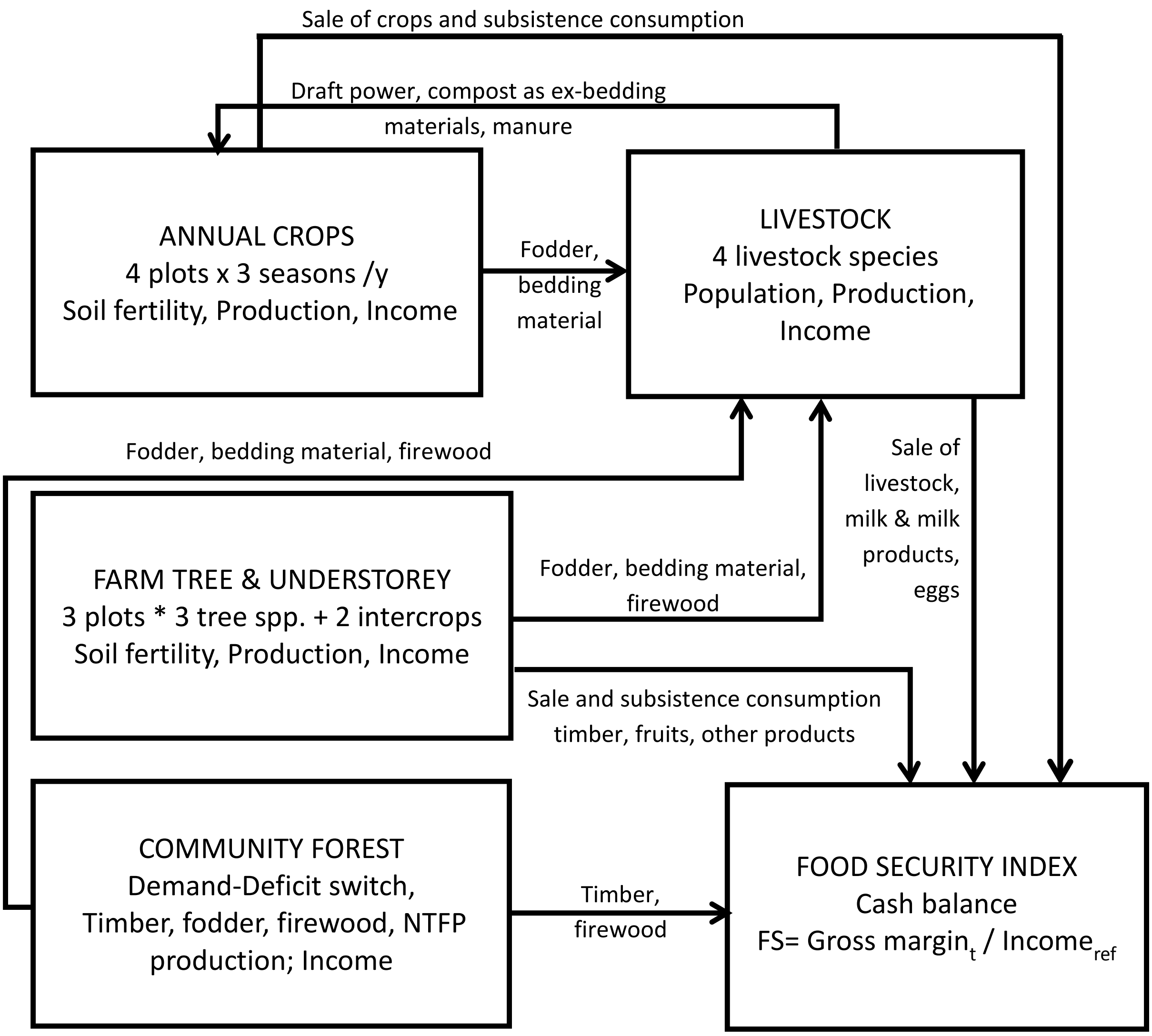


Figure 2. The five main modules of EnLiFT model version 1.0 and the interactions between modules

Dynamic aspect in the model

The model allows change in land allocation for components of the agroforestry system and product price (e.g. price of yield or fertilizer) across the year. The yield of tree and understorey components in the system varies across time depending on the growth stage. The model allows different plot areas, product prices and yields of perennial plants across 25 years (i.e. rotation for timber production). This dynamic aspect in the model allows users to design different scenarios related to land allocation, market mechanisms and plant productivity. Other dynamics in the model can include:

- Scenario of inflation in product price by a certain rate across the year;
- Introduction of higher quality propagules or improvements in planting or harvesting techniques can be translated as higher productivity of trees or understorey across a year or during productive periods of plant growth;
- Climate change modifies the pattern of plant growth. This can also be translated as a decrease or increase in plant productivity across year.

Annual Crops Module

There are a maximum of 4 plots of annual crops that can be simulated simultaneously by the model, and each plot can consist of a maximum 3 seasons per year. Key aspects of the annual crops module are soil fertility, production and income.

Soil fertility

Soil fertility in the plots of annual crops is modelled following the Trenbath principle (Trenbath 1984, 1989; van Noordwijk 1999) and measured in the scale of 1 to 5. The value depends on soil type (i.e. represented by inherent or maximum fertility of the soil type), natural soil recovery (i.e. recovery not because of fertilizer), and fertilizer application. Natural recovery is a function of maximum and actual soil fertility, and half-time recovery that is the time (in years) needed for the soils to achieve half of their maximum fertility:

$$\delta_{recov} = \frac{(fert_{max} - fert)^2}{(1+h_{1/2}) * fert_{max} - fert} \qquad (1)$$

One unit decrease in the soil fertility scale is equivalent to a production level ($yield_{pot}$, ton ha^{-1}) and to an amount of loss in organic matter (SOM_{ref}, ton ha^{-1}). Therefore, soil recovery by fertilizer input is the ratio between the sum of organic and inorganic fertilizer input (assumed to be equivalent with SOM) and SOM_{ref}. The soil fertility thus can be recovered naturally or by fertilizer application.

Actual soil depletion is a function of current soil fertility and constant depletion rate:

$$\delta_{dep,t} = fert_t * \varepsilon_i \qquad (2)$$

The default value for the constant soil depletion ε of soil type i is 0.2 and the default maximum soil fertility is 5. So, if current soil fertility is 5 (i.e. at maximum level) then the soil depletion is 1. It means actual yield will equal potential yield because:

$$y_{act,i} = y_{pot,i} * \delta_{dep} \qquad (3)$$

If the current soil fertility level is 4 while maximum fertility is 5 and ε equals 0.2 then soil depletion is 0.8. It means actual yield equals 80% of potential yield and so on.

The soil fertility dynamics in the crop plots is thus:

$$fert_{act,t+1} = \min(fert_{max}, \max(0, fert_{act,t} - \delta_{dep,t} + \delta_{natrecov,t} + \delta_{fertrecov,t})) \quad (4)$$

Productivity

The ploughing of the plot of annual crops is carried out by livestock (i.e. buffalo or cattle). Shortage in draft power from the household's livestock holdings is met from external sources by renting from neighbours. Crop growth is supported by both inorganic and organic fertilizer application as well as agrochemical products. Organic fertilizer comes from three sources namely a portion of leftover crop biomass, leftover bedding materials, and livestock manure. Another portion of crop residue will be used as fodder and bedding materials for livestock. Actual crop yield (ton ha^{-1}) depends on soil fertility and potential yield (i.e. achieved at maximum soil fertility) (Eq. 3). Crops produced are generally for household consumption, and in the case of a surplus, a fraction will be used for livestock feeding and the rest will be sold to the market. Food shortages are addressed by buying in the market or from neighbours.

Every year, a fraction of crop yield will be used for the seeds to cultivate in the subsequent year. If the requirement is greater than the supply from the fraction of crop yield, the shortage will be fulfilled by buying seeds in the market. Seed preparation cost covers the costs to appropriately prepare seeds for cultivation.

Income from annual crops

Production cost (NRs per ha) is the sum of the cost of buying seeds, seed preparation, inorganic fertilizer, agrochemicals, renting cost for the shortage of draught power, buying organic fertilizer in the case of shortages, labour cost, 'other' costs, as well as buying crop products in case of shortage for private consumption. Total production cost (NRs ha^{-1}) is the production cost multiplied by area of annual crops (ha). Revenue (NRs) comes from selling of crop yield, seeds, manure, and renting surplus of draught power. Total income (NRs) of cultivating annual crops is the revenue from all crop plots minus the total production cost of all plots.

Tree-Understorey Module

There are a maximum of 3 plots to simulate for three tree species and two understorey or intercrops. The three tree species in one plot of the module is based on the fact that the local householder usually plants three different kinds of tree for different functions such as that for timber, fodder or NTFP.

Soil fertility

The model assumes that soil fertility is stable across time due to the presence of trees which provide a SOM (soil organic matter) balance through aboveground litter fall and belowground root decay. Therefore, soil fertility and its recovery (both natural and due to fertilizer application) are not simulated. It is assumed fertilizer application in the tree-understory module of the system is not necessary

.

Productivity

Tree and understorey propagules are supplied by buying from the nursery/market. In the case of natural tree regeneration, decisions to retain and grow these trees are similar to planting trees, and hence the cost of each tree is taken to be the same as that of purchased propagules. Not like in the case of annual crops, the householders do not produce seeds/propagules by themselves. Yields from tree components are fruits (ton ha^{-1}), timber (m^3 ha^{-1}), bedding materials (ton ha^{-1}), fodder (ton ha^{-1}), and firewood (ton ha^{-1}). They will be allocated for personal use based on demand or otherwise sold to the market in case of surplus. For timber, in the case of shortage, the householders will fulfil a part of the shortage from purchases in the market or they will buy a tree in the community forest. Similarly for fodder, firewood, and bedding materials, in the case of shortages, the householders will collect from the community forest and the rest will be purchased from neighbours. The products of the understorey are expressed in terms of yield (ton ha^{-1}) and bedding material (ton ha^{-1}).

Income from tree and understorey

Production cost (NRs) in multi-storey systems includes labour and 'other' costs for cultivating trees and understorey. Revenues (NRs) come from fruit and timber selling minus any costs for buying these two products in the case of shortages. Revenue from cultivating understorey comes from its yield minus costs for buying propagules. Total income will be total revenue minus total cost.

The Livestock Module

This module simulates productivity and income gained through raising a maximum of 4 types of livestock namely poultry, goat, cattle and buffalo.

Population

The model applies a threshold of livestock population (animal unit) that should be met but when livestock population falls below this threshold they are replaced by purchases from the market. In the case of the population being above the threshold, a fraction of the livestock population will be sold to the market. The population increases due to annual birth rate and decreases due to annual mortality rate. For feeding, the livestock need fodder (ton $animal^{-1}$) and plant residues (ton $animal^{-1}$). For the stable, they need bedding materials (ton $animal^{-1}$) from the plot of annual crops and AF system.

Production

The products from raising the 4 types of livestock include manure (ton $animal^{-1}$), draught power (draught power unit $animal^{-1}$) from the male cattle and male buffalo, eggs from poultry (kg $poultry^{-1}$), milk (litre $animal^{-1}$) from cattle and buffalo, and the processed milk-product or curd (kg/litre of milk). A fraction of milk will be used for private consumption.

Income from livestock

Total production cost (NRs) consists of labour for collecting fodder and bedding materials or in the case of shortages of feed and fodder purchases, production costs for processing milk into curd, and the costs of buying new livestock. Total revenue (NRs) comes from selling livestock and their products (i.e. eggs, milk, processed product from milk), and surplus in bedding materials and draught power.

Fodder and firewood

Fodder supply comes from trees in the tree-understory and community-forest and annual crops modules, whereas firewood is collected from the tree-understory module. In the case of shortages, a fraction of the required fodder and firewood will be provided by collecting in the community forest, and the rest is purchased from the market. Fodder will be used to feed all livestock except poultry. In the case of surplus, remaining fodder will be sold to the market. Firewood supply is used for household activity (e.g. cooking) and to process dairy products from cattle or buffalo milk. If demand has been fulfilled, surplus firewood will be sold to the market.

Community Forest Module
When the demand is greater than the supply of fodder, firewood, or bedding materials, the householders will collect a fraction of the deficit in the community forest for free, and the rest is purchased from the market. For timber, they will buy a tree and collect the timber later. The model takes into account the cost of harvesting fodder, firewood, bedding material and timber from the community forest.

Food Security Index Module
The Food Security Index generated by the model is based on the gross margin of the household. Income is obtained from sales of annual crops, tree products, and livestock and their products, and off-farm sources such as remittance, pension, and skilled jobs. Expenses are incurred in buying items necessary for agricultural activities, but also to buy other food rather than staple food, for health, education and other 'non-food' items. The calculation of the Food Security Index is shown in Equation 5. The reference household income, the reference income, $Income_{Ref}$ is the poverty line set by Nepal and other agencies and defined as the minimum income the household requires to ensure food sufficiency for all members of a family for one year (NRs). The poverty line set by the World Bank for 2015 is US$1.90 per person per day or NRs70,000 (assuming exchange rate of 100NRs =US$1) while the Nepali poverty line is NRs 19,261 per person per year.

$$FS_t = \frac{Gross\ Margin_t}{Income_{Ref}} \qquad (5)$$

If $FS_t \leq 0$ then the level of food security is 'very insecure', $0 < FS_t \leq 1$ means 'insecure', $1 < FS_t \leq 2$ means 'secure', $FS_t > 2$ means 'very secure'. If the expense for education and 'non-food' category are set to be 0 then the calculation of food security index in the Eq. 1 does not involve those two variables.

Developing a Household Typology for Nepal Mid-Hills

The farm households of the Mid-hills of Nepal are heterogeneous in terms of socio-economic conditions and rigid caste differences. As the EnLiFT Model simulates food security at the household level, a typology of these different households is required to allow scaling-up of the model to the community or district level. A survey of 668 households in six selected village development committees in Kavre and Lamjung Districts was undertaken to provide baseline data. The survey data was compiled in SPSS version 21, where a two-step cluster analysis was undertaken using the following criteria that had had been identified by a panel of experts from the EnLiFT Project:

Categorical variables

- Caste (Brahmin/Chhetri, Janajati, Dalit)
- Has family member abroad (Yes, No)

Continuous variables

- Total household income (NRs)
- Total landholding (m^2)
- Total under-utilised land (m^2)
- Livestock holdings (Animal units)
- Active labour force (≥ 15 years old)

- Relative tree density

The six household typologies obtained from cluster analysis are:

Group 4: resource rich Brahmin/Chhetri
Group 5: resource rich Janajati
Group 2: resource poor Janajati
Group 1: resource poor Brahmin/Chhetri
Group 6: Dalit low caste household
Group 3: resource rich caste independent

The characteristics of these household types are shown in Table 1. Group 4 households comprise around a quarter of the respondents and these households have the highest reported income. The resource rich Janajati households (Group 5) are ranked second in terms of household income but their landholdings, livestock holdings and tree holdings are generally lower than resource rich Group 4 Brahmin/Chhetri. Groups 2, 1 and 6 are generally the resource poor households which comprise nearly half of the total respondents. Group 3 represents a small number of households that own five to ten times more land than any other household grouping, nearly six times more livestock than any other grouping, and nearly ten times more trees than the average tree holdings. Household income for Group 3 is, however, only just about the average household income in the mid-hills.

Table 1. Key characteristics of six household typologies

Household Variable	Group 4	Group 5	Group 2	Group 1	Group 6	Group 3
Ethnicity class	Brahmin/ Chhetri	Janajati	Janajati	Brahmin/ Chhetri	Dalit	Mix caste*
Proportion of households (%) with foreign worker	100	100	100	100	56.8	52.9
Area of landholding (ha)	0.83	0.78	0.66	0.79	0.37	4.10
Average under-utilised land are (ha)	0.12	0.15	0.08	0.10	0.06	0.76
Average tree density (trees per ha)	191	81	140	109	126	2,180
Average household income (NRs)	274,279	225,816	115,782	125,036	135,039	171,152
Livestock holding (animal unit)	2.49	2.38	2.44	2.85	2.38	12.25
Average persons per household in active labour force (person)	5.34	5.12	4.1	4.17	4.22	4.53
Proportion of survey respondents (%)	24	23.3	18	17.3	14	3.3

* Group 3 comprised of 47% Brahmin/Chhetri.

Model calibration and evaluation for a typical household in Nepal mid-hills

Thirty-six (36) case study interviews were conducted in six sites in the Kavre and Lamjung Districts to collect data to parameterise the EnLiFT Model. At each site, six households were interviewed representing the six household types. The averages were obtained for the six sites to derive parameter values for the EnLiFT Model. This section presents calibration of EnLiFT Model for Group 5 households and the sensitivity of parameter values were evaluated by a panel of agroforestry and community forestry experts in Nepal.

Model inputs

Stella® communicates with an Excel® file that contains all the necessary inputs to the model. A "Summary" worksheet and "StellaLinks" worksheets are created on excel input file as compilations of derived parameters for an initial year and succeeding 25 years respectively. The formulation of the EnLiFT model is generic for all household types such that systems components that may not be present in other household types or such agroforestry regime is not applied, values are kept zero. This approach is efficient for investigating scenarios for potential systems interventions – which may include agroforestry innovations or better timber policies.

For the EnLiFT Model to function, equations are defined for all relationships defined in every module of the model. Values used in these equations are obtained from the Excel input file. These equations are generic for the model and need not be redefined for new household types or scenarios. This makes the modelling work easier considering there are about 500 equations defined for the current version of the model.

Model Application

The EnLiFT Model 1.0 was tested for 'resource-rich Janajati' households (Group 5) of which inputs and outputs were validated by Nepali community forestry and agroforestry experts and practitioners. The purpose of model validation is to see if the model generates outputs that are expected given the model input. Simulations were run for four scenarios of agroforestry activities namely subsistence-based agroforestry (baseline scenario), expansion of multistorey cropping to bhari land, a supportive timber-policy scenario and intensified fodder production. Results were obtained using specific data sets from case study households.

Subsistent agroforestry livelihood system (baseline scenario)

The EnLiFT Model 1.0 can predict the yield and consequent net revenues for each of the four agroforestry system components given available resources and management regime. The net revenue or savings is summed-up at the household level to include non-farm income and expenses. The results presented here are first approximations for a long-term livelihood performance based on subsistence agroforestry production on khet, bhari and kharbhari lands in Kavre Districts in Nepal. The household practice of rotating maize, rice and wheat crops on 0.27 ha of khet land, and planting 0.32 ha of bhari land to maize, millet and lentils are modelled. The total area occupied by trees on khet, bhari and kharbhari is 0.05 ha, 0.08 ha and 0.5 ha, respectively. The initial livestock holding of the household is provided in Table 2 in which the household generally have the typical domesticated animal of a Nepali household except for female cows. The household receive annual foreign remittance for the first five years of simulation.

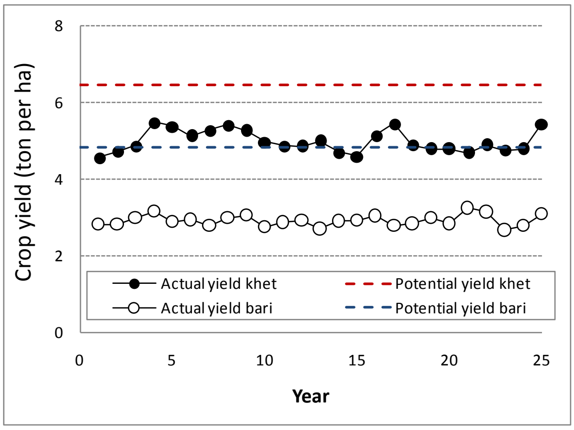
Table 2. Livestock holding values used for the EnLiFT Model for baseline scenario

Livestock type	Initial population (number of heads)	Minimum number to keep annually (number of heads)
Male poultry	10	2
Female poultry	7	3
Male goat	3	1
Female goat	3	2
Male cattle	2	2
Female cattle	0	0
Male buffalo	2	1
Female buffalo	2	2

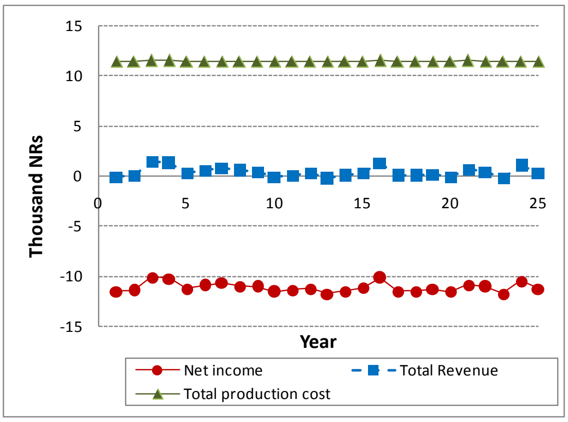
For the baseline scenario, the yield and revenue of annual crops are presented in Figure 3. As expected, the actual yield of annual crops on *bhari* land is considerably lower than *khet* land however these yields are on average 60% and 76% of the potential yield of these land types. The revenue from annual crops is predicted to be negative indicating a high cost of farming inputs. The livestock income fluctuates between -15,000 to +13,000, but on average is about

-1,000 NRs. These fluctuations somehow follow fluctuations in buffalo milk production. Timber products are for household consumption only.

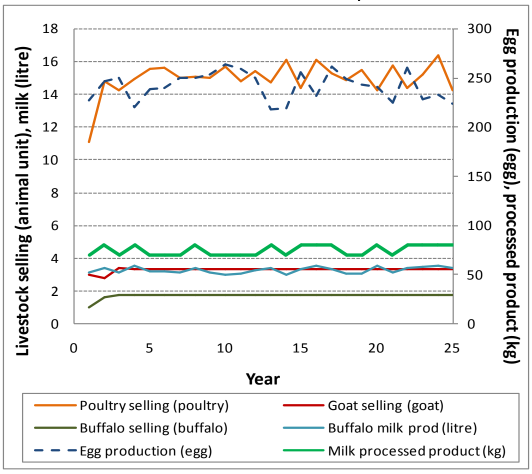
But why households are still engaged in crop production? As shown Figure 3, the combined tree and understorey has positive annual revenue of over NRs 20,000. This illustrates how food security of a mid-hills household is strongly supported by the tree-understory components of the agroforestry system. The extent to which the total household income is driven by off-farm income and foreign remittance is illustrated when the household stops receiving foreign remittance in year 6. This drop in household income consequently affects the annual household savings which defines the food security level of the household. The revenue and savings of subsistence-based agroforestry livelihood systems predicted by the EnLiFT Model suggested the significant role of trees and understorey in the livelihood system and the strong influence of foreign remittance in determining the household food security.



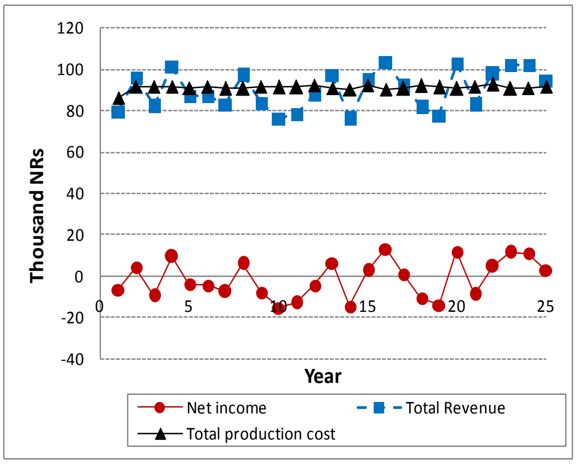
Yield of annual crops



Cost and revenue of annual crops



Yield of various livestock products



Cost and revenue of livestock

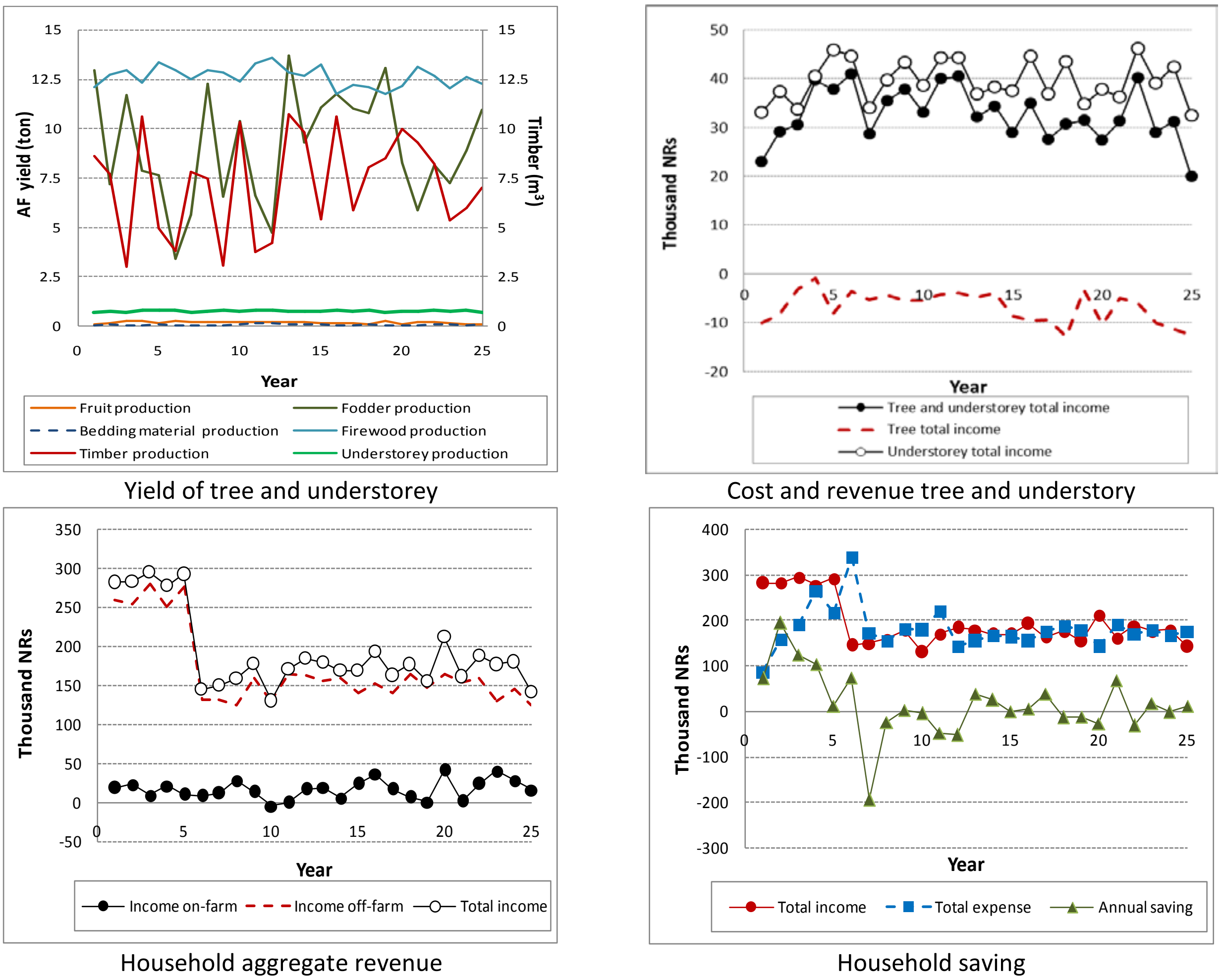


Figure 3. Yield, cost and revenue of agroforestry components and predicted household income and savings predicted by EnLiFT Model 1.0.

Expansion of multi-storey cropping on bhari land (AFE scenario)

The EnLiFT Model 1.0 was run to simulate the livelihood performance whereby the annual crops on bhari land is replaced with fodder trees (Pakhuri, *Ficus globerrima*), banana, and ginger and turmeric as understorey crops – a scenario for intensified fodder-based multi-storey cropping. With change from annual cropping to multi-storey cropping, the area under trees is now 0.4 ha from 0.08 ha and the proportion of area planted to understorey is now increase to 14% from 10%. Like the baseline scenario, timber products are for household consumption only. All other livelihood activities are similar to the subsistence scenario including remittance income. Because it is assumed that timber is only for household consumption, the focus of investigation under this scenario is the change to income from understorey crops – i.e. ginger and turmeric. The EnLiFT Model predicted an increase of income from understorey by nearly two and a half times (from 39,000 NRs to 91,000 NRs). This increase of income from understorey alleviated the household savings particularly in the year when foreign remittance is cut-off but the expansion of multi-storey cropping to bhari land. While an increase on average annual household savings under an agroforestry expansion scenario has been predicted to be about 19,000 NRs, this is slightly higher than the baseline scenario of about 16,000 NRs. Expansion of agroforestry systems does not necessarily propel the household from poverty.

Expansion of multi-storey cropping on bhari land with supportive policy for AF timber marketing (AFE-TP scenario)

The livelihood outcomes of agroforestry systems in Nepal is not only affected by household decisions but with institutional and policy arrangements as well. In the previous two scenarios, the household is not able to sell timber products because of a restrictive timber policy. The EnLiFT Model was run to test its capacity to handle policy-based scenarios. In the previous scenarios, the timber market prices were set to zero which forces the model not to sell. In simulating a supportive timber marketing policy, the household is assumed to have mature timber trees, of which a fraction will be ready for harvest. The timber market price (in real value terms) for Uttis (*Alnus nepaulensis*) and Pine (Pinus sp.) is 14,814 NRs m^{3-1} while for Chilaune (*Schima wallichi*) 18,518 NRs m^{3-1}. The annual income from timber and the annual household savings for the three baseline, AFE and AFE-TP scenarios are presented in Figure 5. It is predicted that household savings under the AFE-TP scenario is generally higher than baseline and AFE scenarios, indicating the role of trees as safety nets. However, there are two points in the simulation (i.e. year 11 and 23) in which extreme plunges of household savings had been predicted. This is because households tend to spend their money on buying more and higher quality (hence expensive) food from 'preceding year's savings', however the income from that year does not replenish the savings account resulting in negative savings. This represents a typical household spending pattern in rural Nepal.

Expansion of multi-storey cropping on bhari land with supportive policy for AF timber marketing and livestock expansion (AFE-TP-LE scenario)

When multi-storey cropping is expanded to bhari land, fodder supply is increased and the incremental revenues from this expansion can be used to expand the livestock enterprise. The EnLiFT model was calibrated to simulate a livestock expansion scenario of keeping one more female buffalo for milk and processed milk products. As shown in Figure 6, the income of this livestock enterprise is increased by on average 70 fold compared to baseline scenario, however similar to the supportive timber market scenario, there are years where annual savings drop dramatically indicating higher risks with enterprise expansion.

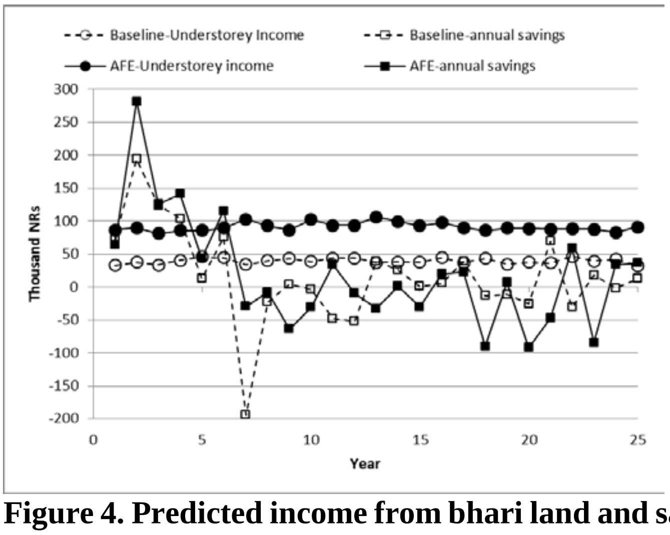


Figure 4. Predicted income from bhari land and savings under baseline (dotted line) and agroforestry expansion (AFE, solid line) scenarios

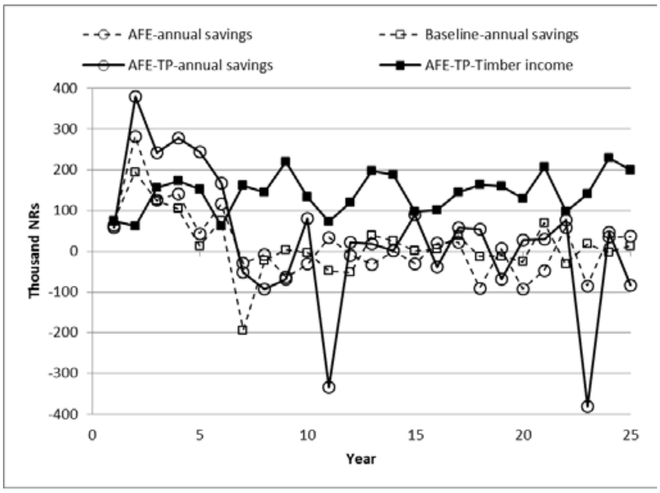


Figure 5. Predicted income from bhari land and savings under baseline (dotted line) and agroforestry expansion (AFE, solid line) under supportive timber marketing scenario

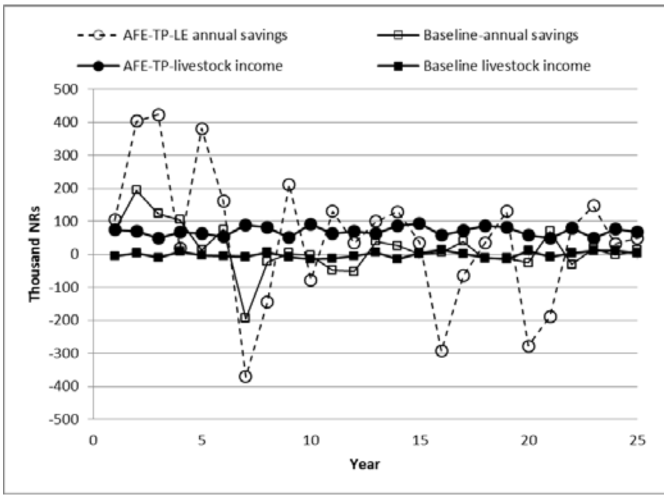
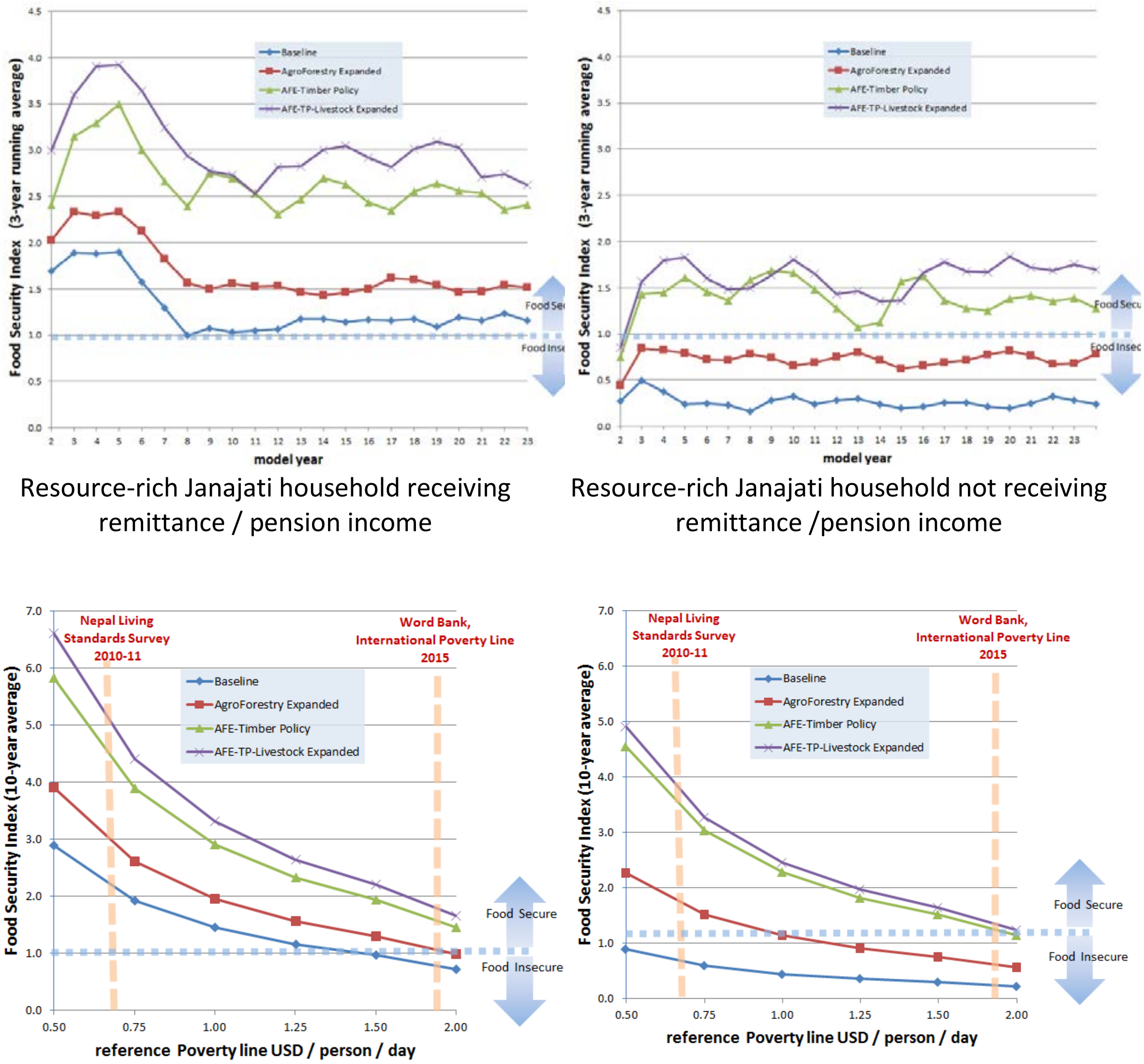


Figure 6. Predicted annual savings and livestock income under baseline scenario (square) and annual savings and livestock income under agroforestry expansion, supportive timber market policy and livestock expansion scenario (circles).

Estimating food security index for four agroforestry production scenarios

The EnLiFT model estimated the food security index (FSI) for the four agroforestry production scenarios with and without remittances or pensions. The three-year running average of the FSI and the ten-year average of FSI at various poverty lines are shown in Figure 7. The EnLiFT Model showed that resource rich Janajatis (Group 5) are generally food secure when they are receiving remittance and pensions. When these households are not receiving remittances and pensions, they are food-insecure throughout the modelling period under baseline and agroforestry expansion scenarios. They then become food secure under timber market policy and livestock expansion scenarios indicating the importance of improving timber market policy and expansion of livestock enterprise when the households are not receiving remittance or pension. The FSI at varying levels of reference poverty lines showed that resource-rich Janajati's are food insecure under the baseline scenario when they are not receiving remittances or pensions in all levels of reference poverty lines but food secured for all scenarios when reference poverty line is below US $1.25 per day per person. Resource-rich Janajatis are generally food secure on other scenarios except the baseline. Figure 7 shows the sensitivity of FSI to reference poverty line signalling caution for selecting appropriate reference income for determining food security.



Resource-rich Janajati household receiving remittance / pension income

Resource-rich Janajati household not receiving remittance /pension income

Resource-rich Janajati household receiving remittance / pension income

Resource-rich Janajati household not receiving remittance /pension income

Figure 7. Three-year average of food security index and FSI at various levels of reference poverty lines for four model scenarios.

Concluding Comments and Future Modelling Work

The rationale of the EnLiFT model is to estimate the impact of technical and policy interventions to improve the livelihood and food security of households in the mid-hills of Nepal. Before any interventions can be conceived, the model helps identify the ‘leverage’ points of the livelihood system with scientific confidence. This is difficult when livelihoods are derived from community forests and privately-held agroforestry systems, as well as off-farm income and remittances from overseas. Most analyses to date have just considered the agroforestry and community forest separately. The EnLiFT Model is therefore a first attempt to holistically analyse the mid-hills livelihood system.

This paper has summarised the concept and specifications of the EnLiFT Model. The process of developing the model has involved a series of workshops and consultations of community forestry and agroforestry modelling experts in Nepal and abroad. This initial output of the model calibrated for a typical mid-hills household has been validated by Nepali community forestry and agroforestry scientists and practitioners. Model simulations for the four scenarios presented in this paper shows the capacity of the model to answer both technical and policy questions. The household level model (EnLiFT Model 1.0) is the building block of the community-level model where simulations of socially, economically, ecologically and politically acceptable interventions are plausible. The community-level EnLiFT Model, which is currently under construction, will serve two main purposes: (1) assess the community level food security given available resources – land, labour and capital to household and (2) evaluate the impacts of an improved community forestry management and policy regime.

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Improving the Implementation of Community-based Forest Management (CBNRM) in Ratanakiri Province, Cambodia

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Abstract

Community-based Natural Resources Management (CBNRM) was adopted by the Royal Government of Cambodia (RGC) as an approach for confronting social and environmental issues, including the mismanagement of forest resources that threaten the country's forests and the lives and livelihoods of the people who are heavily reliant on those resources, including indigenous people particularly those living in Ratanakiri province. CBNRM was identified as a suitable approach for addressing indigenous peoples' problems relating to loss of access, control and management of their traditional territories. These issues were largely the result of increasing development investments in the province, including agro-industrial farming granted to local and foreign business interests, and illicit acquisition of indigenous peoples' land by rich and powerful people in the country. In the province of Ratanakiri and Cambodia as a whole, hierarchical and top-down governance systems are practiced, which present a major challenge to the implementation of CBNRM, in which participation and cooperation are key elements. The basis of this study was an Action Research project designed to answer the question '*How can the implementation of the CBNRM project in the province of Ratanakiri be improved*?*'* The study establishes that there are opportunities and leverage points for the implementation of participatory CBNRM within hierarchical and top-down governance systems. However, it was found that despite these, CBNRM is at odds with the hierarchical and top-down governance system. The government of Cambodia was found to be not ready for CBNRM. In fact, they are part of the problem and therefore need to be part of the solution to improve the implementation of CBNRM. For CBNRM to succeed in Ratanakiri province the government needs to first recognise indigenous peoples' rights over their traditional lands, which in a way enables them to become equal partners in the implementation of CBNRM.

Keywords: CBNRM, Action Research, participation, Ratanakiri province, hierarchical, top down.

1. Introduction

Since 1990 Cambodia has made significant progress in re-establishing its economy, in restoring economic growth, and in undertaking policy reforms (World Bank, 1997; Ministry of Planning, 2007). Peace and security were established after almost three decades of war and civil conflicts. Cambodia has strengthened its democratic institutions and transformed the isolated, state-controlled, and subsistence-oriented economy, to become a market-driven and open economy (World Bank, 1997; Ministry of Planning, 2007). This economic progress has been especially rapid since the formation of the Royal Government of Cambodia in 1993 (World Bank, 1997). A decade later, Cambodia's GDP growth was reported as high as 10.8 percent in 2006 (Ministry of Planning, 2007).

The exploitation of natural resources underpins Cambodia's economic progress. World Bank (1997) reported that Cambodia has among the highest endowments of forest in East Asia (World Bank, 1997) and raising revenue from forestry is a major element of the Government of Cambodia's reform efforts. The country is rich with natural resources, including water, forests and non-timber forest products, wetlands, and minerals including recently explored oil and gas reserves. Most of these resources provide critical food security for rural Cambodians, whose livelihoods rely on agriculture as a major source of income.

Growth in production, to a large extent, is coming from increasing exploitation of natural resources through large-scale economic land concessions for agro-industrial uses, e.g. agricultural plantations, water-related development projects such as hydropower dams that inundate large areas of land to create reservoirs, and extractives involving coal, gold, semi-precious stones, and oil and gas mining (NGO Forum in Cambodia, 2009). These economic developments have been reported as undertaken with inadequate safeguards relating to unsustainable natural resources exploitation and management (Bann, 1997; Tyler, 2006). Environmental degradation, especially forest depletion and water quality degradation issues, is increasingly reported (Ministry of Planning, 2003, 2007). There are about 2.7 million ha of land associated with agricultural commercial exploitation, including those in Ratanakiri province, with exclusive user rights of up to 99 years (Leuprecht, 2004). For indigenous peoples in Ratanakiri province, continued agricultural commercial exploitation, logging of forests and increasing illicit land acquisition (World Bank, 2006; Global Witness, 2007) results in the loss of access to their traditional territories and sources of food, income, and livelihoods (Yash Ghai, 2007).

In response to the above situation and in an effort to improve the country's economy, the Royal Government of Cambodia (RGC) has initiated reforms including the Decentralisation and Deconcentration Reform (2001), which aimed at addressing unsustainable management of land, forests, and fisheries. This embraces the administrative and governance reforms in natural resources management, and provides clear guidelines and procedures to increasingly devolve responsibilities for local development to provincial and commune levels (Sunderlin, 2004; Ministry of Planning, 2007). Alternative approaches to natural resources management have appeared including the concept of integrating community-based forms of natural resources management, within the context of decentralised governance structures (Van Acker, 2010). Community-based Natural Resources Management (CBNRM) is amongst the significant approaches that have been endorsed and adopted by the RGC since 2002 (Tyler, 2006) with the primary intention to enhance reform efforts, including decentralisation reform, and reforms in forestry, fisheries, and land management (Tyler, 2006). The CBNRM approach had previously been used and experimented with by some government programs and projects in several provinces, including Ratanakiri province.

The CBNRM theory is, in itself, an evolving concept as a development strategy. It is an approach that starts with communities as the foundation, and also ends with communities as a focus or a means. It is characterised by local communities playing the central role in identifying resources, defining development priorities, choosing and adapting technologies, and implementing practices (IDRC/MoE, 2005). The CBNRM has been popular due to its people-centred and participatory approach. However, the adoption of CBNRM is fraught with several issues. One of these is how government and communities share management rights and who has ultimate authority over resources, particularly when these resources are under pressure for economic development. Vandergeest (2006) sees this as a potential condition for conflict between indigenous peoples and the government in promoting CBNRM as a government driven project in Cambodia. Vandergeest (2006) further raises the issue of power and decision making between indigenous peoples and the government in CBNRM. This includes the treatment of local people as passive recipients rather than equal partners in implementing the CBNRM (Pimbert & Pretty, 1995). The success of CBNRM implementation relies heavily on the government's sincere commitment to the implementation process, and giving local people control and responsibility for management decisions relating to local resources.

Since the early 1990s, Ratanakiri province has undergone rapid change, especially in the area of natural resources for economic development. For instance, the RGC has granted mining and land concessions for various agro-industrial purposes in the province, including timber, cashew and oil palm production, which encompass many of the traditional and current farmlands of indigenous peoples. Bann (1997) reports that Ratanakiri is a richly forested province where the forestland is an extremely valuable natural resource that needs to be correctly managed. Civil society groups fear that the increasing economic development attention in Ratanakiri province will expose the indigenous peoples to a range of vulnerabilities including putting the indigenous people at risk of losing their land. The increasing land pressure in the province has resulted in shorter or no fallow periods, replacing the traditional 10-15 years fallow periods. Many indigenous peoples have been pushed further into forested areas, to open new land for cultivation. Many are also seeking new but insecure livelihoods as labourers in plantations.

The land use changes in Ratanakiri province fundamentally risk changing the ecological and biophysical systems of the forest, which can be expected to have extensive impacts on the province. An economy based on rich non-timber forest products that sustained the health, food, and cash incomes of indigenous communities in the province for generations, has been critically restrained because of restricted access to mined areas and areas that are under economic land concessions. Social cohesion has started to break down in some indigenous communities, resulting in changed social behavior and increasing violence in some communities. Indigenous elders have also reported that they are losing control, access, and management of their traditional territories.

The CBNRM concept was initially introduced to provincial authorities in Ratanakiri province in 1995. This was through action research conducted by the International Development Research Council (IDRC). The results of this action research laid the basis for important consideration of policy decisions and the adoption of CBNRM as an approach for promoting the decentralisation processes. In Ratanakiri province the implementation of CBNRM was viewed by several local Non-Governmental Organisations (NGO) and relevant government agencies as a strategic response for addressing indigenous peoples' problems of loss of access, control and management of their traditional territories.

This paper presents the research that was undertaken to answer the question '*how can the implementation of CBNRM project in Ratanakiri province, Cambodia be improved'*? The study aimed to contribute to developing the theory and practice of implementing CBNRM in indigenous communities. Also, the findings were envisaged to support community development workers in implementing community-based programs and projects in similar hierarchical and top-down governance systems.

2. The Case Study Site

Ratanakiri is one of 24 provinces that comprise the Kingdom of Cambodia (NIS, 2009). Cambodia is situated in East Asia, in the southern part of Indochina. It borders Lao PDR in the north, the Socialist Republic of Vietnam in the East/Southeast, and Kingdom of Thailand in the West (SCW, 2006). The country covers an area of 181,035 sq. km and in 2009 had a total population of 13.3 million (NIS, 2009). Approximately 80 percent of the population resides in rural areas and are dependent upon agriculture as their primary source of livelihood (NIS, 2009).

Ratanakiri is one of the most remote and isolated provinces within Cambodia. Located in the northeast of the country, it borders with Laos to the north, Vietnam to the east, Mondoulkiri province to the south, and Stung Treng province to the west (Figure 1). The province of Ratanakiri is 636 km from the capital, Phnom Penh. The province covers an area of 11,673 sq. km and has a population of approximately 150,000, representing about 1.1 percent of Cambodia's total population (NIS, 2009). Reports (e.g. Le Meur, et al., 2008) estimate that in-migration due to job opportunities relating to plantation and mining developments has been adding about 100 people each year since 1996.

Figure 1. Location of Ratanakiri Province in Cambodia

Ratanakiri province comprises nine districts, 49 communes, and 240 villages. Approximately eighty percent of the province's population (about 120,000 people) are from indigenous groups (Seila/PLG, 2004). Char Ung commune was the study site and also a pilot area. It is home of the Kreung indigenous group. The commune is situated approximately 15 km northeast of Ban Lung the capital town of the province. It has five villages and had a total population of 2,187 and 505 households. Women comprised slightly more than half of the total population of the commune.

Kreung people are traditionally farmers and gatherers. Their farming activities are based on complex agricultural practices involving rotational or shifting cultivation known as 'swidden agriculture' or "*Chamcar*". Kreung people used to rotate their *Chamcar* in a 10-15 year cycle. However, during the period of this study, it became apparent that practicing swidden agriculture had become a significant issue. Much of the Kreung peoples' fallow lands were taken up by concessions for plantations and bought by outsiders and had become privately owned lands. Because of these changes, many of the Kreung people had to settle permanently and farm on less productive lands where crop yields were reported to be low, often providing insufficient food to meet the subsistence needs of families. Some families moved deeper into forested areas to try and seek better land to meet their basic food needs. Also, many indigenous people sought seasonal work in plantations to augment their incomes, a situation they have never experienced before.

3. Methodology

3.1 Rationale for choosing Action Research in this Study

Action Research was the methodology used for the study. Action Research provides an emergent, yet critical, method for engaging with a complex problem for which there is no clear solution (Dick, 2002, 2004). According to Dick (2002, p 160) Action Research is data driven research, which is relevant when the existing literature cannot provide precise answers to a complex problem. Action Research is a simple, yet powerful, cyclical methodology. Rigour in Action Research is achieved through multiple cycles of planning, acting, observing, and critical reflection, to understand what is happening and to improve subsequent processes of action or research to address the complex problems (Kemmis, 1980; Kemmis & McTaggart, 1988; see also Susman, 1983; McIsaac, 1995; Wadsworth, 1998; Dick 1999; Herr & Anderson, 2005; Ariizumi, 2005).

The reflection sessions facilitated the analysis and interpretation of experience (see Murray & Kujundzic, 2005). The analysis involved the identification of similarities, differences, and emerging information, followed by the extraction of key themes to arrive at our interpretations (Miles & Huberman, 1994). The interpretations were validated through working with multiple information sources, such as engaging a wide group of stakeholders who provided multiple views, conducted in different times, and by applying a multi-method approach (Dick, 1987). This is known as a triangulation process in research (Jick, 1979). Critical reflections enabled enhanced learning, and deepened understanding of the research situation, which resulted in informed decisions, actions and approaches.

The reasons for choosing Action Research in this study included:

- It would develop the capacity of the local indigenous people and local CBNRM project staff, by actively engaging them in all phases of the Action Research methodology.
- The critical reflection steps at each stage of the project help improve project implementation and provide the basis of final recommendations for province wide replication of the CBNRM.
- Action Research facilitates the encouragement and management of the participation of a wide range of stakeholders that open up opportunities for indigenous peoples to participate in participatory and bottom-up processes.
- Action Research facilitates selection, collection, and interpretation of information (Kemmis, 1980; Dick 2002). It encourages collective and self-reflective enquiry (Seymour-Rolls & Hughes, 2000) that involve those who are affected (McTaggart, 2002).
- Promoting cooperation and collaboration between all stakeholders in the implementation of CBNRM.

- It would enable the implementing team to learn and understand the indigenous culture and its unique conditions, traditions, and language, and to also understand the political sensitivities, while engaging with the problem and improving the implementation of the CBNRM project in the province.
- It would manage and facilitate my role as an insider of the project, to avoid researcher bias and meet the standards for ethical research.

This study involved two main Action Research cycles with the second cycle consisting of multiple levels of sub-cycles. This is illustrated in Figure 2.

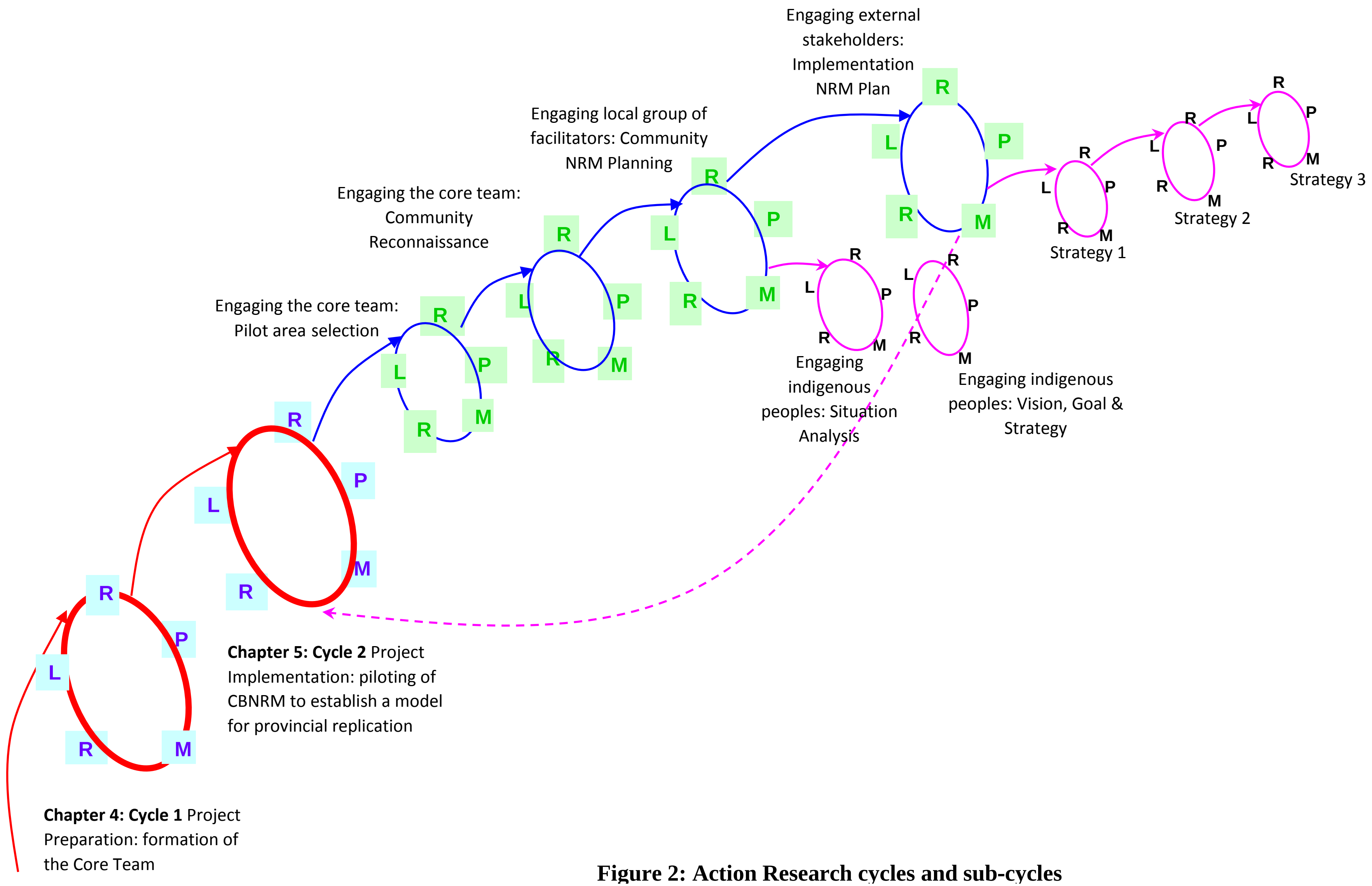

Figure 2: Action Research cycles and sub-cycles

4. Results and Discussion

The results presented in the following sections focused on the approaches and recommendations for improving the implementation of CBNRM within a hierarchical and top-down governance system.

4.1 Gaining support, managing and understanding issues hindering CBNRM implementation

Gaining support of all key stakeholders and decision-makers in the province, and managing and understanding their issues, interests and agenda was an approach that is important in improving the implementation of CBNRM. This was done through:

- Actively engaging all key stakeholders such as relevant line departments, local decision-makers, civil society groups, and indigenous peoples in every step of the CBNRM implementation process. This was critical in successfully gaining stakeholders support as well as an opportunity to influence their differing views and interests in how CBNRM should be managed in the province. This approach encourages some local decision-makers to become strategic allies that advocated for and influenced local decisions to support a participatory implementation of CBNRM within a hierarchical and top-down governance system and promoted coordinated action.

- Issues if not properly managed and understood significantly hindered implementation. It was very important to manage and understand differences in views, interests, and agenda of each key stakeholder, to facilitate ways for meaningful conversations, as:

    - Some line departments pushed CBNRM to be used as an approach for agroforestry and land-use planning. Other departments were too concerned about donor prescribed changes, which were focused more on academic explanations and approaches to CBNRM. Some departments were unconvinced that the indigenous people would sincerely engage with CBNRM implementation and would have liked to implement the project even without indigenous community support. Despite 'participation' being a word often used by higher authorities and departmental officers, many of these people lacked knowledge and understanding of participatory concepts. In fact, 'participatory approach' was a very new concept and was actually very challenging to them.

    - Indigenous peoples and civil society groups critically doubted the government's intention and sincerity in implementing the CBNRM. Civil society groups, in particular, viewed that the CBNRM was mechanically implemented and managed by outsiders employing contextually inappropriate CBNRM approaches, and felt they discounted indigenous communities' active participation in CBNRM. They viewed that for the CBNRM to work, indigenous rights had to be fundamentally respected and the customary practices of the indigenous people needed to be integrated in the implementation of CBNRM, and they felt this was ignored in early years of implementation.

4.2 Managing participation within hierarchical and top down systems

To manage participatory CBNRM implementation within hierarchical and top-down governance systems, different processes at different levels: provincial, project participants, commune, and village, were applied. It is believed that these processes, in part, rose to the challenge of Mohan and Stokke (2000), who question whether participation can flourish within the context of an already well-established anti-participatory structure.

4.2.1 Provincial level: engaging, consulting and keeping decision-makers informed, and coordinating the support of external stakeholders

At the provincial level project staff engaged and kept key decision-makers and line department officers informed of every step of the project implementation process. This engagement involved regular consultation meetings that provided adequate, timely, and continuous feedback on implementation outcomes, including issues encountered, and the identification of possible solutions. To maintain their participation in consultative meetings, we tried to manage their expectations. This was done by carefully respecting their decisions and avoiding conditions that jeopardized or harmed the government's reputation, such as by carefully assessing risk when dealing with sensitive political issues, e.g., the alleged involvement of the government in the illicit sale of indigenous peoples' lands, illegal exploitation of natural resources, and corruption allegations. Further, we also endeavored to develop allies and friends among the decision-makers. This was helpful in accessing information and assistance to advocate and influence decisions.

However, the above strategy required trade-offs. An example is in establishing boundaries when it came to dealing with deeper issues of natural resources management in the province that involved the government. This was not easy, as indigenous people viewed government policies as primary causes for losing their traditional territories and management rights. Indigenous peoples land ownership claims and access to their fallow lands are currently threatened by the government's economic policies and agenda. For example, economic land concessions granted by the government to private investors are increasingly occupying indigenous peoples land. Putting attention to the above issues and identifying ways to sensitively manage them was necessary. This was a potential condition for conflict between the indigenous communities and the government in promoting CBNRM.

Establishing and coordinating regular coordination meetings of key stakeholders in the province enhanced collaboration. This does not only support implementation but also reduced duplication of efforts and allows maximization of limited resources in the province. In addition, it enhanced the awareness of key line department officers and local authorities, who were mostly non-indigenous people, in relation to indigenous peoples' problems about land and natural resources. Engaging them in regular and open discussions by means of a coordination meeting resolved some important differing views in natural resources management. This was also an excellent means for consolidating limited resources in the province and a way to provide solutions to a fragmented working environment, as they work together. However, this process requires managing sensitivities as this could render stakeholder's cooperation and collaboration to become fragile, and can cause cooperating stakeholders to separate.

4.2.2 Project staff level: understanding the context and adopting a range of roles to respond to multiple realities

Meaningfully engaging and immersing with indigenous peoples' situations provided deeper understanding of their socio-economic, religious, cultural, and political situations and issues. This understanding encourages commitment and recognizes sensitivities that were important to appropriately engage with indigenous peoples. It was understood that the use of indigenous language (this was not a usual practice before) during community consultations encourages indigenous peoples' participation. This becomes a vehicle to promote wider participation. The majority of indigenous peoples were Khmer (mainstream language) illiterates, especially the women and elders. Promoting the use of indigenous language during CBNRM implementation was achieved through working with emerging indigenous leaders who speak Khmer. They provided locally-specific knowledge and informed choices for appropriate approaches in engaging with indigenous peoples. These leaders also become our bridge to the elders and to rest of the community. In addition, understanding indigenous people's lack of trust of the government on issues over natural resource matters improved our ability to relate, and make appropriate choices and informed decisions and actions making project activities suitable to indigenous peoples' contexts.

To appropriately respond to indigenous people's context, project implementers adopted a range of roles. These roles included facilitators of processes, catalysts of change, engagement in collaboration with various stakeholders, evaluators of process, educators, and advocates. This was necessary to respond to multiple realities to bring about outcomes. Further, adopting different roles was needed as wide disparity in capacity, power and influence between indigenous peoples and the government presented impediments for equitable implementation of CBNRM.

4.2.3 Building the capacity of project staff, local authorities and indigenous peoples

For CBNRM implementation to continue when external support and funding support ceased, building capacities of local authorities, indigenous peoples, and project staff was seen necessary. This involves:

- Identification of training needs and facilitating delivery of needed training. This offers a range of practical benefits, including improved levels of confidence of local authorities, indigenous peoples and project staff. It was hoped that over time this will eventually develop sustainable changes in their practices.

- Engaging indigenous people in every step of project implementation and decision-making processes such as planning, collecting and analyzing information, problem solving processes, and collective actions. As a result of these measures, indigenous peoples learn how to engage in discussions, build consensus and compromise. Such processes also raise their level of awareness and knowledge of their situation in relation to natural resources, raise their skills for actively working together to identify and analyse their problems, develop solutions to these problems, and collectively achieve results.

- Mentoring of CBNRM project staff and local authorities to be able to continue providing support to CBNRM implementation after external support and funding ceases. This involves learning from each other's skills and capabilities that facilitates the transfer of knowledge and skills through "learning by doing". However, this was not sufficient for a sustainable CBNRM implementation in Ratanakiri province. It is a view that this requires a "changed" government system for the CBNRM implementation to succeed and become sustainable. It is identified that the government was part of the problem; therefore, they are a part of the solution for CBNRM implementation to succeed.

4.2.4 Village-based approach to encourage participation

A village-based approach was applied to promote participation within a hierarchical and top-down governance system. Implementation of CBNRM engaged people at the village level such that consultation processes start at the village level providing opportunity for all indigenous peoples to participate in discussions that were significant to them. This approach partly responded to a report that only a selected few were invited to participate in consultation meetings held outside village and outside the province. Botes and Rensburg (2000) called this selective participation. This practice was found to be politicized, which marginalized and disadvantaged the majority of indigenous people in the village.

The village-based activities manifested a bottom-up process, where discussions started at the village level and moved up to provincial level. Blunt and Turner (2005) theorise this as a form of delegation of decision-making power to the lowest level, promoting greater participation. This approach was crucial in ensuring good project outcomes, since project decisions were not made by just a few people, but were the result of a series of community discussions, agreed to by the majority of indigenous people. This puts the indigenous peoples first and at the centre of project implementation, which consequently enabled project responses that were appropriate to their needs and capabilities. This was important in making CBNRM project activities locally specific. This approach also necessitates government authorities having to consult and engage in dialogue with the indigenous peoples in villages.

However, a village-based approach requires time, resources and the ability to relate with indigenous peoples in the villages. This involves finding suitable times for meetings that facilitate the attendance by the majority of the indigenous people. This also requires an understanding of indigenous peoples' socio-cultural, religious and political cultures, including sensitivities and taboos. Sometimes, government authorities viewed placing importance on getting indigenous peoples in the villages participate in every step of project implementation as a waste of time, lengthy, and challenging. But it was a view that the reaction by government authorities was potentially due to their loss of decision-making control and the lack of understanding of the concept of a participatory approach and CBNRM principles.

In addition, promoting greater participation through a village-based approach weakened as the process moved up to district and provincial levels because of monetary constraints and availability of indigenous peoples. But, government authority representations increased towards the higher level of the process. Therefore, indigenous people's representatives in higher level discussions were fewer, compared to government representatives, who often dominated discussions. Government authorities present power and authority, a condition that intimidates indigenous peoples, thereby affecting their ability to meaningfully engage and influence decisions to respond to their issues. It was feared that indigenous people's participation could be used to serve or be used to support or legitimize government authorities' interests in the natural resources development agenda in the province. To ensure indigenous people's voices were not undermined in the process, civil society groups' engagement in the process was encouraged to maintain the democratic flow of the bottom-up approach as the process moved up. The civil society groups, particularly NGOs and indigenous peoples' networks often shared similar views and perspectives with the indigenous peoples and were therefore likely to speak in support to indigenous people's situations and issues in these discussions.

4.2.5 Use of local the language to promote ability to engage

Many government run projects and organized consultations in Ratanakiri province only use the Khmer language (the mainstream language). This was because most government authorities and departmental staff do not speak or understand the indigenous peoples' languages. The use of Khmer inhibited indigenous peoples from fully understanding discussions, and therefore limited their ability to engage, despite having the opportunity to participate. The use of the local language in all village-based activities encourages the participation of a wider group of indigenous peoples in project activities. This enables the indigenous peoples, particularly their elders, to understand what has been discussed and then motivates them to engage, by sharing what they think and feel about the topic being discussed. This means that the issues discussed were thoroughly debated, understood, and a genuine consensus achieved. It was found that use of indigenous language was an important tool to promote participation. This was also in the best interests of the project because it helps bridge the cultural gap and language divide that often inhibits understanding.

4.2.6 Formation of a team of indigenous facilitators

Formation of a team of indigenous people as CBNRM facilitators further encouraged indigenous peoples to participate in CBNRM implementation. The team ensured indigenous language was used. The team became a bridge between project staff to gain the trust of indigenous peoples. This also enables indigenous peoples in villages to clearly understand reasons for each and every step of CBNRM process. The formation of indigenous peoples as facilitators established the conditions for co-management of the natural resources at commune and village levels to occur. This promoted shared leadership responsibilities between local authorities and indigenous people facilitators, which overtime could result in a negotiated co-management arrangement that incorporates indigenous traditional practices. However, it is viewed that if the government remains hierarchical and top-down this potentially overshadows this initiative.

4.3 Recommendations

Improving the implementation of CBNRM in Ratanakiri province requires many complex solutions. The following are recommended interventions to improve the success of implementing CBNRM in the Ratanakiri province and similar provinces in Cambodia:

4.3.1 Granting indigenous peoples their rights over their traditional territories

Fundamental to the success of CBNRM is granting indigenous peoples legal rights to their traditional territories backed up with policies to legitimize their rights. There is an urgent need for:

- Speedy implementation of the Forest Law (2002) Permanent Forest Reserve and Land Law (2001) Article 23 to 28, Part II in Chapter 3, the communal titling of indigenous peoples lands. This allows indigenous peoples to manage community forests, provides indigenous people security of their tenure, and an opportunity to improve their socio-economic conditions. Therefore, this has direct significance for CBNRM.

- Temporarily halting the processing of the sale of indigenous peoples lands. Rich and powerful people in Cambodia are taking advantage of the indigenous peoples' lack of awareness and understanding of the relatively new Forestry Law (2002) and Land Law (2001), and of how these laws can be used to protect their rights. This condition is one of many factors that has contributed to the dramatic increase in the illicit sale and acquisition of indigenous peoples lands by rich and powerful people for private ownership.

- Removing the Commune Council's role in approving and registering land bought in indigenous territories, to discourage their alleged involvement in the illicit sale of indigenous peoples' lands. Commune Councils are authorized to approve and register lands bought in Ratanakiri province. However, there are reports (e.g. Bann, 1997; World Bank, 2006; Tyler, 2006; Ojendal & Sedara, 2006; Global

Witness, 2007) that Commune Councils are involved in the illegal sale of indigenous peoples' lands. Removing Commune Council's role to approve and register lands in the province would be a step to discourage their alleged involvement in the illicit sale of indigenous peoples' land. It is believed that this would help Commune Councils to regain their reputation and to re-establish the trust of indigenous peoples.

4.3.2 Promote incentives that encourages indigenous peoples to continuously participate in CBNRM implementation

Promoting incentives can sustain engagement of indigenous peoples. In the province of Ratanakiri, monetary incentives were used to motivate the indigenous peoples to participate in government organized community activities. This was through a per diem (or allowance), a direct cash incentive. Although the use of per diem can be a tool to promote community participation in CBNRM, it can also promote selective and passive participation. There are studies (see McNeely, 1988 and Birchall & Simmons, 2004) that suggest direct cash incentives produce a long-term disincentive to local peoples' motivation to participate because this creates dependency on financial support. Therefore, it is recommended to adopt non-monetary or indirect incentives in implementing CBNRM. These can be through:

- Use of participatory approaches that empower indigenous people. Participatory approaches encourage indigenous peoples to own identified solutions to their issues, because these approaches when implemented appropriately, may lead to responses to local issues. This can motivate people to continuously participate in CBNRM.

- Capacity building programs for indigenous people so they can meaningfully engage in decision-making discussions and influence decisions that can have significant implications for them. Comprehensive training and education programs enable indigenous peoples to acquire knowledge and skills, which can have a motivational effect on them. However, such programs need to be tailored to their capacity building needs and situations, rather than to project needs that might not be specifically useful or appropriate to the indigenous peoples' needs and problems.

- Providing livelihood support through income generating projects or activities. Income generating activities can serve the interests of indigenous peoples, and therefore generate sustained participation in CBNRM. However, income-generating projects need to ensure an equitable sharing of benefits, otherwise they could cause discontent and undermine community initiatives.

5. Conclusion and Policy Implications

This study finds that despite the participatory implementation of CBNRM in Ratanakiri province and its achieved outcomes, CBNRM is at odds with a hierarchical and top-down governance system. The government of Cambodia was found to be not ready for CBNRM. In fact, the government is part of the problem and therefore part of the solution to improve the implementation of CBNRM. For CBNRM to succeed in Ratanakiri province the government needs to first recognise indigenous peoples rights over their traditional lands, which in a way enables them to become equal partners in the implementation of CBNRM. Further, this study finds that achieving equitable outcomes of CBNRM as a government-driven project presents issues of power and decision-making control, wherein the government continues to be powerful over indigenous people.

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Quantitative and Qualitative Assessment of Timber Harvesting Residues: A Case Study of a Balsa Plantation in Papua New Guinea

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Abstract

The quantity and quality of the harvesting residues in a balsa plantation located in East New Britain Province of Papua New Guinea has been evaluated in this paper. The plantation was harvested manually with chainsaw and man-power to extract the industrial wood at age six years. A standard harvesting residue assessment method was applied using line transects. The total weight of the remaining harvest residues on the site after wood extraction was 211.7 t_{GREEN} ha^{-1} and the major component was un-merchantable stem wood (121.3 t_{GREEN} ha^{-1}; 57.3%). Bark was the next major component of the residue (59.3 t_{GREEN} ha^{-1}; 28.0%). The average moisture content of the wood components recovered over the two days was determined. The average moisture content in harvesting first day was 50% while the average for the day following harvest operation was about 48%. The elemental content of the harvest residues was estimated based on published data for eucalypts in the absence of data for balsa and it showed that calcium was the largest component while phosphorous was the lowest elemental component of the harvest residues. The results indicate that the level of remaining harvest residues in this study area was relatively higher than other reported studies which reflects the combination of the log specification applied and the nature of the stem defects in balsa trees. The level of residues indicated the possibility of additional woody recovery for bioenergy.

Keywords: Balsa plantation, harvesting residues, harvesting method, nutrient level, moisture content

Introduction

Balsa (*Ochroma pyramidale* (Cav.ex Lam.)) is a fast growing species endemic to Central America, extending from southern Mexico to Bolivia and eastwards through most of Venezuela and throughout the Antilles (Francis, 1991). The species was introduced into Papua New Guinea (PNG) prior to 1938 with the first comprehensive introduction referred to as “Milner’s Balsawood” occurring in 1947 or 1948 (Howcroft, 2002). Since that time the species has been developed in East New Britain Province (ENBP) as an important commercial crop for wood production, local processing and export (Midgley et al. 2009). Balsa is exported from PNG and supplied into the industrial market (e.g. for use in wind turbines as a composite sandwich product) and the hobby market (e.g. for model plane making and general craft). Both markets have a high quality control, with specific wood density requirements. The trees are grown on a short rotation of approximately 5 to 6 years before harvest and processing. Balsa as a cash-crop has been adopted by smallholders in the Gazelle Peninsular of ENBP as part of their livelihood strategies and it has been incorporated into local garden systems as a strategic cash-crop diversification and supplement to cocoa production. Post-balsa-harvest residue management by smallholders varies but can include a complete site clean-up prior to either subsequent rotations of balsa with or without an intermediate but overlapping garden crop during the early stage of the balsa crop. The impact of such management on the potential yield of the sites is of concern (Midgley et al. 2009). While comprehensive nutrient deficiency guides are available for eucalypt species (Dell *et al.* 2001), similar supporting materials is not available for balsa growers.

Keeves (1965) provided evidence of a second rotation decline for *Pinus radiata* D. Don growing in South Australia. Subsequent research resulted in management practices changing (i.e. genetics and site specific management) and an analysis of operational results indicated a 60 to 70% increase in productivity (O'Hehir and Nambiar, 2010). Such practices have been adopted across many Australian industrial plantation estates. The impact of plantation management practices on the productivity of subsequent crops has been researched for short rotation plantations and Yamada et al. (2004) stated: "There is concern about the potential decrease in productivity caused by nutrient loss by intensive and repeated harvesting. It is important to determine the nutrients removed and conserve them as much as possible to prevent productivity loss and for sustainable management of industrial plantations. Careful management of the nutrient cycle through residue retention and fertiliser application is necessary to maintain high productivity."

The level of harvest residue on sites after industrial wood recovery depends on various parameters such as applied harvesting method, equipment, stand age, product type, silvicultural regime, species, site and stand quality. The common reasons for removing harvest residues post-harvest include reducing pest risks (e.g. bark beetle hazard), preparing the site for tree planting, harvesting biomass for energy, and reducing fire risk (Schnepf et al. 2009). However, harvest residues (leaves, needles, bark and woody debris) protect soil from excessive moisture loss, recycle nutrients for trees and other plants, add structure and organic matter to soil, reduce soil erosion, and provide food and habitat for a wide variety of wildlife. A trial of residue management impact on nutrient stores and fluxes, and the growth of subsequent rotations of *Eucalyptus globulus* Labill. (O'Connell *et al.* 2004) concluded that the impact of harvest residue management (including complete removal) had little impact on growth for more inherently fertile sites, whereas on less fertile sites, harvest residue management could adversely impact (reduce) subsequent crop productivity. The elemental content of the different biomass components is understood for a range of species. For example, Judd (1996) presents the elemental content of foliage, branch, bark, wood and litter for eucalypts (plantations and natural forests) which can be combined with species biomass allocations to estimate the nutrient impact of different residue management strategies. Balsa-specific elemental content data has not been identified nor has a breakdown of the biomass components remaining onsite after harvest and recovery of the target logs.

A comprehensive set of studies has been conducted by the Forest Industries Research Centre in Australia since 2010 to evaluate the harvest residues for different plantations. Sixteen case study areas located in a range of plantations were assessed. The study results showed that the harvest residues in sites clearfallen by cut-to-length (CTL) at the stump harvesting method (101.7 t_{GREEN} ha^{-1}) was higher than sites clearfallen by whole tree extraction to the roadside methods (6.1 t_{GREEN} ha^{-1}). Subsequent recovery of a proportion of remaining harvest residues with biomass collection technologies resulted in lower weight of distributed slash on the sites harvested by the CTL method. Based on the fraction test, the largest parts of the remaining slash was for stem-wood and branches (Ghaffariyan, 2013).

ENB smallholder farmers sell their balsa to local processors as standing trees. The current balsa harvesting systems can be segmented into a 100% manual system of tree falling, cross-cutting, debarking and loading of the cut logs onto trucks for transport to the processors and a manual system incorporating skidding of the fallen stems to a central point in the stand for cross-cutting, de-barking and loading onto trucks. A key difference between the two systems is the concentration of harvest residues at the landing in the skid to roadside system compared to the more dispersed harvest residues of the 100% manual system.

The level of balsa harvest residues is a concern to smallholder growers and is often encountered in discussions with smallholders. As a first step to addressing the issue of residue management, site productivity concerns and the perception of excessive "waste" as a result of balsa harvest, the following paper details the analysis of the post-harvest residues remaining onsite for a single stand of balsa growing in the Gazelle Peninsula of ENBP. This study was conducted to address the following objectives:

- Evaluate the weight of the harvest residues for a balsa harvest site;
- Measure the share of each component of the harvest residues and moisture content of the residues to determine the harvest residue dry mass;
- Exploring the reasons for leaving the residue on harvesting site;
- Generate a high level estimate of the nutrient content of the harvest residues.

Materials and Methods

The study site

The study site was a 6 year old plantation of balsa (Figure 1) located in a PNG Balsa Limited plantation in ENB, PNG, approximately 20km south west of Kokopo near the town of Warangoi, in the Rung Creek plantation (4º28'20"S 152º10'38"E). The mean annual rainfall is approximately 2,000mm, monthly mean maximum temperature varies from 31ºC in July to 32.2ºC in October and mean monthly minimum temperature throughout the year is 22ºC. The site was previously used for smallholder gardens and nutritional status of the site is unknown. The plantation was established at a spacing of 3 m × 3 m (1,111 stems ha^{-1} initial stocking) and at the time of harvest, the stocking rate had reduced to 377 stems ha^{-1}.The reduction in stocking was due to natural thinning rather than management interventions.

Figure 1. The stand of balsa prior to harvest (21/11/2013).

Stand attributes sampling

A single 0.07 ha inventory plot was installed the day before the site was harvested with each tree individually numbered to capture individual tree data. The diameter at breast height over bark (DBHOB) of all trees in the plot was measured at 1.3m, and 5 basal areas sweeps were conducted with a basal area factor (BAF) 2 prism wedge. The trees within the plot had a basal area of 44.6 m^2 ha^{-1}, a mean diameter at breast height (DBHOB) of 38.3 cm, a mean total height of 34.5 m and an estimated total biological volume over bark of 838.9 m^3 ha^{-1} (Jenkin et al., 2014). Post falling, the height of each tree bole to a merchantable small end diameter (SED) of 20cm and the total height of the tree was measured. Stump height and diameter was measured and recorded.

Harvesting operation

A fully manual harvest system was applied. That is, the fallen stems were processed into logs where they fell. Trees were manually felled with a chainsaw, and once felled, each tree was measured and marked prior to being docked into log lengths (Figures 2 and 3). Bark was removed from each log with manual tools. The log specification applied was 1.4 m to 1.8 m lengths with minimum centre diameter >20 cm. Each log was measured and log length rounded down to the nearest 0.1 m and centre under bark diameter to the nearest 1.0 cm was recorded onto the log with a water-proof crayon. Logs with an under-bark centre diameter of between 20 – 27cm were produced, marked and tallied (and paid for), however these logs were left in the field due to market conditions with only logs of equal or greater than 27 cm centre diameter over bark recovered. Each log length and diameter within the study site was recorded on an individual tree basis. Logs were manually removed from the site and loaded onto field bins, before being loaded onto a truck fitted with a hook lift.

Figure 2. Tree felling with chain saw

Figure 3. Carrying debarked logs

Harvesting residues assessment

The Forest Industries Research Centre (FIRC) standard methodology for harvest residue assessments (Ghaffariyan et al. 2012a) was considered and modified to take account of the different levels and nature of harvest residues present in a post-harvest balsa coupe. The sample point plot was increased from 0.5 m × 0.5 m to 1.0 m × 1.0 m (Figure 4). The modified system was applied to estimate the onsite green weight of the harvest residues and to estimate the percentage of each residue component (as defined in Table 1) to detail the nature of the balsa residues. The post-harvest area was walked to determine the uniformity of distribution of the harvest residues. It was determined that the residues distribution pattern while variable, did not exhibit distinct stratums: that is, the harvest system did not aggregate the harvest residues. The harvest residue assessment was conducted in this balsa plantation commencing in the 0.07 ha plot and extending along a ridgeline within the study site. The assessment covered a study area of approximately 1 ha along the harvested ridge and the plots were located every 10m following a straight transect. A total of 21 plots were installed: 4 plots were sampled on the 11/09/2013 and 17 plots on the 12/09/2013.

Table 3: Attributes of the residue sample components.

Material	Description
Bark	The bark of the stem of the balsa tree.
Small branches	Branches from the tree crown on to which the leaves were attached.
Medium Branches	Branches from the tree crown which were secondary to the jorquette but which did not have leaves attached.
Large branches	Branches from the tree resulting from the jorquette but not present as a multi-stem.
Large Butt Stem-wood	Stem-wood taken from within less than 2 m from the tree stump.
Small stem-wood	Stem-wood with an mid-stem over-bark diameter of less than 20 cm.
Leaves	Leaves from the crowns of the trees (which included a large petiole).

Within each of the 21 1 m × 1 m plots as well as weighing the total weight, all stem-wood was weighed separately, and a reason recorded why it was not recovered as a log. From the 21 plots, 10 plots were randomly selected to have the fractions weighed individually to estimate the percentage share of each fraction (Figure 5). The moisture content of the residues was measured from the collection of 7 samples taken the day of harvest and 7 samples the day following harvest. Samples were oven dried in a laboratory oven to a constant weight to determine oven dry weight.

Figure 4. Laying the 1m square plot. Figure 5. Cutting large harvest residues to weigh

The outcome of the biomass fractions analysis was converted from green to oven dry weight using the determined moisture content for the residues harvested on the same day. In the absence of specific elemental content data for balsa trees grown in PNG, a composite dataset for plantation grown eucalypts was used to calculate an estimate of the elements contained within the different residue components (see Table 2). These fractions were applied to the estimated oven dry residue components to generate a high level and indicative elemental content of the harvest residue components.

Table 4: A breakdown of the elemental content (% dry weight basis) of plantation grown eucalypts (*Symphyomyrtus*) species (Judd, 1996).

	Nitrogen (% dry weight)	Phosphorous (% dry weight)	Potassium (% dry weight)	Calcium (% dry weight)	Magnesium (% dry weight)
Stem-wood	0.12	0.005	0.12	0.10	0.035
Branches	0.40	0.04	0.35	0.75	0.15
Bark	0.35	0.04	0.32	2.40	0.19
Leaves	1.75	0.12	0.70	0.75	0.30

Results

Harvesting residues

Based on the inventory data, the average weight of the harvesting residues in the study area was 211.7 t_{GREEN} ha^{-1} (standard error= 33.5). The major component of the harvest residues was stem-wood (121.3 t_{GREEN} ha^{-1}) which formed about 57.3% of total harvesting residues. The share of other components of harvest residues is presented in Table 3.

Table 3. Share of remaining slash components

Component	Percentage (%)
Stem-wood	57.3
Branches	14.2
Bark	28.0
Leaves and petioles	0.5

The average moisture content of the wood components for two days is presented in Table 4. The average moisture content on the day of harvesting was 50% while the average for the day following harvest was about 48%. Although it had rained during the day after harvesting, due to tropical weather conditions, there was a 2% moisture loss based on the sampling results. For the harvesting day moisture content assessment, the small branches had the highest moisture content (63%) while for the day following harvest, large branches were the wettest component of the residues with moisture content of 53%. Figure 6 presents the dry weight of residues in the different plots.

Table 4. Moisture content of different wood component in two days

Type	Moisture content in harvesting day (%)	Moisture content in day following harvesting (%)
Bark	53	50
Small branches	63	51

Med Branches	46	41
Large branches	47	53
Large Butt Stem-wood	44	38
Small Stem-wood	40	50
Leaves	54	56

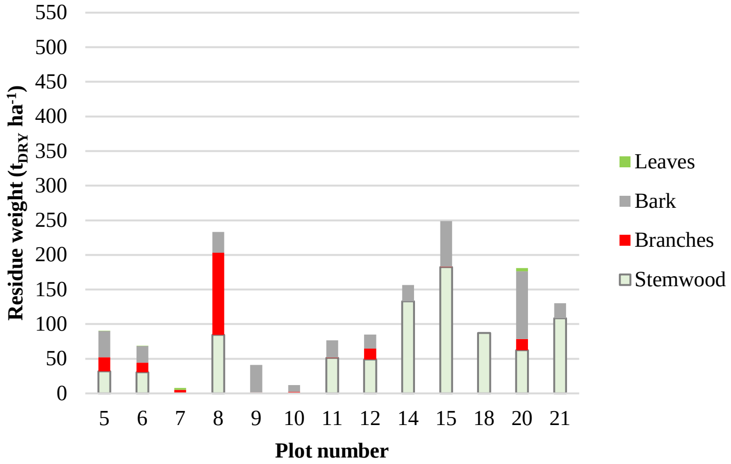

Figure 6. Total harvest residues per plot in t $_{DRY}$ ha^{-1} segmented into the different harvest residue components.

The components of 18 residue samples were specifically analysed to determine their bark thickness, weight, length, diameter and the reason for the residue remaining onsite. These results are shown in Table 5. From the results, 22.7% of the weight of residue stem-wood was bark weight where the individual stem-wood weight averaged 11.0 kg/piece with an average length of 2.4 m and a diameter of 26.9 cm.

Table 5. Characteristics of the residue stem-wood.

	Average	Standard deviation	Confidence interval
Net bark weight per log (kg)	2.5	2.4	± 1.2
Net stem-wood weight per log (kg)	8.5	10.0	± 5.0
Total length (m)	2.4	2.8	± 1.4
Diameter (cm)	26.9	6.5	± 3.2
Bark thickness (cm)	6.6	1.6	± 0.8

Given the importance of addressing the issue of concern as to the levels of harvest residues and a need to better understand the cause of stem-wood residues, the plot sample data was collated to determine the detailed attributes of the residues. Figure 7 indicates that the percent by weight of the bark residue component is 21.1% and the under-bark stem-wood was 78.9% of the stem-wood residue (45.4 and 169.9 t_{GREEN} ha^{-1} respectively) (Figure 8). The attributes of each piece was measured for each sample indicating a mean bark thickness of 6.5 mm (SD=1.6 mm), a mean under-bark diameter of 26.5 (SD= 6.5 mm) and a mean length of 2.6 m (SD = 2.8 m). The cause of stem-wood rejection on a t_{GREEN} ha^{-1} basis was collated. The two sets of analysis have been included as the rankings of the main causes of stem-wood rejection on a weight basis provides the true impact of the rejection whereas it is possible that the number of pieces creates a greater visual impact and perception. On a weight basis, butt log red heart was the main cause of rejection (31%), whereas on a number of pieces basis, stem sections with an under-bark diameter below the minimum under-bark diameter specification (< 20 cm) accounted for 47% of rejects. Stem defects (e.g. due to jorquettes) resulted in 24% by weight of the rejects but only 16% by piece numbers: the low piece number may result in a perception that this issue is of less significance. Under the current market conditions the take or pay logs (with mid log under-bark diameters of 20 to 27 cm) accounted for 13% of the rejections on a weight basis and 21% on a piece number basis.

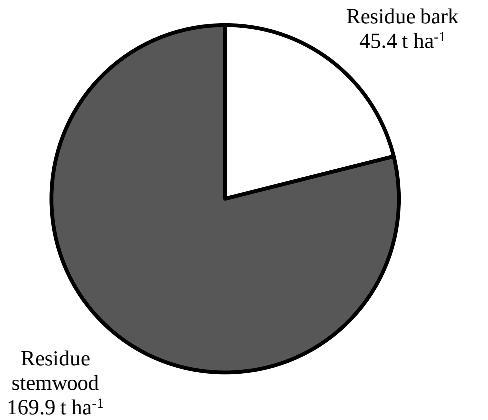

Figure 7. A breakdown of the bark and stem-wood on a green weight basis.

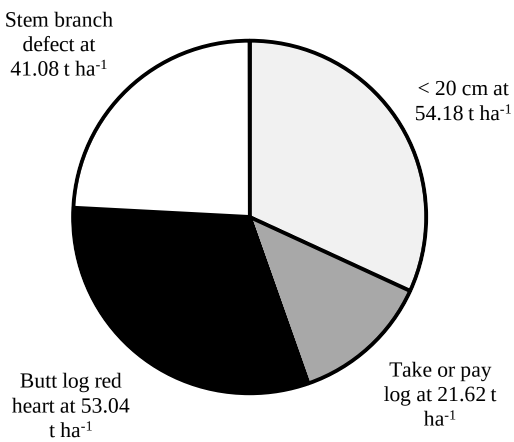

Figure 8. A summary of the cause of stem-wood rejection identified in the sample plots on an under-bark green weight basis.

Nutrient level of harvesting residues

Based on the estimated harvest residue dry matter and the indicative plantation-grown eucalypt biomass elemental component, highly indicative elemental contents were estimated (Figures 9 and 10 present indicative elemental content of the harvest residues on a kg per hectare basis). Based on the weight of residues onsite and the indicative elemental content, the balsa bark is the most critical component with the branches and stem-wood being of similar importance. The leaves are the least significant of the harvest residue components. Calcium is the most significant element by weight, followed by nitrogen and potassium.

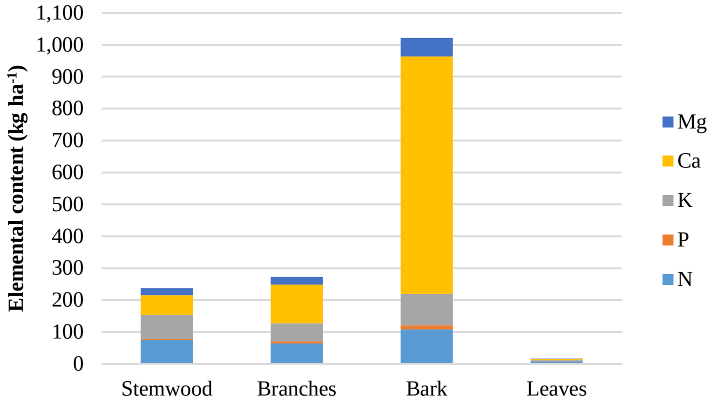

Figure 9. The elemental content of balsa harvest residues.

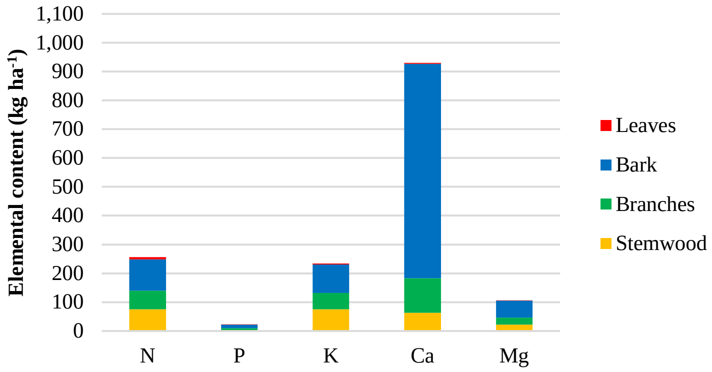

Figure 10. Total elemental content segmented by balsa harvest residue component.

Discussion

The total amount of harvest residue of 211.7 t_{GREEN} ha^{-1} is relatively high compared to other harvesting residue studies in hardwood forests in other countries; 106.5 t_{GREEN} ha^{-1} for eucalypt plantations harvested by cut-to-length (CTL) harvest method and 6.1 GMt/ha in whole tree extraction method in Western Australia (Ghaffariyan, 2013), 64.0 t_{GREEN} ha^{-1} for eucalypt plantation harvested by CTL method in south-western Australia (Shammas et al. 2003) and 160 t_{GREEN} ha^{-1} for hardwood stands in USA (Beardsell, 1983). Based on the data presented in Figures 7 and 8 the driver of the harvest residues is a combination of acceptable log specifications and the nature of the balsa tree e.g. the inherent defects in the stem.

Harvesting method was found to be a significant factor influencing the level of harvesting residues in Australian plantations (Ghaffariyan, 2013). The current CTL method as applied on this site is a reflection of the internode length of the balsa stems; the length of the boards in the sawmill – around 1.4 to 1.8 m maximum; the length of the manufactured product e.g. balsa end grain blocks of approximate dimensions of 900×900×900 mm. The manual measurement and optimisation of logs from within the stem takes account of the lack of uniformity with balsa as a crop. One recent mechanisation has been to skid the full balsa stems to the roadside for processing on a landing. This accumulates the significant harvest residues at one point. If the full stems were to be taken to a landing, a significant volume of residues would result particularly if the stems were extracted with the bark on. The introduction of higher levels of mechanisation is an option but great care would be required to realistically assess this under the local circumstances.

There are no current markets for balsa harvest residues. The level of harvest residues presents an opportunity for supply as feedstock to additional industry development such as bioenergy. The moisture content of the samples is within the range of reported harvesting residues (Ghaffariyan et al. 2012b). If the future aim of the plantation management is using residues for bioenergy purposes, the residual stem-wood could be dried naturally (which would be a relatively fast process in the operating environment as shown by a 2% drop in one day in this trial) at the storage point to reduce the moisture content and increase net calorific value (Acuna et al. 2012). All fine materials such as leaves, twigs, small branches or bark and leaves can be left on the site to maintain soil fertility (Rothe, 2013). There are two key considerations: recovery of the materials and the impact on sustainability.

If market opportunities were identified for the harvest residues, the dimensions of residue logs (2.4 m length and 26.9 cm diameter) and average weight of 11 kg per log indicate the appropriate piece size for man-powered wood extraction which is currently the dominant extraction method in the region. In the case of identified markets for the harvest residue, further exploration of the efficiency of using draught animals or mechanical systems would be warranted and could build on experience from Europe (Magagnotti and Spinelli, 2011) and past studies in PNG (Pumfrey, 1983). However, the small piece size is likely to present a real challenge for any efficiency application of mechanical extraction technology as small piece size would increase the cost. Experience in other plantation operations around the world has shown when there are market opportunities for harvest residue recovery, the most efficient method tends to be to skid the full stems to a central point for processing into logs and recovering the residual materials at the same time.

The main micro nutrient of interest in ENBP is boron, however nitrogen is also a concern (Midgley et al., 2009). There is a lack of general information on the impact of the different nutrients on balsa as a crop unlike other species where comprehensive guides are available (e.g. see Dell et al. 2001). Figure 10 provided a summary of the estimated elemental content of the harvest residues and calcium was the largest component. Calcium is critical for root tip and shoot growth as it is essential for cell division and growth (Dell et al. 2001). Nitrogen was estimated as the next most significant component and it is a structural component of cell walls and a component of amino acids, amides, amines, N bases, nucleic acids, alkaloids, chlorophyll and many co-enzymes (Dell et al. 2001). Potassium was the next highest estimated component of the harvest residues. In deficient plants, protein synthesis, photosynthesis and cell extensions are impaired (Dell et al. 2001). Magnesium was estimated to be the next highest component of the harvest residues and its role is as a co-ordinated metal in chlorophyll (Dell et al. 2001). Phosphorous was the least of the elemental components of the harvest residues and it is essential for plant growth via its role in metabolic processes (Dell et al. 2001).

The actual impact of any harvest residue management will depend on the interaction between the local soils. For example, how would soil pH and absolute nutrient content affect the ability of balsa trees to access the available nutrients? The role and outcome of harvest residue management on site productivity will depend on the rate of decomposition of the harvest residues, the quantity remaining after harvest and the result of site management. The bark component of the harvest residues is the most significant in terms of quantity of the elements held but the impact of any bark management practices is unknown hence any shift to greater recovery of the logs with the bark on, needs to be viewed with caution. At the other end of the spectrum the leaves on-site hold the least quantity of nutrients but given their rapid decay onsite, the importance of the leaf component may result from a continuum of nutrient release based on the decay rates of the different components.

Conclusions

The level of balsa harvest residues is greater than for other plantation harvests, which in part validates the perception of the smallholders that there appears to be a significant level of waste. However the materials remaining are un-merchantable stem-wood (due to defects or market conditions), bark and branch materials. The level of residue is a function of the nature of balsa tree stem attributes and the specifications of the logs recovered. While this analysis has significant limitations (e.g. the key assumption that the nutrient content of plantation grown eucalypts is a proxy for balsa), it does highlight the need for caution in the method of harvest residue management to maintain site fertility. While the nutrient status of the residues has been considered, there is a need to address the nutrient removal in the wood taken from the site for processing.

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Unlocking the Wealth of Forests for Community Development: Commercializing Products From Community Forests

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Abstract

Community and smallholder forestry regimes now encompass more than 689 million ha and comprise about 26% of the world's forests. It has long been argued that community forestry has the potential to deliver major livelihood benefits for local communities. However, to do so, it needs to move beyond providing mainly subsistence goods and become a vehicle for the development of forest enterprises that can contribute to a genuine new forest economy. Most effort in community forestry to date has been devoted to implementing the initial stages of the community forestry process, i.e. the establishment and formal recognition of community forests and their membership groups – the first generation stage of community forestry. However, a growing number of countries are now facing a new set of issues associated with moving to a second generation stage of community forestry, i.e. one involving the commercialization of forest products. This paper reviews experience in commercializing products from community forests in several countries. Overall, community forestry is grossly underperforming, particularly in delivering financial benefits to community members. In most countries, even when community rights are secure, multiple and complex bureaucratic procedures imposed by public forest and other government agencies place significant impediments in the path of communities that effectively prevent them from managing their forests to deliver their economic potential. Other constraints also apply, including a lack of entrepreneurial and business management skills in communities (and remote rural areas generally) plus a range of legal and market-related issues. A consensus is emerging that commercialization will not progress in most countries without addressing two major policy issues: (1) Providing communities with the rights to harvest high-value forest resources, including timber and, (2) Improving the enabling environment for small enterprises so that forest communities can register businesses, access financial services, negotiate partnerships and attract sustainable investment to enable them to increase the benefits from the sustainable management of their forests. The ultimate challenge for policy-makers is to look beyond the forests and trees to the markets and facilitate the development of enterprises based on the sustainable management of community forests, while avoiding low value-added forest exploitation, but still allowing traditional forest uses to continue.

Keywords: Community forestry; commercialization.

1. Introduction

During the past two decades transitions have been taking place in the formal tenure arrangements that apply to forests in many parts of the world. White and Martin (2002) analysed forest tenure in 24 of the 30 most forested countries and noted that: "*There is a major, unprecedented transition in forest ownership underway... The recognition of indigenous rights and community ownership — and the broader rationalization of forest* *tenure — present an historic opportunity for countries to dramatically improve the livelihoods of millions of forest inhabitants*." (p. 22).

This transition has resulted in the adoption of community forestry in many countries, particularly in Asia, Africa and Latin America, as a mainstream form of forest management. It is estimated that community and smallholder forestry regimes now encompass about 689 million ha, which equates to about 26% of the forest land in the 62 countries assessed across all regions of the globe (Gilmour In press). In most countries the rationale for embracing community forestry as a distinct forest management modality has been two-fold: (i) to improve the condition of forests, and (ii) to improve the socio-economic well-being of the communities involved, although, as noted by Warner (2007), the first of these is dominant in many situations. Tole (2010), reporting on a global survey of community-based forest management, noted that government officials consider that regenerating and protecting forests is the paramount goal, while communities view food and income security as being the most important. Most of the documented results of community forestry focus on the biophysical aspects, and describe how forest conditions have improved since the establishment of community management regimes. There are fewer documented examples of communities deriving substantial financial and social benefits from their forests. A global review of 40 years of community forestry (Gilmour In press) concluded that community forestry has not been particularly successful in generating income to improve community and household livelihoods, and as a generalization, it is fair to say that community forestry is grossly underperforming.

Most effort in community forestry to date has been devoted to implementing the initial stages of the community forestry process i.e. the establishment and formal recognition of community forests and their membership groups. This might be described as the first generation stage of community forestry. Issues addressed in this initial stage include: clarifying tenure; identifying appropriate communities; defining their forest areas; putting in place an enabling regulatory framework; preparing management plans; building strong local level institutions and in some cases, building forest assets. These aspects pose their own difficulties and will continue to be important. However, communities in some countries have now passed this initial stage and are poised to move to a new level of community forestry, one where the wealth locked up in the forests can be realized and used to contribute to significant community and national development, while sustaining the forests into the future. These communities are now facing a series of issues associated with moving to a second generation stage of community forestry, i.e. one involving the commercialization of forest products.

Many of the examples included in this paper are based on limited data. One conclusion from scouring the literature is that there is a dearth of well documented case studies on the costs and benefits associated with managing community forests for commercial purposes. Most of those that are available tend to focus on conventional approaches to determining financial benefits, and overlook the environmental and particularly the wider social costs and benefits.

Both timber and non-timber forest products (NTFPs) are considered in this paper, as the commercialization of both is inhibited by numerous constraints, often of a similar nature. However, the two are sometimes treated very differently within national regulatory regimes. In particular, governments in many countries demonstrate a much greater reluctance to allow the commercialization of timber from community forests compared with NTFPs, particularly where the timber value is high (Warner 2007). An example of this distinction is given by Foppes et al. (2011) who report for an area in central Myanmar that "*…villagers mentioned the main reason they do not sell the timber from community forests is because they are not* *allowed by the Government to sell timber to other villages, they can only use it in their own village*". (p. 17). However, they are allowed to sell NTFPs. A similar situation occurs in other countries, and Warner (2007) notes that, in general, community forestry was conceived and implemented to provide poor and marginalized people access to degraded forests that, if well managed, could provide fodder, fuel, medicinal plants and a small amount of income. Warner concludes by noting that "*…rights over timber…* tend to be *…excluded or narrowly prescribed"*. (p. 15).

By and large, timber is the most valuable product in most forests and this makes it worthy of special consideration, as commercializing timber can make a significant contribution to wider community development as well as to general livelihood enhancement. Overall, there is little focused discourse on issues associated with commercializing timber from community forests, and little donor support.

2. Examples of Community Forestry Enterprises

Examples of the development of forest enterprises based on community forests are not widespread when compared with the total area under community forestry management regimes. However, they do occur and give guidance as to how community forestry commercialization might proceed. The following examples describe a variety of enterprises.

Example 1**:** Bampton and Cammaert (2007), using data from the Department of Forests in Nepal, estimated that Community Forest User Groups in the Terai region of the country (the lowland areas in southern Nepal) derive substantial income by selling timber to non-User Group members. They were selling some 890,000 cu ft of Sal timber (*Shorea robusta*), 470,000 cu ft of other species and 14.2 million kg of Khair timber (*Acacia catechu*) annually. They calculated that the Sal timber alone would be worth approximately US$ 1.3 million per year to those User Groups involved (the number of groups was not specified). This is in spite of the regulatory, bureaucratic and other constraints that apply to the sale of timber from community forests in Nepal.

Example 2**:** Ouedraogo et al. (2007) describe a project in the West African Sahel aimed at promoting community microenterprises based on NTFPs. This pilot project adopted a Market Analysis and Development (MA&D) approach for organizing small producers into enterprises that extract and process NTFPs. The MA&D approach, especially developed for application in areas with high illiteracy and limited access to markets, enables poor rural households to assess potential returns and risks associated with different strategies for the development of NTFP-based enterprises.

At the end of the pilot project, 186 business plans involving 1,800 village entrepreneurs from 180 NTFP interest groups were developed. Sixteen products from 10 tree and forest resources were selected by villages for income generation. The potential income of the 16 products amounts to a sum of about £800,000. However, some of the businesses required further refinement and strong input from project supervisors, facilitators and co-facilitators. Substantial problems were reported in implementing the business plans. Among the constraints were:

- Lack of financial capital, limiting investment, notably in improving product quality;
- Declining tree and forest resources, leading to declining supplies of NTFPs;

- A shortage of outlets and wholesale buyers and problems in storing products, resulting in gluts on the market, and depressing prices;
- Lack of skills in processing;
- Large price fluctuations, with limited access to useful market information;
- Transport problems, as much from the place of harvest to the village as for transport from the village to major markets; and
- Limited experience in enterprise organization among small producers and community members.

***Example 3*:** (Adapted from Stoian, 2007.) In 1996, the Carmelita community in Guatemala was granted a community concession of 53,798 ha for a period of 25 years. Following a series of institutional changes, the community is now legally constituted as a cooperative with 127 members. Legally recognized forest use started on an area of 100 ha in 1997 with timber being sold on the stump to the local industry. In 1999–2000, "flitches" (i.e. logs sliced with a chainsaw) were sold to the local industry. During 2001–2003, machinery was rented for local processing and the first exports were sent to the US and the UK. On-site sawmilling commenced in 2004 and has allowed Carmelita to offer expanded services to international buyers of certified mahogany and tropical cedar, as well as lesser-known species.

Of 20,400 ha earmarked for timber extraction, 3,795 ha were harvested between 1997 and 2006, when a total of 9,800 m^3 of timber were extracted. Table 1 gives an indication of the income derived from the enterprise in one year (2003).

Table 1. Production costs, gross and net income of the Carmelita enterprise in 2003.

Production costs (US$)	**Income from timber sales (US$)**	**Net income (US$)**
158,244	430,572	272,328

Carmelita's constitution stipulates that 30% of the income be reinvested in social projects. Though this stipulation has not always been fully accomplished (the general assembly can set other priorities) investments have been made in a potable water system, wages paid to non-community members for repairs or other work at the local school, and educational stipends for primary and secondary schools (about six to eight stipends each year). In general terms, enterprise development has had positive effects on community organization, women's participation, education, human resource development, local infrastructure and service development, health and income generation. In addition, dividends have been paid at the end of each year. Dividends per member typically vary from US$140 to $210.

Lessons that have been learned from this study include:

- Production of high-quality wood products is hampered by limited technical skills and insufficient and/or inappropriate technology;
- Long-term access to business development services is critical to upgrade management capacities and other business skills and increase returns from community forest management;
- The enterprise is administered by community members rather than professional managers, and they have limited experience in business administration or timber marketing; and
- Skill development is critical for continued success of the enterprise.

Example 4: A Forest User Group at Thulo Sirubari in the hill district of Sindhu Palchok in Nepal owns and manages a small sawmill that is used to mill plantation timber from their community forest that they established in the 1980s. In this example, the Forest User Group manages all aspects of the operation: tree felling, transport of logs to the sawmill, sawing, transport of sawn timber to the capital of Kathmandu in a truck owned and operated by the User Group, and direct sales of the timber to merchants. The User Group is able to derive economic benefit at each stage of the value chain and finally market a high value product. The sawmill does not operate full time, but only when orders are received and mainly during less busy periods of the agricultural cycle when local labour is available. The User Group has used profits from the sawmill operations to diversify investment by constructing a two storey building adjacent to the sawmill that generates retail and residential rents. The income derived from these enterprises funds a number of forest management and social activities. These include activities aimed at enhancing social welfare – for example, loans to a group of widows to develop a separate enterprise focused on processing, packaging and marketing a valuable NTFP (i.e. fruit from a tree (*Chorespondias axillaris)* grown widely on private land in the area). While the overall enterprise might not rate as being highly efficient from a purely economic perspective, it does optimize the financial and social benefits for the community.

Example 5: (Adapted from Foppes and Wanneng, 2007.) At least 50% of all 36,120 families in Xiengkhouang Province in Lao PDR collect NTFPs regularly for both subsistence use and for sale into the market. The cash equivalent of the products used for subsistence equates to $200-350 per family per year. Direct cash income from selling NTFPs is worth $36 per family per year, which contributes around 30% of the total family cash income. In remote districts sale of NTFPs may provide up to 80% of family income. The total value of trade in NTFPs exported from the Province was estimated to be around $1.3 million in 2005. It is second only to corn, which provided an export income of around $3.45 million in 2006.

Virtually all NTFPs in the Province are harvested from wild resources, and there is very little domestication. The market structure is based on a chain of traders from the village through districts and provinces to the larger buyers/exporters in other provinces. Most products are exported to Thailand (food products), China (medicinal plants) and Vietnam (rattan).

The main problems faced by village NTFP collectors and traders are:

- A steady decline in NTFP availability from wild sources;
- Low prices, few options to add value by improving product quality;
- Limited access to markets and support services; and
- Over-regulation.

It is worth noting that this example, while demonstrating the importance of NTFPs for livelihood enhancement, is not strictly an example of community enterprises. By and large, the collection of NTFPs is unregulated (i.e. there is no community decision-making to regulate harvesting) and the individual collectors sell directly to middle men. However, there is considerable potential to develop community collectives and other mechanisms to improve financial returns to collectors, and examples of bamboo producer groups have been reported.

***Example 6*:** Chavez (2010) describes community forests in Mexico as being divided into five types based on the extent to which communities are able to use their resources. They range from communities with little organization that have not yet developed their forest management plan or begun to benefit from their resources (level 1 of development) to producers with the necessary infrastructure for secondary processing, value-adding and marketing of their forest products (level 5). An example of level 5 is the Nuevo San Juan

Parangaricutiro community in Michoacán in the southwest of the country. This community owns land covering about 18,000 ha, including 10,000 ha of natural production forest, 578 ha of protection forest, and 1,300 ha of plantation forest. In 1981 the community had no money, no equipment and no level of organization. Now there is a strong enterprise and a thriving industry, including a highly productive sawmill, a resin-production operation, a wood-processing facility that produces furniture and mouldings, and a water-bottling facility. Success depended on good organization for the management and harvesting of resources.

Example 7: (Adapted from ITTO, 2010.) Small and Medium Forest Enterprises (SMFEs) in Ghana make a significant contribution to local economies through informal markets. They contribute an estimated 5% of GDP, while the formal forest industry sector contributes 2%. Recognizing this contribution and supporting the formalization of SMFEs and their access to formal markets will improve their sustainability and their contribution to local and national development.

These seven examples illustrate several approaches to enterprise development:

1. Extracting a royalty type payment by selling a product (generally standing timber or NTFPs) to an outside entity.
2. Contracting out some aspects of the processing chain, such as tree felling and log conversion, but retaining ownership of the sawn timber and managing its sale.
3. Managing the downstream stages of the processing chain to add value to their products.
4. Moving from commercializing an initial product to developing a creative blend of varied forest-based and other enterprises.

Clearly, the more involvement of communities in managing the downstream components of the processing chain, the greater the potential for retaining economic benefits. The shift towards commercializing forest products is quite a fundamental transition as it involves moving from being a subsistence harvester to a primary producer (i.e. producing a product for the market) to managing secondary and even tertiary production (i.e. processing and marketing the product). The extent to which communities wish to move down the value chain of harvesting and processing products from their forests will vary enormously depending on a multitude of factors. These include the objectives they set in their forest management and business plans as well as their interest in and capacity for managing different types of enterprises. There are several examples of communities commencing as primary producers and moving further along the processing chain as experience grows and capacity is enhanced (as shown in Example 3 from Guatemala and the results of a case study in Mexico described by Torres-Rojo et al., 2005). Torres-Rojo at al. also describe how the El Balcon community in Mexico used the services of a professional manager, with oversight from a Council of Principals, to assist with the transition.

3. Characterization of Community Forestry Enterprises

3.1 Types

There are several ways in which enterprises established to commercialize products from community forests could be characterised. Many of them fall into the broad category of Small and Medium Forest Enterprises (SMFEs). Donovan et al. (2007) and CATIE (2007) give numerous examples of SFMEs, and discuss their potential to deliver economic benefits and the policy and other constraints that limit their ability to operate efficiently. Mayers (2006) notes that SMFEs constitute up to 80% of forestry operations in some countries, but that it is a volatile and fragmented sector where on average 70% of enterprises fail in the first three years.

Community Forest Enterprises (CFEs) and Community Based Forest Enterprises (CBFEs) are similar and could be considered as sub-sets of SMFEs, as both encompass enterprises where there is some level of community decision-making, which is not necessarily a component of SMFEs. FAO (2011) describes CBFEs as being "*...designed with the help of participatory methodologies such as Market Analysis and Development (MA&D) and operate within the framework of participatory forestry mechanisms that enable those people who have a direct stake in forest resources, to be part of decision-making in all aspects of forest management*." However, there are obviously many common elements shared by SMFEs, CFEs and CBFEs.

Torres-Rojo et al. (2005) note that CFEs have a different 'logic' from privately owned capitalist enterprises as CFEs tend to have multiple goals that may not be shared by privately owned enterprises. These include generation of income, conservation of forests, production of public goods for community benefit, and the participation of community members in the enterprise. In spite of these differences, CFEs must compete and survive in an economic context that demands efficiency and competitiveness.

Some of the examples of enterprises described in the previous section display the characteristics of 'social businesses', as first defined by Professor Muhammad Yunus in his books (see for example Yunus 2008 and Yunus 2010). In Yunus' definition, a social business is a "*non-loss, non-dividend company designed to address a social objective within the highly regulated marketplace of today*" (Wikipedia, 2011). It is distinct from a non-profit organization because the business should seek to generate a modest profit but this will be used to expand the company's reach, improve the product or service or in other ways to subsidise the social mission. A wider definition of a social business is possible, including any business which has an explicit social as well as a financial objective.

The notion of a social business may be a useful construct for future discussions of community forestry enterprises, as the definition fits many of the enterprises that are beginning to emerge in many countries, with their multiple (but often implicit) mix of environmental, financial and social objectives. This mix also has implication when assessing the costs and benefits associated with community forestry enterprises.

No judgement is made here on the most appropriate form that community forestry enterprises should take. This will be influenced to some extent by the management objectives set in individual management and business plans.

3.2 Profitability

It is evident from the examples of community forestry enterprises given in Section 2 that they have the potential to generate significant income at the community level that can be used in various ways. One thing that is apparent from perusing the literature is that there is little analysis of the profitability of such enterprises or the impact that they are likely to have on a national scale.

Antinori (2005) reported on the difficulties associated with determining the profitability of community forestry enterprises in Mexico. She noted that while they can generate income, this requires competitiveness in the market place, which in turn demands management, technical and sales expertise. At the same time, management of common pool assets can provide social, cultural and other non-market benefits to local stakeholders which are difficult to quantify. However, the complexity that surrounds the commercializing of common pool assets makes it unclear how common property institutions fit into the broader market economy. Indeed, she also notes that some people claim that rural community structures are incompatible with efficient markets. However, she proposes an approach to determining profitability that involves a transaction cost analysis as a framework for taking into account the difficulties mentioned above.

Wollenberg and Nawir (1998) reviewed 10 studies from Africa, Asia and Latin America to determine income and costs associated with marketing NTFPs and concluded that rigorous information is scarce. Not only was basic data not available, but appropriate valuation techniques are also not available, and those that are available (such as contingent valuation) have been poorly applied. They also noted that some basic economic concepts do not fit the values, perceptions or conditions of forest dwelling communities very well.

4. Constraints to Commercializing Forest Products

The examples given in Section 2 give a sense of the potential for development that can be realized from community forests, but they are exceptional and are not widespread. In many countries relatively little attention has been given to harvesting and marketing forest products, particularly commercial timber, where the bulk of the economic potential of the forest rests. As noted by Dipak et al. (2011) in Nepal, "…*most of the policy debates take place around non-timber forest products, environmental services and more recently on carbon, limited emphasis has been given on timber*" (p. 2) and "*...donors' funds are more focused on livelihoods, capacity buildings and conservation issues whereas the timber management never got their priority*" (p. 4). This has led to a situation where "*...timber issues have always been sidelined on the forest policy discourses, the state and the communities have failed to get the maximum financial benefits out of it. At the same time, illegal logging and forest encroachment is an increasing trend"* (p.2). They conclude by stating that "*...the timber market in Nepal is distorted*" and "*...the potentiality of timber to contribute in national economy and poverty reduction has been foregone*". (p.7). This is a specific Nepali example, but similar situations occur in many other countries.

While there are numerous examples of communities which have successfully commercialized their forest products, in most cases their ability to do this is heavily constrained by governments who retain most power by granting limited user rights, often only to satisfy subsistence needs. As Molner et al. (2011) noted, "*The persistence of antiquated approaches and regulatory frameworks in forest governance has been a major hindrance to the emergence and growth of smallholder and community-based forest enterprises and their integration into productive value chains and markets*" (p. ix).

Globally, forest tenure rights of local and indigenous people remain weak and this limits their ability to manage their forests for commercial benefits (RRI 2014). In response to this situation, considerable international attention has been focused on the importance of secure tenure in contributing to sustainable forest management and delivering benefits to local and indigenous communities. However, a recent global study on poverty and the environment cautions that forest dwellers may not necessarily benefit from living in areas where enforcement of forest ownership is strong, due to the difficulties in accessing and commercializing valuable forest products (CIFOR 2011). Clearly secure tenure is important, but it needs to be accompanied by an enabling regulatory framework and strong governance systems. These issues are generally addressed during the early stages of community forestry establishment, but frequently need to be re-visited when management moves from a focus on subsistence to one that embraces commercialization.

Pacheco (2012) noted that regulatory constraints often create additional obstacles for smallholders and communities in Latin America, pushing them into informal logging. He observed that their engagement with markets tends to be dominated by patron-client relationships and asymmetrical access to information. The resulting market distortions often inhibit both the ability of communities to increase their capacity as well as further market development, and tend to be perpetuated rather than reversed.

Most community forestry enterprises involve interfacing between community groups and the private sector at some point along the processing chain, whether at the point of sale of the primary product or further along the chain. This interface can be a difficult one to negotiate, as different institutional values apply on both sides. As a result, communities frequently depend on intermediary brokers. These middlemen often receive a disproportionately large portion of the profits compared with those received by the growers. However middlemen are often indispensable in organizing the critical links between growers and the processing industry (Pretzsch et al. 2014). Because timber is a valuable commodity, weak governance arrangements often lead to lack of transparency along the value chain with many opportunities for rent seeking and corruption. Dipak et al. (2011) noted that in Nepal "*...where the flow of money is high*" allegations of corruption involving politicians, bureaucrats and some elite community leaders are widespread (p. 6). These groups have essentially captured the market. Antinori (2005) argues for the encouragement of joint ventures between community and private sector groups as one way to overcome these difficulties.

Foppes and Wanneng (2007) reported that in Lao PDR the sale of NTFPs is regulated by a complex system of permits and quotas. A range of fees and taxes have to be paid to three Government offices: agriculture, trade and finance. While the official tax rate is about 47%, traders can reduce this burden to around 6% by exporting a greater volume than that reported. The quota system has several disadvantages:

- The complex system of permits is time consuming for traders;
- The quota does not have any positive effect on NTFP resource management; and
- The quota system seems to give a low tax revenue rate to the Government of perhaps 6% of the export value of NTFPs per year.

An FAO survey of CBFM in Nepal, Guatemala, Sudan and Peru (FAO 2005) gave a mixed picture of the potential of CBFM to generate sustainable income opportunities, particularly beyond small-scale, internal markets. It found that micro-credit is a key enabling vehicle, but also stressed the importance of capital formation and institutional and organizational conditions. The general conclusion of the FAO survey was that successful CBFM depends on more than just micro-credit. Other factors are also important, such as the effective development of business services, the selection of good entrepreneurs, the transfer of technical and managerial skills to the community, the promotion of market linkages, clear and legally enshrined forest tenure rights and boundaries, transparency in lending practices, and appropriate institutional and legal structures to ensure equality and sustainable production.

Merino-Perez and Segura-Warnholtz (2005) noted that in Mexico during the 1970s and 80s "*Although the communities were recognized by the state as the true forest owners, at the same time government institutions exercised direct control over these resources and, in some cases,* *they appropriated most of the benefits*." (p. 55). A similar situation was reported from Nepal, where an analysis of case studies across all major ecological zones in the country revealed that even though local rights of access and usage were guaranteed in national policies and laws, "*...a latent hesitation exists among government field officers to fully transfer the rights to communities*." (Paudel et al., 2008 p. 27).

A conference in Costa Rica in 2006 (FAO, n.d.) considered the institutional and policy options for promoting more viable and sustainable SMFEs. The delegates concluded by identifying numerous constraints along with possibilities for addressing the constraints. The major conclusions from the conference included:

- Governments can play a critical role in strengthening SMFEs to reduce poverty;
- SMFEs can improve their own competitiveness in national and international markets for forest-based products;
- Business development services for SMFEs require greater coverage and quality;
- Financial services are critical for the start-up and development of SMFEs; and
- Non-governmental organizations and development agencies can strengthen the existing capacities of SMFEs.

An analysis by Greijmans and Gritten (2015) identified three key components hindering or preventing the development of community forestry enterprises:

1. Legal and regulatory structures are unsupportive and are characterized by limited rights and complex regulations inhibiting equitable benefit sharing. This is compounded by the perception that local benefits are incompatible with national benefits, an uneven playing field regarding state, private and community forests and weak participatory decision-making processes.
2. Local governments and communities have low organizational and institutional capacities, and lack technical skills.
3. A lack of investment in community forestry, as a result of: unclear business policies; high initial costs; undeveloped infrastructure and untrained workforce. (p.1).

While governments are often prepared to give away degraded forest to communities, they frequently try to regain control (by introducing taxes and other measures) when it is realized that the forests have become valuable assets after the communities have spent several decades restoring them to a productive condition. This emphasizes the importance of embedding access and usage (tenure) rights as 'hard' rights in the regulatory framework so that it is difficult for government officials to change them through the application of bureaucratic discretion.

A summary of some of the constraints that frequently apply to commercialization of products from community forests is given in Table 2.

Table 2. Examples of some of the key constraints applying to the commercialization of products from community forests

Type of constraint
Regulatory
Tenure rights of local and indigenous people remain weak and frequently limit harvested products to those for subsistence use. This limits their ability to manage their forests for commercial benefits.

Management decisions to harvest products commercially are limited by requirements for very detailed management plans.
Regulatory requirements for non-forest sectors (such as transport) frequently inhibit transport and marketing of forest products.
Policies tend to favour industrial scale logging over community scale operations by requiring prescribed forms of forest management.
Onerous taxes and fees to multiple agencies apply to forest products at various stages of the value chain.
Requirement for special permits from forest officials (who are often distant from the forest) to harvest forest products, particularly trees, even if harvesting is scheduled in the management plan.
Requirement for special permits to transport goods to market, often from multiple authorities who are frequently distant from the forest.
Governance
Weak governance often leads to lack of transparency along the value chain with many opportunities for rent seeking and corruption, which constrains the ability of community forestry enterprises to operate effectively.
Business and legal
Limited business management capacity in many village settings.
Lack of forest producer organizations that can lobby for improvements to the regulatory framework and provide services to members.
Lack of finance to fund start-up activities.
Banks are often hesitant to loan funds for commercializing common property assets.
Limited capacity to develop business plans and develop and apply business skills.
Uncertainty about how to commercialize common property resources and share benefits.
Uncertainty about how to interface community institutions with private sector institutions.
Uncertainty about how to address legal issues including taxation.
Market
Remote communities have difficulty in transporting products to markets.
Breaking into established markets is difficult.
Readily available market information is lacking to enable communities to tailor their products to meet market requirements.
Timber market is often distorted (favours political figures and other elites) and lacks transparency, making it difficult for communities to operate effectively.
Corruption is widespread and limits ability of communities to realize the full benefits from harvesting timber.
Technical
Technical skills for basic processing and other value adding are not available, particularly in remote rural areas.
Bureaucratic
Resistance by government officials to relinquish control over forests, even where they are required to do so under the regulatory framework inhibits the ability of communities to commercialize their forest products.
Demands by government officials for unofficial incentives to provide necessary permits limits the returns communities can receive for their products.

5. Discussion and Conclusions

During the past few years there has been a growing awareness of the potential of community forestry to become a more potent force for income generation for local community development as well as for sustainable forest management. Associated with this awareness have been increasing calls for action that can support communities to become more effective forest managers and to benefit from their efforts.

Three international conferences in Latin America, Africa and Asia (Rio Branco, Brazil in 2007, Yaounde, Cameroon in 2009 and Lombok, Indonesia in 2011) on the topic of forest tenure, governance and enterprises emphasized the importance of recognizing community rights over forest resources. Representatives from more than 75 countries participated in these three conferences and they made recommendations that governments recognize community rights over forest resources more explicitly, and also support communities to become more dominant forest management players.

There were several consistent threads running through the outcomes of these conferences. The first two of these can be summarized as:

1. The rights of local and indigenous communities need to be recognized and secured.
2. Good governance[2] and enabling regulatory frameworks need to be developed and applied to support communities to become sustainable forest managers.

These translate in practical terms to the first generation stage associated with the establishment and formal recognition of community forests and their membership groups.

Once this first stage has been embedded, communities can take on increasingly complex tasks such as active forest management (applying appropriate silviculture) and more commercially oriented harvesting and marketing of forest products. However, there are some examples (Mongolia is one case) where harvesting and marketing of forest products are explicitly built into the initial stage of the community forestry process.

Some of the other issues highlighted at these international conferences apply to this second generation stage and focus on:

2. Providing communities with the rights to harvest high-value forest resources, including timber and,
3. Improving the enabling environment for small enterprises so that forest communities can register businesses, access financial services, negotiate partnerships and attract sustainable investment to enable them to increase the benefits from the sustainable management of their forests.

The case does not need to be made that commercialization of products from community forests is a desirable policy objective – the recommendations from recent international conferences referred to previously make that abundantly clear. However, almost universally, there are significant impediments in the way of communities who want to move from managing their forests largely for subsistence products to managing them for both subsistence and commercial products. In spite of the obvious benefits to local and national economies of

[2] Good governance refers to the quality of the process of governance whereby key principles are addressed explicitly. These include: transparency, accountability, participation, predictability, empowerment, inclusiveness, equity and benefit sharing.

commercializing forest products, issues surrounding commercialization have been kept in the margins of policy discourse, particularly for timber. To a large extent this has never become a priority and has received only limited investment from both governments and donors.

Based on the examples and arguments presented in this paper there is considerable value in promoting the potential of community forestry to move beyond providing primarily subsistence goods to become a vehicle for the emergence of forest enterprises and being part of a genuine new forest economy that can contribute to both community and national development. Such a promotion would be assisted by a concerted effort to carry out the following activities:

- Document examples of successful community forestry enterprises,
- Enhance understanding of factors for success,
- Analyze the constraints that prevent communities from realizing the full economic potential of their community forests,
- Advocate for the removal of constraints and support for communities to obtain economic benefit from the sustainable management of their community forests,
- Support the development and spread of appropriate technologies,
- Develop/improve marketing approaches that fit community forestry enterprises,
- Support capacity building of members of community forestry enterprises, and
- Integrate the development of community forestry enterprises into the early stages of implementing community forestry.

Real change needs to take place at both national and community levels, as each country and community has its own unique historical, cultural, economic and political context. The ultimate challenge for policymakers is to look beyond the forests and trees to the markets and to facilitate the development of enterprises based on the sustainable management of community forests, while avoiding low value-added forest exploitation, but at the same time, allowing traditional forest uses to continue.

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Understanding the Challenges in Implementing a National Policy to Regulate the Quality of Forest Reproductive Materials for Reforestation Programs in the Philippines

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ABSTRACT

The use of low quality forest reproductive material is one of the major reasons for the mixed results of past watershed rehabilitation programs in the Philippines. Since 2010, a national policy on forest nursery accreditation has been implemented to regulate the quality of forest reproductive materials. Implementers of forest rehabilitation programs are directed to use high quality seedlings from accredited seedling suppliers. Despite this requirement, low quality seedlings are still largely planted in reforestation projects including the recent National Greening Program (NGP). Surveys of the forest nursery sector in Eastern Visayas and Northern Mindanao regions were carried out to determine the effectiveness and challenges in implementing the forest nursery accreditation policy. The survey has identified factors that limit the effectiveness of seedling quality regulation including insufficient seedling production schedules due to delayed disbursement of project funds, inappropriate criteria for seedling quality assessment, lack of auditing of seedling quality in accredited nurseries, and insufficient monitoring of seedling supply chain among the network of nurseries supplying seedlings for reforestation programs. The limited sources of high quality germplasm, nursery operators' limited information on the attributes of high quality planting materials and insufficient knowledge on high quality seedling production technologies contributed to the widespread production of low quality seedlings. Nursery accreditation represents a huge leap in promoting the success of watershed rehabilitation nationally. However, considerable improvement of the implementation system and establishment of support mechanisms is necessary.

Keywords: Germplasm, mother tree, seedling production, nursery accreditation, reforestation

INTRODUCTION

The quality of forest reproductive material[3] is a major factor for the success of watershed rehabilitation. Harrison et al. (2008) argued that forest conservation and regeneration efforts require the use of reproductive materials that meet the appropriate genetic, morphological and physiological quality standards. Although seedling quality is widely understood as a requisite to effective watershed rehabilitation, the use of high quality planting materials is often overlooked in the overall reforestation process. Grossnickle (2012) claimed that while high

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[3] A term referring to seedlings (including bare-root and containerised stock) or vegetative propagules (such as rooted cuttings, grafted stock and tissue culture material).

mortality of out-planted seedlings is attributed to several factors including environmental stress, damage by grazing animals, pests and diseases, in many cases low quality planting stock is a major cause of plantation failures. Sáenz and Martínez (2000) reported that in Mexico, the low survival of seedlings in most reforestation projects was mainly attributed to planting of low quality seedlings. Mc Dowell et al. (2008) also argued that the inferior quality of planting stock and inability to couple with environmental conditions largely explains low survival of seedling in large-scale reforestation programs of many countries.

While policies to regulate the quality of forestry seedlings have been institutionalized in various countries (see Sheil 2013, He et al. 2012, Nyoka et al. 2011, Department of Forestry and DANIDA 2007, House of Parliament 2002), there is a dearth of knowledge regarding the constraints and challenges encountered in the implementation of such policies and the corresponding intervention measures that were adopted. A few reports (e.g. Nyoka et al. 2014, Ha et al. 2011, Graudal and Lillesø 2007) revealed that developing an effective seedling quality regulation system is fraught with various constraints.

In the Philippines, it is well recognised that low quality seedlings significantly contributed to the less than expected success in reforestation programs (Israel and Lintag 2013, Combaliser 2010, Gravoso et al. 2007, Carandang et al. 2006, Gregorio 2006, Tolentino, et al. 2002, Lapis et al. 2001, Lasco et al. 2001, Nixon et al. 2000). With lessons from past watershed rehabilitation initiatives, the recent National Greening Program (NGP)[4] was designed to use only high quality planting materials in terms of both genetic and morphological characteristics (DENR 2011). For this purpose, the seedling production for the NGP is governed by Departmental Order 2010-11, which sets out the appropriate methods of collecting and handling high quality germplasm, and distribution to nursery operators in various regions of the country. It also states the protocol for accrediting germplasm sources and forestry nurseries. DAO 2010-11 states that only seedlings from accredited nurseries shall be used for government forestation programs including tree plantation development, tree farms, agroforestry, urban forestry and other reforestation activities (DENR 2010).

The implementation of the NGP in various regions of the Philippines has been successful in terms of achieving the target area of land for planting. The accomplishment report of the NGP for calendar years 2011, 2012 and 2013 revealed 129%, 111% and 111% of the target area had been planted, respectively (DENR 2014a). However, inventory of seedling survival in plantations revealed less success. For example, the performance validation report of the DENR for three-year old NGP plantations in 10 barangays in Philippines Region 8 (Eastern Visayas) revealed an average seedling survival rate of only 39% (lowest 16.2%; highest 68.7%) (DENR 2014b). This report was corroborated by the result of the NGP plantation assessment in Region 8 (Eastern Visayas) and Region 10 (Northern Mindanao) of the country undertaken by the ACIAR Watershed Project (Baynes et al. 2014). Senior staff members of the Ecosystems Research and Development Bureau of DENR admitted that low quality of planting materials is a major reason for the low survival of seedlings in NGP plantations (Barriga 2013). This is an unwelcomed finding given the recent legislation regulating the quality of planting materials for reforestation programs in the Philippines and the requirement to use high quality seedlings for the NGP.

[4] The NGP is a government-initiated and stakeholder-based watershed rehabilitation flagship program of Pres. Aquino which aims to reforest 1.5 M ha of public domain land from 2011 until 2016, to promote sustainable development for poverty reduction, food security, biodiversity conservation, environmental stability and climate change mitigation and adaptation (DENR 2012).

This paper discusses the seedling production system for the National Greening Program in the Philippines and the challenges in regulating the quality of seedlings. The study is envisaged to improve the success of regulating the quality of forest reproductive materials for watershed rehabilitation programs in the Philippines and in other developing countries. This study was undertaken as a component of the review of the effectiveness of National Greening Program (NGP) implementation in Philippines Regions 8 and 10, which is one of the major research activities of the project ACIAR ASEM/2010/050 *Improving Watershed Rehabilitation Outcomes in the Philippines through a Systems Approach*.

RESEARCH METHODS

Description of the Study Site

ACIAR research project ASEM/2010/050 – also named ACIAR Watershed Rehabilitation Project in partnership with the Department of Environment and Natural Resources (DENR) carried out a survey of forestry nurseries in six provinces in Regions 8 and 10 of the Philippines in June and July 2013. The provinces included are Biliran, Leyte, Southern Leyte, Samar, Bukidnon and Misamis Oriental (Figure 1). These regions were selected because they are the research sites of the ACIAR Watershed Rehabilitation Project. Region 8 is composed of three islands and six provinces. It comprises 7.2% of the country's total land area, and 52% of the area is classified as forest land[5]. Among all regions in the Philippines, Region 8 had the highest plantation target in the 2011 NGP planting.

Region 10 is composed of five provinces. It has a total land area of 2.05 M ha, with more than 60% classified as forest land. Agriculture and forestry make the greatest contribution to its regional economy in terms of income. In 2011, Region 10 achieved 100% of its NGP plantation target (DENR 2014).

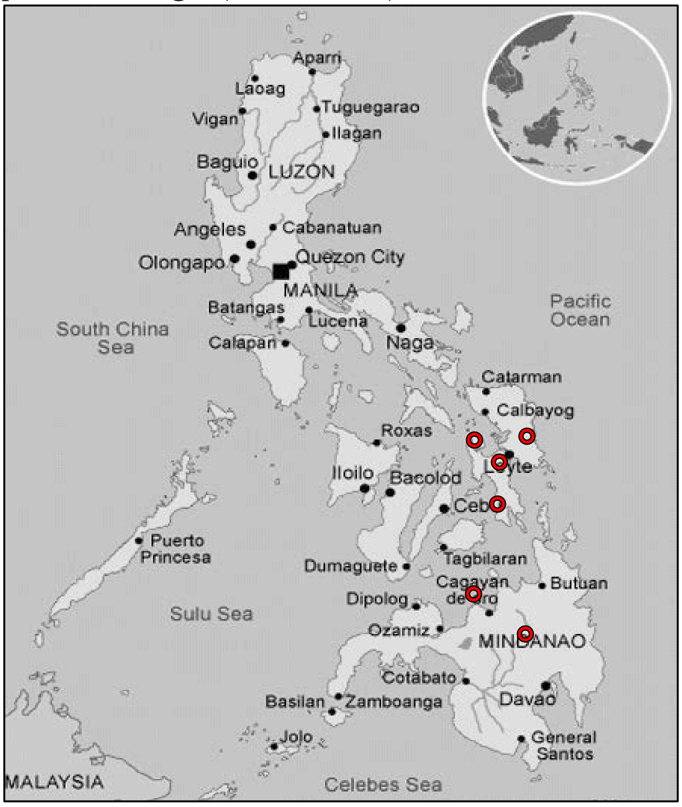

Figure 1. Map of the Philippines with location of the study sites indicated by circles

5 Forest land includes public forest, the permanent forest or forest reserves, and forest reservations. It covers all land of the public domain with a slope of 18% or more including those without forest cover.

Data Collection and Analysis

Nurseries included in the survey were selected based on recommendations of the DENR, particularly the Forest Management Service (FMS) of Region 8 and the Ecosystems Research and Development Service (ERDS) of Region 10. These nurseries produce seedlings for the National Greening Program. Operators of identified nurseries were notified and approval was sought for the project staff and DENR personnel to carry out the survey. The survey was undertaken in two parts, namely interviews with nursery operators and an assessment of the nursery seedling production including the evaluation of seedling quality. Using an open-ended questionnaire as a guide, information on the seedling production systems including nursery silvicultural practices and quality control measures, and the market of seedlings were gathered during the interview. The respondents were also asked about the constraints experienced in nursery operation and the marketing of forest reproductive materials. Discussions with key DENR personnel were also undertaken to obtain information regarding the organisation of the seedling production for the NGP, and the seedling quality control protocol of the DENR and the challenges encountered in its implementation. Interviews of nursery seedling producers and DENR staff allowed corroboration of some information provided by each group.

Nursery seedling production was assessed by examining the physical quality of seedlings, the nursery set-up and the technical capability of the nursery operator to produce high quality forest reproductive materials. The assessment adopted the method, criteria and standards developed by stakeholders (i.e. DENR, Department of Agriculture, forestry experts from both the academe and research groups, local government units, seedling producers and tree farmers) during the implementation of the earlier ACIAR project ASEM/2006/091, otherwise called the ACIAR Q-seedling Project. The latter project was implemented in Regions 8 and 10 during 2007 to 2010, with the aim of enhancing the supply of high quality seedlings for government and private reforestation programs in the Philippines (ACIAR 2011).

The process of assessing the physical quality of planting materials involved destructive sampling of 50 seedlings of plantable size (i.e. at least 20 cm tall) at each nursery, examining the seedling health and measuring seedling physical parameters, namely base diameter, seedling height, sturdiness, root-shoot ratio, stem form, root form and health. The seedlings in the nursery were considered as a population unit and sample seedlings were chosen following a systematic selection across all species available during the survey period. The overall volume of seedlings was divided by 50 and the quotient corresponds to the n^{th} seedling sample. The nursery owners provided all sample seedlings for free.

The height of seedlings, which is the distance from the stem base to the tip of the bud, was measured using a metre stick. The diameter at root collar was taken with digital callipers. These measurements were used to calculate the sturdiness quotient of the seedling, which is the ratio of stem height (cm) and root collar diameter (mm) (Jaenicke 1999). Roots of seedlings were separated from shoots at the root collar level and fresh weights were taken using a digital balance. The roots were thoroughly washed with water to remove soil particles and wiped with absorbent paper before weighing. Shoots and roots for each seedling were then placed in a paper bag and dried inside an oven at a temperature of $80^{o}C$ for 48 hours to determine the dry biomass. Dry biomass measurements of shoots and roots were used in determining the shoot-to-root ratio of the seedlings. The root form was assessed by examining the taproot whether it was straight, coiled or having a J-form. The stem form was examined based on the deviation of stem growth from the vertical axis. Seedling health was evaluated by examining the presence of pests and pathogens or symptoms and signs of disease.

The technical capability of the nursery operator was assessed based on the number and type of training events relevant to nursery operations that they had attended and their experience in nursery seedling production. In regards to the nursery set-up, the facilities present in the nursery, the type of seedling container used and the quality of potting media were assessed. Table 1 summarizes the criteria used and parameters measured during the nursery and seedling quality assessment, and the importance weights attached to each criterion. The maximum overall score for a nursery is 32 and the minimum acceptable score is 20.

Table 1. Category and criteria used in assessing the nursery seedling production and seedling quality

Criterion	Description	Maximum score
Seedling physical quality		15
Health	Absence of pests and diseases	
Stem form	Straightness of the stem	
Root form	Absence of root deformations e.g. J-roots, pot bound roots and root curling	
Sturdiness	Sturdiness of the stem (Sturdiness Quotient)	
Shoot-root ratio	Balance of shoot to root biomass	
Skills of the nursery operator		6
Training	Training in nursery management	
Experience	Years of experience in nursery seedling production	
Nursery facilities		9
Facilities	Presence of necessary nursery facilities for high quality seedling production	
Seedling containers	The type of container used in seedling production	
Potting medium	Texture and nutrient content of the potting mix	
Production capacity	Capacity to supply planting stock in substantial quantity	2

The survey sample included 23 nurseries, 9 from Region 10 (8 from Bukidnon and 1 from Misamis Oriental) and 14 from Region 8 (5 from Biliran, 3 from Leyte, 3 from Southern Leyte and 3 from Samar). Of these nurseries, private operators owned 9, 12 were managed by people's organisations (POs) involved in the NGP implementation, and 2 were established and managed by the DENR.

A workshop with stakeholders was held in Naval in Biliran Province on July 2, 2013 to convey and validate the results of the survey. Key representatives of the DENR in Regions 8 and 10, seedling production contractors (private nursery operators, NGOs, POs), NGP implementers and researchers of the ACIAR Watershed Project attended the workshop. The methods used in the survey and key findings were presented, and reactions and comments from participants were sought. Discussions on some critical issues including the awarding of seedling production contracts and monitoring of seedling quality were facilitated. Important information arising from discussions and comments of stakeholders were recorded and incorporated in the survey results.

Data were analysed using the Statistical Package for the Social Sciences (SPSS). Descriptive statistics including frequency distributions and means were computed. Chi-square and

Pearson's correlation tests were undertaken to determine if a relationship exists between species category and type of germplasm used, hardening and seedling physical quality, and germplasm type and resulting seedling physical quality. A conceptual model of the seedling production system in Regions 8 and 10 was developed.

RESULTS AND DISCUSSSION

The Organisation of Seedling Production for the NGP

The implementing guidelines of the NGP described in DMC 2011-01 *Guidelines and Procedures in the Implementation of the National Greening Program* (DENR 2011) stipulated that seedling production should be a collaborative undertaking of several groups including local government units, government agencies, academic institutions, the private sector and communities. For the 2011 to 2013 NGP plantings in Regions 8 and 10, people's organisations, commercial large-scale individual nurseries and non-government organisations produced most of the seedlings. Although efforts had been made by the DENR to mass-produce genetically superior seedlings through clonal propagation in partnership with academic institutions (DENR 2014), the complexity of legal arrangements to transfer funds, the period required to construct clonal nurseries and the small number of centralised clonal nurseries limited the use of government-produced seedlings in several regions of the Philippines.

The conceptual model of the seedling production system for the NGP implementation in Regions 8 and 10 in the Philippines is presented in Figure 2. The production of planting materials is divided between the government and non-government sectors but the latter has the greater production share (approximately 75%). Seedling production with the non-government sector is categorised into two arrangements – (1) direct contracting with POs and (2) open bidding with accredited nurseries (including private seedling producers, POs and NGOs). In areas with prior tenure agreement with communities (including Community-based Forest Management and Protected Area Community-based Resource Management), the PO beneficiaries were given direct contracts by DENR to produce the seedlings. The solid arrow in Figure 2 from PO nurseries to NGP sites with tenure agreement indicates that POs produce most of the seedlings (approximately 70%) for these sites. In areas without existing tenure arrangements, selection of nurseries to supply seedlings is conducted through a bidding process following the Philippine Government Electronic Procurement System (PhilGEPS) as explained in RA 9184 '*An Act Providing the Modernization, Standardization and Regulation of the Procurement Activities of the Government and Other Activities*' (PhilGEPS 2013). PhilGEPS is an internet-based bidding system that provides seedling producers access to government bid notices; allowing them to enter the bidding and view bid results. For a nursery operator to participate in the bidding, the nursery must be accredited by DENR-ERDS and the operator must hold a PhilGEPS certificate of registration.

Monitoring the quality of seedlings from accredited nurseries and those managed by POs is the responsibility of the DENR. Specifically, the DMC 2011-01 indicates that it is the responsibility of the DENR Ecosystems Research and Development Service (ERDS) to ensure the production of high quality seedlings for the program. However, in practice the ERDS regulates the quality of seedlings for the NGP in untenured planting sites and the Forest Management Service (FMS) regulates seedling production for tenured areas. The FMS manages the implementation of reforestation projects in tenured areas including sites of Community-based Forest Management Program (CBFM).

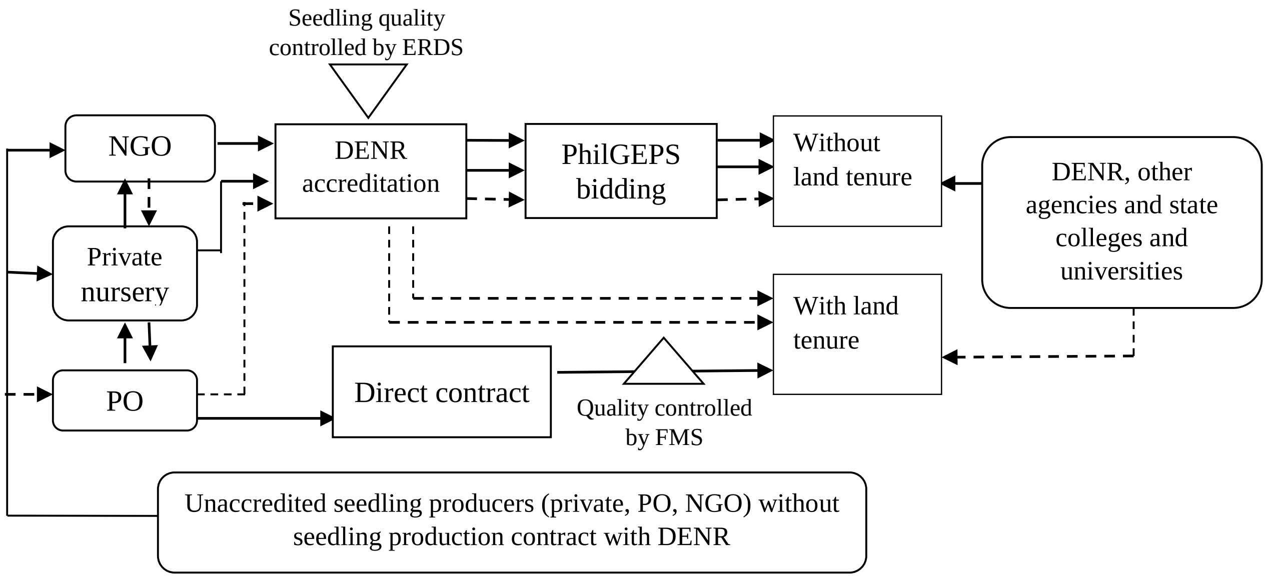

Figure 2. A conceptualized model of the seedling production system for the NGP

Most accredited nurseries (about 80%) in Regions 8 and 10 are owned by NGOs and private seedling producers, hence the solid lines in Figure 2 connecting NGOs and private nurseries to NGP sites without tenure arrangements. A relatively small quantity of seedlings from POs (approximately 20% of the overall seedling requirement) is planted on sites without existing tenure instruments (indicated by dotted line in Figure 2) because few POs have been able to obtain nursery accreditation. Most POs are unaware of the accreditation process and those who are informed view the application for accreditation as a daunting task. A DENR officer in Region 8 indicated that NGOs and private seedling producers are favoured for accreditation because of their greater financial resources and technical capability. Unlike POs, the activities of which are usually dependent on the mobilisation fund provided by the DENR, NGOs and private seedling producers have the financial resources to continue to produce seedlings and bridge the usual delayed disbursement of funds. Also, it is presumed that NGOs and private seedling producers are more likely to have the experience and technical skills to produce high quality seedlings. With the NGP having limited funds to support the capacity building of POs to produce high quality planting materials, assigning of the seedling production to experienced private seedling producers and NGOs is considered as the safest way to quickly satisfy the high quality seedling requirement for the program.

The above schemes of seedling production for the NGP are the most prominent, but other schemes also exist. The POs with contracts to produce seedlings for their respective NGP areas purchase seedlings from other nurseries (particularly from other POs and private nurseries mostly not accredited by DENR) instead of establishing their own nurseries. Although POs with seedling production contracts purchasing seedlings from other nurseries is not widely practiced (hence the broken line in Figure 2), seedlings from unaccredited seedling producers enter into the NGP seedling supply system through this scheme. Seedlings are sold at a lower price than indicated in the seedling production contract between the DENR and the PO. For example, the DENR pays PhP10 to the PO for each seedling but the latter purchases the seedling from other seedling producers at PhP4, hence imposing a mark-up of PhP6/seedling. While this may appear desirable in the view of providing income to the POs, a major drawback is that the capacity of POs to produce high quality planting stock is not improved. Also, with seedlings purchased from unaccredited sources, the objective of using high quality seedlings in the program is undermined to some extent.

Accredited seedling producers (i.e. accredited private nursery operators and NGOs) having seedling production contracts with the DENR are also engaging in the purchasing of seedlings from unaccredited nurseries. Approximately 80% of accredited private nurseries included in the study have purchased seedlings from unaccredited seedling suppliers. This practice is very pronounced, hence indicated in Figure 2 by solid lines from unaccredited nurseries to accredited private and NGO nurseries. An extreme case is that some accredited nursery operators cease operating their nurseries and purchase seedlings from unaccredited nursery operators. This scheme is widespread because of the absence of auditing and monitoring of the seedling production of accredited seedling suppliers. The accreditation process involves examination of the quality of seedlings of the supplier at the time of application for accreditation. The quality of seedlings on subsequent production runs is less regularly monitored. A lack of DENR personnel and trust that nursery operators conscientiously comply with the requirement to produce high quality planting materials are reasons for the limited monitoring of seedling production in accredited nurseries.

A slight modification of POs purchasing seedlings from other nurseries was noted in some municipalities. The DENR purchased seedlings from accredited nurseries and delivered these to POs for planting in tenured and untenured sites. For example, seedlings for the NGP in some municipalities in Region 8 were provided by an NGO operating outside the municipalities but contracted by DENR at the regional level. The POs that are recipients of the seedlings indicated that this approach is undesirable for several reasons including site-species mismatch in terms of biophysical conditions of the planting site and social preference. Also, seedlings are largely damaged during transport.

The bidding process to supply seedlings for most of the untenured sites is open to all accredited nursery seedling producers. It was noted that there are a few nursery seedling producers in the province who receive the majority of seedling production contracts. While a single nursery winning most of the bid for nursery seedling production quota could result from a fair and unbiased bidding process, several seedling producers have expressed their suspicions that the awarding of contracts is largely influenced by strong affiliations of a few nursery operators with officials involved in the contract and awarding process.

The Seedling Quality Regulation Policy of the DENR

The DMC 2011-01 stipulates that seedling production for the NGP must be governed by DAO 2010-11. This departmental order introduces the seedling documentation and registration system for effective and sustainable forest tree seed and seedling production. It also indicates the protocol for accrediting germplasm sources and forest nurseries, illustrates the methods of establishing and maintaining seed production areas, and outlines the criteria for assessing the physical quality of mother trees. The accreditation of germplasm sources (e.g. seed stand, seed production area, seed orchard and seed trees) implies the necessity to use genetically superior germplasm. However, no process currently exists which requires seedling producers to procure germplasm from accredited sources. Although seedling producers are required to indicate germplasm sources when applying for accreditation, the mechanism to monitor the collection and use of germplasm from accredited sources is lacking. A senior officer of the DENR R10 indicated that the number of identified, established and recognised germplasm sources nationwide is not enough to supply the volume of high quality planting materials for the NGP. Also, the diffusion pathway of high quality germplasm is not well established. Given this scenario, suppliers of seedlings for the program including the accredited seedling producers are not strictly required to use high quality germplasm. This condition in effect defeats the fundamental purpose of forest nursery accreditation.

The forest nursery accreditation process, as stipulated in DAO 2010-11, involves the two stages of lodging the application and assessment of the nursery and the seedling quality. The set of assessment criteria for seedling quality includes seedling health (leaf colour and absence of infestations), size of seedlings (height and stem diameter), stem form, root form, sturdiness, age of seedling and sun hardening state. However, details on how the criteria should be applied – for example, specific weights assigned for each criterion and information on how the seedlings will be rated – is absent. It was emphasized by the DENR officer that their office uses subjective judgement of their trained staff when assessing seedling quality. However, without the specific guidelines, seedling producers will never be guided on appropriate silvicultural treatments in order for their seedlings to pass the assessment process. Also, the absence of the guidelines leaves seedling quality assessment decisions by DENR staff subject to questions and arguments, particularly for nursery operators who fail to reach the passing mark.

A seedling production contract obtained from a PO in Region 8 indicates that DENR officers may have devised a modified set of criteria in their respective jurisdictions. The contract stipulates that seedlings should be assessed based on sufficient height (more than 30 cm from the root collar), at least 5 mm base diameter, with straight stem, good health and having at least 6 leaves. Apparently, the seedling height requirements of more than 30 cm (and 50 cm depending on the species) do not preclude overgrown seedlings because the evaluation criteria do not indicate an upper limit on seedling height. The number of leaves is not a particularly useful criterion in judging seedling physical quality. A large number of leaves together with low root volume are detrimental to seedling survival (Ritchie 1984). This is aggravated when there is low soil moisture, which is a common characteristic of reforestation sites in the Philippines.

While stipulated in DAO 2010-11, in practice the root system assessment is not included in the evaluation criteria even though root form and volume in relation to above-ground biomass are crucial indicators of seedling survival and establishment in the field.

Observations on the Quality of Planting Stock in the Nursery

Interviews with seedling producers revealed that the quality of mother trees was given little emphasis in germplasm collection. About half of the nursery operators (48%) were found to deliberately collect germplasm from phenotypically superior trees. The limited number of mother trees, lack of concern on the importance of genetically superior gemplasm for trees, and the need to grow a high volume of seedlings in a short period are among the main reasons for the failure to procure high quality germplasm. This finding is consistent with the result of the surveys on the nursery sector of Leyte and Mindanao Islands reported in Gregorio et al. (2010), Edralin et al. (2010), and Koffa and Roshetko (1999). While substantial efforts to improve the supply of high quality seedlings in Regions 8 and 10 were undertaken by local and foreign research and development agencies, these have not totally resolved the aforementioned constraints. DENR officials of Regions 8 and 10 unanimously indicated that the lack of germplasm sources is a bottleneck in using genetically superior germplasm.

A total of 1,150 sample seedlings belonging to 54 species from 23 nurseries in Regions 8 and 10 were examined to assess the physical quality of seedlings. Of the nurseries investigated, only three have produced high quality seedlings. Table 2 presents the summary of percentages of sample seedlings in all nurseries that passed each assessment criterion and the average values of parameters measured. The mean score of sample seedlings for physical quality of 4.5 (range of scores 0 to 11), was very low compared to the maximum possible score for this criterion, which is 15. This indicates the prevalence of seedlings with inferior physical quality. Most of the sampled seedlings (88%) appeared healthy with relatively straight stems. However, many of them (36%) had root systems that were deformed (J-rooting and coiling) and growing outside the container. Further, the majority of the seedlings were not sturdy (82%) and had imbalanced shoot-to-root ratio (79%). The J-rooting occurs when seedlings with long taproots such as wildlings are potted without root pruning or insufficient care is taken to avoid bending the taproot during potting (Carter 1987). The low sturdiness and imbalanced shoot-to-root ratio was largely attributed to the commonly observed practice of over-shading and dense stacking of seedlings on transplant and hardening beds, and placing seedlings on the ground instead of using elevated beds. Elevated beds promote sturdy seedlings because of root air pruning preventing the unregulated absorption of water and nutrients from the ground. Also, the use of elevated beds minimizes the physical damage of root system when seedlings are removed for out-planting (Wightman 1999, Gregorio 2009).

A Chi-square test of data from sample seedlings failed to find a significant relationship between sturdiness and use of elevated hardening bed (χ^2 = 12.74; p = 0.47). However, this does not imply that placing seedlings on elevated beds does not have a positive impact on seedling sturdiness. Nurseries using elevated hardening beds also produced lanky seedlings because these were arranged densely and watering and application of fertiliser were not optimised.

Table 2. Percentage of sample seedlings that passed each assessment criterion (mean of all sample seedlings, minimum and maximum for individual nurseries); and mean, maximum and minimum scores of samples for physical quality, sturdiness and shoot to root ratio

Statistic	Health	Stem form	Root form	Shoot to root ratio	Sturdiness	Physical quality (Ideal 15)	Sturdiness (ideal <6)	Shoot-root ratio (ideal 1)
Mean	88.4	79.8	64.3	21.0	17.6	4.5	8.6	2.8
Min.	58	32	22	0	0	0	5	1
Max.	100	100	100	92	60	11	14	5

Measurements of seedling height indicated an average of 38 cm. Jaenicke (1999) argued that the optimal height of seedling for out-planting is between 20-25 cm. Over-grown seedlings, as tall as 60 cm, were noted in several nurseries. It was noted that overgrown seedlings were all grown on the ground. With small seedling containers (usually 4 in. by 6 in.), seedlings grew tall because root mass developed outside the polybag and absorbed excessive moisture and nutrients from the ground. With roots often cut when seedlings are pulled from the bed immediately before field planting, overgrown seedlings are less likely to survive because of faster transpiration than water uptake. Grossnickle (2012) argued that tall seedlings could be ideal for planting if seedlings have to compete with other vegetation in terms of above-ground growth requirements (e.g. sunlight and space). But when the competition is below ground (i.e. for moisture and nutrients), height is of less importance than root system development. In most reforestation sites in the Philippines, sunlight is not as limiting a factor as soil nutrients and moisture, hence seedlings need not be tall but root systems should be well developed.

A strong correlation was found between seedling physical quality and the type of germplasm used in seedling production. A negative correlation (r=-.450; p=0.031) existed between the use of wildling and the resulting physical quality of the planting material. This implies low seedling quality is more likely when wildlings are used. For example, more seedlings had imbalanced shoot-to-root ratios and lanky and less developed root systems when wildlings were used. This observation was attributed to the insufficient recovery period of wildlings in the nursery. It is normal for wildlings to have severe root damage during collection but root systems recover while the seedlings are growing in the nursery. However, the tight production schedule commonly reported by the nursery seedling producers resulted in seedlings that appeared healthy with suitable height for out-planting (based on DENR criteria) but having root systems that were barely developed.

The use of wildlings is common in propagating seedlings of native tree species. The cross tabulation of frequencies in Table 3 shows that most of the native species were grown using wildlings while exotics were produced from seed. Chi-square tests proved that the use of either wildlings or seed in seedling production is related to the nature of the species, being native or exotic (χ^2=152; p=0.005). The limited information pertaining to the location of germplasm sources, and phenology and seed technology of native species is one of the reasons why seedling producers use wildlings. The use of wildlings has escalated due to the DENR's recommendation to plant more native tree species for the NGP (DENR 2014).

Table 3. Number of seedlings by species category and germplasm type

Category	Number of sample seedlings		Total
	Seed	Wildlings	
Exotic	257	128	385
Native	75	690	765
Total	332	818	1150

Another reason for the widespread use of wildlings is the short seedling production schedule due to delayed release of funds for seedling purchase. This is particularly true for seedling production of POs that are relying on the mobilisation fund from the DENR to commence the nursery operation. With late release of funds, a fixed planting schedule and the need to satisfy the seedling quality assessment criteria of the DENR, nursery seedling production is squeezed to a short period, usually 2-3 months. Growing seedlings from seed will definitely not meet the height and diameter requirements from DENR (i.e. more than 45cm tall, with a diameter of at least 5mm and with at least 6 leaves) within this period. Consequently, wildlings (generally relatively old ones) are used for planting and must meet the seedling quality evaluation criteria. However, relatively old wildlings are more prone to root damage during collection and have lower capability to recover from collection and potting stress.

CONCLUSION AND POLICY IMPLICATIONS

The success of the NGP, like any reforestation program, is largely influenced by the quality of planting materials. DAO 2010-11 provides guidance on how nursery seedling production should be regulated, however, as with many government policies, the implementation of DAO 2010-11 has several flaws, which result in low quality seedlings being widely used. Nursery accreditation represents a huge leap for the DENR to promote the success of Philippine watershed rehabilitation. But further improvement in its implementation is necessary.

The widespread production of low quality planting materials is attributed to several factors, principally the following:

- lack of awareness and information regarding the use of high quality planting materials;

- limited sources of high quality germplasm and lack of information on the phenology of mother trees, particularly of native species, resulting in the widespread use of wildlings;
- absence of regulation measures ensuring that seedling producers collect germplasm from accredited sources;
- limited knowledge and skills on high quality seedling production technologies;
- late release of funds resulting in insufficient period for seedling production;
- in practice, less appropriate criteria adopted by the DENR for seedling quality assessment; and
- a lack of appropriate auditing and monitoring on the quality of seedlings and seedling production system of accredited nurseries.

Capacity-building support is needed for the nursery operators. This may include information dissemination to improve nursery operators' understanding of the attributes of seed quality and high quality seedlings. Also, training could be provided to enhance their skills in high quality seedling production, especially for native tree species. Providing support to enhance their knowledge about the forest nursery accreditation process and online bidding procedure is clearly necessary.

It is apparent that a stringent process to monitor the operation of accredited nurseries is required. In the absence of monitoring, accredited nursery seedling suppliers are producing low quality planting materials, and their purchasing of seedlings from unaccredited nurseries instead of producing high quality planting stock is common. Nursery accreditation should not culminate in the issuance of accreditation certificates and assume that accredited seedling suppliers will always deliver high quality seedlings. There should be a mechanism of auditing the performance of accredited nurseries to ensure that the accreditation will serve its intended purpose and the standards for high quality seedlings are maintained.

To support the production of high quality seedlings, a strategy is necessary to promote a sustainable supply of high quality germplasm for a wide species base. With the promotion of indigenous trees in the NGP, there is a need to identify new seed sources of native trees. It is necessary to scale up the identification of superior mother trees and establishment of SPAs so as to increase the supply of high quality seeds. A database of mother trees and SPAs are necessary to provide information about mother tree distribution and corresponding seed years. Mother tree identification could be conducted in partnership with communities, and an effective mother tree conservation program could be instigated.

A review to improve the seedling quality assessment criteria developed by the DENR could be undertaken. The present criteria do not consider important attributes for seedling survival including adequacy of root systems. It is particularly necessary to consider root systems during seedling inspection, especially given that wildlings dominate the production system for planting materials. Wildlings may appear healthy with appropriate height and collar diameter even though the roots are poorly developed.

The nursery accreditation protocol appears to favour a few large-scale private nurseries and non-government organisations. People's organisations have limited knowledge of the accreditation procedure making the entirety of the accreditation process daunting and complicated. Also, the POs are poorly informed of the PhilGEPS bidding process, hence unaware of the protocol and the opportunity for them to engage in seedling production as a livelihood enterprise in implementing the NGP and other reforestation programs. The opportunity to enhance community livelihoods through engagement in reforestation programs in developing countries is widely recognised (Estoria 2004, Scherr et al. 2004, Sayer and Campbell 2001). In the NGP, a substantial proportion of the reforestation funding is allotted to seedling production. Recognizing the aim of the NGP to reduce poverty and the need to provide livelihood projects for communities, it is worthwhile providing support to the POs to venture into seedling production. Besides seedling production skills, support could include information dissemination to promote understanding of the nursery accreditation protocol and the PhilGEPS bidding process, and guidance in the application for nursery accreditation and participation in the bidding process. He et al. (2011) cited that incentives in the form of providing market information and capacity-building are essential in promoting the participation of smallholders in the sustainable supply of high quality planting materials for the national reforestation program in China.

Lastly, it is necessary to allow ample production time for seedlings to reach the planting size and exhibit a well-developed root system before out-planting. Reducing the seedling production schedule to two or three months because of delayed awarding of seedling production contracts and disbursement of funds negatively affects the quality of seedlings and the success of planting activities. Sun-hardening was not practiced in several nurseries because of the limited seedling production period. Planting unconditioned seedlings is a waste of resources as this results in lower seedling survival. Similarly, when wildlings are used, sufficient time is necessary to ensure full root system recovery prior to out-planting.

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Financial Modelling of Mixed-species Agroforestry Systems in Fiji and Vanuatu, Based on Traditional Tree Species

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ABSTRACT

Multi-species agroforestry has a long history in the Pacific Islands, and many benefits of this practice have been identified. The area of agroforestry declined in these countries during the colonial era and, although there has been renewed interest over the last 30 years, only a small area has been planted. Many tree species with high-value timber and other products are indigenous to the Pacific Islands, but there has been little experience of growing most of these in plantations. In a research project funded by the Australian Centre for International Agricultural Research (ACIAR), a component was included on developing financial models of multi-species agroforestry systems including 'novel' tree species, in Fiji and Vanuatu. This involved developing a suite of financial models for individual tree and crop species, identifying suitable planting sites and compatible mixtures with financial and environmental potential, and then integrating these multi-species models in Excel workbooks. This paper discusses choice of financial analysis method, identifying priority multi-species mixtures for Fiji and Vanuatu, and performing financial analysis. Financial performance estimates are reported for a number of agroforestry systems judged suitable for particular site conditions. Comments are made about the strengths and weaknesses of the analysis approach, and policy implications of the study, and suggestions are made for further research.

Keywords: Multi-species agroforestry, intercropping, species-site matching, wildfire

INTRODUCTION

Agroforestry has been a widely practiced landuse in Fiji and Vanuatu. Thaman et al. (2000, p. 27) noted that 'Thousands of years of observations, study, and experimentation by Pacific Island peoples produced a diversity of highly sophisticated multi-species agroforestry systems'. These authors described various phases in the evolution of traditional agroforestry systems in the Pacific Islands, from the first human settlement 1000 or more years ago, through 'colonial agrodeforestation' during the 19th and 20th century (when colonial governments promoted 'monocultural export cropping and livestock grazing' of coconuts, cocoa, sugarcane, and other crops), then *Post-World War 2 agroforestry* of growing cash crops and unsustainable logging, with discouragement of traditional agroforestry practices accompanied by increasing rates of 'nutritional disorders', to late *21st century agroforestry re-enrichment* when there was 'active promotion of MSA' or mixed-species agroforestry.

A potential impediment to agroforestry development in Fiji is that – unlike agriculture and forestry which have particular departments in government responsible for their activities – no single department is the champion for agroforestry, which 'falls through the cracks' in terms in terms of administrative support. Clearly, the Fiji Department of Forestry (within the Ministry of Fisheries and Forests) and Department of Agriculture (within the Ministry of Agriculture, Rural and Maritime Development and National Disaster Management) have responsibility over various facets of agroforestry. But so would the Ministry of Lands and Mineral Resources (including the Department of Lands and Surveys which is responsible for the administration of all development on State Land in Fiji), Ministry of Local Government, Housing, Environment, Infrastructure and Transport (in which the Department of Local Government oversees activities of Fiji's 12 municipal local governments), and Ministry of Industry and Trade and Tourism. As well, the iTaukei Land Trust Board (TLTB), formerly known as the Native Land Trust Board, has a major stake and influence in land use. In Vanuatu also, there is no single authority to champion agroforestry.

Agroforestry development is seen to have many attractive features in Pacific Island countries, including promotion of agricultural development, reduction in land degradation, import replacement, and improved community health. The ACIAR project ADP/2014/013 – *Promoting sustainable agriculture and agroforestry to replace unproductive land-use in Fiji and Vanuatu* – was undertaken to examine financial, social, environmental and policy aspects of agricultural and agroforestry development in areas of declining sugar production and senile coconut plantations in Fiji and Vanuatu. The focus was on using Pacific Island tree species not generally used in industrial forestry (including timber, fruit and nut species) together with food crops. A series of 12 unpublished working papers has been prepared in the ACIAR project, by the authors and with contributions from others in the project, relating the land use and agroforestry in the study area, from which this paper draws extensively.

Recent pronouncements on agricultural policy in Fiji favour modernization and a larger scale of production, which does not necessarily favour agroforestry. The report Fiji 2020 on modernizing agriculture (Fiji Ministry of Agriculture, 2014), stresses that 'The country's pace of transformation from subsistence to commercial scale agriculture is still slow' (p. 7) and that 'the twin goals of import substitution and food security remain elusive (pp. 14-15). However, reference is made to 'agroforestry in the upland areas where the forestry and agriculture sectors converge', through adaption of 'Sloping Agriculture Land Technology (SALT) and the Line Planting Technology' (p.2). The former is referred to as 'a form of alley farming in which field and perennial crops are grown in bands 4-5 m wide between contoured rows of leguminous trees and shrubs. The latter is envisaged as commercial trees and agriculture crops where the trees are planted at close spacing in rows in an east-west direction to maximize sunlight entering alleys in which 'Root crops, legumes, sweet sorghum, and other biofuels crops are used as the intercrop'.

Some parallels and differences may be drawn between designs of mixed-species plantation systems that were adopted for rainforest cabinet timbers in tropical north Queensland and MSA systems for Fiji and Vanuatu. Carrying out financial analysis of *novel* or *rarely-planted indigenous tree species* faces difficulties in understanding and modelling silviculture requirements, obtaining yield and stumpage price data, and model refinement and validation. However, the challenge becomes even more difficult when modelling mixtures of timber, fruit and nut tree species, and the various short-rotation and annual food and other species which can be intercropped with them. As well, it has been recognized that there can be many species interactions in agroforestry systems – a major reason why particular tree and crop mixtures are adopted – and modelling these interactions can be particularly difficult. As noted by Wikipedia (2015), intercropping or growing two or more crops in proximity is designed to 'produce a greater yield on a given piece of land by making use of resources that would otherwise not be utilized by a single crop'.

Questions arise as to what species for landholders to grow (and for government to promote) in new agroforestry plantings, referred to by Thamen and Clark (1993) as *institutional* agroforestry systems as distinct from *traditional* systems which often contain small numbers of many species suiting individual household food needs. One component of this research is to determine the likely financial performance of proposed new agroforestry plantings which, together with social, environmental and institutional impacts, can guide choice of species mixtures. Financial analysis can also help guide the choice of measures which could be adopted to encourage such plantings and levels of financial support which may be required.

Various forms of agroforestry have been identified in the Pacific Islands, categorized as plantation-crop combinations, multipurpose trees, homegardens, alley cropping or hedgerow intercropping, taungya, sequential cropping systems, dispersed trees with understory intercropping, silvopasture, shelterbelts and windbreaks, live fences and border plantings, and improved fallow and land rehabilitation (e.g. see Elevitch and Wilkinson, 2000, p. 123, Alavalapati et al, 2004, p. 2-3). In this paper the primary focus is on intercropping, i.e. *multi-species* (or *mixed species*) agroforestry, MSA. Wikipedia (2015) identified four types of intercropping, viz. mixed intercropping (crops totally mixed in the available space), row cropping (including alley cropping), combining species with differing growth rates and harvest times, and relay cropping (planting different species at different times, where the crop times overlap).

While traditional or informal agroforestry systems often comprise a seemingly random collection of trees and other plants, institutional agroforestry systems are generally designed with a systematic planting pattern, such that the areas and planting time arrangement of the various components are identifiable, so in principle the future annual cash flows associated of each species can be isolated and predicted. Hence it should be possible to perform a financial analysis, although a large number of parameter estimates and assumptions may be required.

CHOICE OF FINANCIAL MODELLING APPROACH FOR AGROFORESTRY SYSTEMS

A number of approaches have been adopted for financial analyses of MSA systems. Ellis et al. (2004) reviewed various 1990s computer-based decision-support tools used in agroforestry, including databases, geographical information systems, computer-based models, mathematical computer models, knowledge-based or expert systems, and hybrid systems. Four examples reported by Ellis et al. are: *DESSAP (Agroforestry Planning Model)* – a multi-objective linear programming model to assess feasible agroforestry alternatives based on land, labour and cash constraints, developed by Garcia de Ceca and Gebremedhin in 1991; *BEAM (Bio-economic Agroforestry Model)* – a bioeconomic model to assess physical and financial performance of agroforestry systems, developed at the University of Wales; *AEM (Agroforestry Estate Model)* – an economic model to evaluate agroforestry in combination with other farm activities, developed by Middlemiss and Knowles in New Zealand in 1996; and *AME* (*Agroforestry Modelling Environment*) – an object-oriented modelling tool to graphically visualize, construct, integrate and exchange agroforestry models, developed by Muetzelfeldt and Taylor in 1997. AME has apparently now been developed into the SIMILE simulation package designed for building general ecology models.

In another classification system, Alavalapati and Mercer (2004) divided financial or economic methodologies for evaluation of agroforestry systems into: enterprise or whole-farm budget models (nowadays mostly performed with spreadsheet packages, and sometimes including discounted cash flow analysis); policy analysis matrix (PAM) models (in which accounting matrices of revenues, costs and profits are constructed for the study of selected agricultural systems); risk assessment models (ranking of competitiveness, efficiency and transfer effects of policies); dynamic optimization models; linear and non-linear programming models; non-market valuation models (e.g. hedonic price and contingent valuation methods); and regional economic models.

Several financial models have been developed for multi-species plantings of lesser-known tropical rainforest tree species. Herbohn et al. (1998) reported the development of a forestry financial model (the Australian Cabinet Timber Financial Model, ACTFM) to predict potential returns from small-scale plantations of high-value rainforest cabinet timbers for which there was little experience of plantation commercial production. A detailed description of the model is provided in Dayanandra (2002, Ch. 13). The ACTFM consisted on linked spreadsheets in an Excel workbook (supported by Visual Basic macros) – with individual sheets designed to perform particular functions (e.g. store data, perform calculations and display results including the NPV, LEV and IRR criteria) – for a woodlot containing up to a five tree species. Default yield, price and other parameter data were provided, which could be overwritten by the user. Estimates of pessimistic, best guess and optimistic growth rates (mean annual increments, MAIs) and stumpage prices were obtained for 32 species with potential for plantation use, through a Delphi survey of forestry experts. Harrison et al. (2001) used the ACTFM with the @RISK software add-on to estimate the financial risk of a three species mixture, in terms of the cumulative relative frequency curve for NPV.

To extend the capabilities of the ACTFM, Herbohn et al. (2009) developed a whole-farm financial model – referred to as the Australian Farm Forestry Financial Model (AFFFM) – which can be used to evaluate the financial performance of farm tree, crop and livestock production. In developing the AFFFM it was found that Excel had insufficient capacity to undertake the calculations, and Visual Basic was adopted instead. Interesting features of this model were the inclusion of a user-friendly menu system, and model validation through continuous interactions with users, replication of previous studies, development of case studies and testing by an undergraduate student class. Harrison et al. (2004) provided a review of the ACTFM, AFFFM, and a forestry financial model developed in the Philippines, including descriptions of model validation tests.

In summary, financial of economic analysis of agroforestry systems, which may include identification of optimal agroforestry systems in terms of the species components, has been performed using a wide variety of software. For this study, a decision was made to use a Microsoft Excel spreadsheeting approach for modelling agroforestry systems in Fiji and Vanuatu because this software is well known to researchers and the community in general, has extensive modelling features, and is relatively easy to use. Excel contains a wide variety of financial functions to aid discounted cash flow analysis, including those needed for calculating financial performance criteria and also for sensitivity analysis, breakeven analysis and scenario analysis. The ability to trace precedents and dependents assists in checking formulae. The ability to combine spreadsheets in the one Excel workbook creates the opportunity for a modular approach to developing MSA models.

STUDY AREA AND RESEARCH METHOD

The study areas as suggested for the research by ACIAR were the sugarcane growing areas in the Western Division in Viti Levu in Fiji and Efate Island in Vanuatu. In the former the sugar industry, though still important to the Fiji economy, has contracted with declining sugar prices. In the latter, due to a decline in international copra prices, some of the coconut plantations are aged and have reduced yields, and opportunity exists for intercropping or replacing these plantations.

Applying financial analyses to potential mixed-species agroforestry plantations based on traditional tree species presents major challenges in terms of data collection and of model formulation and validation. The approach adopted has been to collect data from field visits and limited surveys under ACIAR project ADP/2014/013, and literature search, to initially model individual species, and then to adapt and integrate the single-species models into agroforestry systems models. A number of research steps were required:

1. Identify priority tree and crop species for Fiji and Vanuatu;

2. Compile information on site requirements, for example in terms of land type, climate, shading requirements and shade tolerance;

3. Develop a suite of financial models for individual tree and crop species, for use as modules in MSA models;

4. Choose promising mixed-species agroforestry systems; and

5. Develop financial models for selected MSA systems and compare their financial performance.

RESULTS

The results are reported in the sequence listed in the research method section.

1. Priority tree and crop species for Fiji and Vanuatu

Many lists have been developed for priority species for both Fiji and Vanuatu over the last 20 years, based on various criteria, including the need for conservation of genetic material, the proven performance of the species growing naturally, as sources of timber and other products, international or domestic marketability of the timber and other products, potential for genetic improvement, potential for value-adding of products, suitability for growing in mixed-species agroforestry systems, and traditional values of the species to particular Pacific Island communities. Among the most recent recommendations, Padolina and Kete (2014) of the Secretariat of the Pacific Communities (SPC) identified priority tree and crop species for agroforestry for Pacific Island Countries (PICs) as in the following table (Table 1).

Table 1. Recently listed tree and crop species for mixed-species agroforestry in Fiji

Timber and tree species	Tree species for essential oil
Teak (*Tectona grandis*)	Sandalwood (*Santalum spp.*)
Poloumi (*Flueggea flexosa*)	Coconut (*Cocus nucifera*)
Caribbean pine (*Pinus carribaea)*	Dilo (*Calophyllum inophylpum*)
Mahogany (*Swietenia macrophylla*)	Mokosoi (*Cananga odorata*)
Tropical almond (*Terminalia cattappa*)	Agarwood (*Aquilaria spp*.)
Pandanus spp.	
Trees that provide food, fruit and nuts	**Multipurpose trees**
Coconut (*Cocus nucifera*)	*Grilicidia sepieum*
Breadfruit(*Artocarpus altilis*)	*Azadirachta indica*
Coffee (*Coffea arabica*)	*Moringa oleifera*
Cocoa (*Theobroma cacao*)	*Moringa citrifoia*
Ngale or canarium nut (*Canarium indicum*)	
Mango (*Mangifera indica*)	
Avocado (*Persia americana*)	
Papaya (*Carica papaya*)	
Citrus spp.	

A list of about 60 priority tree species of the Fiji Department of Forestry was made available to the authors, which is notable for including some species not traditionally found in Fiji, including Australian eucalypts. Republic of Vanuatu (2014) noted that 'Five tree species have been selected as priority species for reforestation. These are the sandalwood *(Santalum austrocaledonicum)*, mahogany (*Swietenia macrophylla)*, namamau or flueggea (*Flueggea flexuosa*), whitewood *(Endospermum medullosum)*, and nangai (*Canarium spp.*)'. With the possible exception of mahogany, these species have been recommended for agroforestry systems. In both Fiji and Vanuatu, important food crops sometimes grown together with tree species include citrus, root crops (notably cassava, taro and kumera) and kava, and various vegetable species.

2. Site conditions and species-site matching

A characteristic of many islands in the Pacific region, including Viti Levu which is the most populous island in Fiji, is that eastern areas have high rainfall and western rainshadow areas have lower rainfall and a relatively dry summer, limiting the range of tree and crop species which can be grown. In Efate Island in Vanuatu, the climate is less restrictive.

Government land-use planning in general prescribes that the type of land to be used for agroforestry is not prime agricultural land where agroforestry would not be the 'highest and best' use. Biological constraints restrict planting on low quality land to the more site-tolerant forestry species (such as Caribbean pine or eucalypts). Fiji has adopted a Land Use Capability Classification System based on seven sets of information, relating to geology, soils, relief, erosion, vegetation, land use and climate (Department of Agriculture, nd, p. 7). Eight land capability classes are defined, classes I to III being suitable for intensive agriculture, IV to VII being unsuitable for ploughing but suitable for less intensive cropping under traditional cultivation methods (and hence potentially suitable for agroforestry), and class VII is regarded as unsuitable for productive vegetation.

In the Western Division of Viti Levu, the dry winter months limit the choice of species for agroforestry systems. Tree species suitable for this area include sandalwood, vesi, mango, teak and Caribbean pine, and the food crops of pineapples, cassava, upland taro, and possibly kava. More northerly areas of the Western Division have a more favourable climate, and a wider range of crops can be grown, particularly in lowland and relatively flat areas. Particular requirements of some species were identified, including a need for early shading (e.g. canarium nut), a need for a dry period in the year to flower and hence produce fruit (mango), a need for protection from strong wind (many species), protection from fire (most species), and a requirement for a host species for survival (sandalwood).

3. The financial models for individual species

Data from various sources, including research visits to Fiji and Vanuatu, discussions with ACIAR project in-country collaborators in the SPC and web searches were used in development of a number of financial models, as modules for use in overall MSA system models. These were initially developed for the 10 tree species of breadfruit (*Artocarpus altilis*), canarium nut (*Canarium indicum*), cacao (*Theobroma cacao*), poumuli (*Flueggea flexuosa*), Pacific kauri (*Agathis macrophylla*), sandalwood (*Santalum austrocaledonicum* and *S. yasi*), Tahitian or Polynesian chestnut (*Inocarpus fagifer*), tropical almond or sea almond (*Terminalia cappata*), whitewood (*Endospermum medullosum*) and vesi or merbau and kwila (*Intsia bijuga*), as well as for the annuals taro or dalo (*Colocasia esculenta*) and velvet bean (*Mucuna pruriens*) as a green manure crop.

In that development of new financial models was found to be highly time consuming, and recent gross margins budgets developed by Leslie (2013) were discovered, the gross margins for additional trees and crops were adapted to generate financial models for use in MSA models. The setting of the GM analyses is as income-earning opportunities for farming on land from which sugarcane production has ceased, in western Viti Levu, Fiji. The coverage is in fact food crops, including fruit trees, and some of the models were for multi-year species and were in effect a hybrid between gross margins and multi-year budgets. Adaption included inflating prices to mid-2015, adjusting labour costs, and adjustments in cash flow timing to the beginning and end of the year. In this way, financial models were developed for nine multi-year species, viz. avocado (*Persea americana*), kava (Yoona) (*Piper methysticum*), mango (*Mangifera indica*), Papaya (*Carica papaya*), Pigeon pea (*Cajanus cajan*), Pineapple (*Ananas comosus*), plantain (*Musa balbisiana*) and sweet orange (*Citrifolia sinensis*), as well as three annuals, viz. dryland taro (tannia, dalo-nitans) (*Xanthosoma saggitifolium*), sweet potato or kumala (*Ipomoea batatas*) and cassava (*Manihot esculenta*).

The financial models take the form of spreadsheets consisting of a number of blocks, setting out the physical and financial parameter values, annual cash flows, financial performance criteria and labour requirements for each tree or crop species. A standard area unit of 1 ha is adopted. The discount rate (weighted average cost of capital) is set at 8%. Yield levels of some tree and crop species – notably fruit and nut species – are specified as schedules of step functions over time.

A major component in the financial models in the labour cost. Work rates for the main silvicultural operations (presented in Table 2) were obtained from consultation with foresters and personal experience of the authors in a forestry joint venture and a silvopastoral system of cattle and macadamia nuts.

Table 2. Work rates for main silvicultural activities

Task	Rate (mins/tree or plant)			
	Timber trees	Fruit & nut trees	Shrubs	Root crops
Land preparation	0	2	2	1
Hole digging and planting	10	15	5	0.5
Fertilizing or mulching at planting	2	2	2	5
Subsequent fertilizing	0	4	3	5
Ring weeding, per round	5	7	5	.01
Pruning, low	3	6	2	0
Pruning, high (e.g. pole pruning)	6	10	2	0
Thinning to waste, small trees	2			
Thinning to waste, large trees	8			

Other work rates

Site clearing: highly variable depending of site – say 12 hrs/ha
Site fencing, when required – say 16 hrs/ha
Travel to field site and set-up time (incl. tool sharpening) – 10 mins
Field layout: 8 hrs/ha (plus time when hole-digging)
Transport of seedlings to field site: 1 min/seedling
Nut collecting, from ground: will vary with species – say 4 mins/kg
Nut husking: will vary with species – say 6 mins/kg

Wage rates are based on the reported minimum wages in Fiji and Vanuatu for an 8-hour working day, of F$ 18.56 in Fiji and 1400 Vatu in Vanuatu, equivalent to $A 11.50 and A$ 16.80 per day respectively.

4. The mixed-species agroforestry systems selected for financial analysis

Various potentially viable agroforestry systems were identified, drawing on those observed on site visits, suggested by in-country project participants or described or suggested in the literature. Given the time constraints of a one-year project, only five of these species mixtures – labelled agroforestry models AFM1 to AFM5 – were chosen for detailed analysis, as potentially suitable in Fiji, Vanuatu or both. The systems, presented in approximately increasing order of complexity, are:

AFM1 – mango (*Mangifera indica*) + cassava (*Manihot esculenta*)

AFM2 – breadfruit (*Artocarpus altilis*) + pineapples (*Ananas comosus*) + cassava (*Manihot esculenta*)

AFM3 – citrus (*Citrifolia sinensis*) + Sandalwood (*Santalum yasi*) + Pigeon Pea (*Cajanus cajan*)

AFM4 – cacao (*Theobroma cacao*) + sandalwood (*Santalum austrocaledonicum* or hybrid) + sweet potato (*Ipomoea batatas*)

AFM5 – canarium nut (*Canarium indicum*) + plantain (*Musa sapientum*) + kava (*Piper methysticum*) + Pacific kauri (*Agathis macrophylla*)

The project life of each agroforestry system is set at the longest harvest age of a timber species, or a more arbitary number of years where a fruit or nut tree has the longest life. Where timber species are included, the analysis extended up to the recommended harvest age of the latest-harvest species, e.g. 20 years for sandalwood and 40 year for Pacific Kauri. To determine the areas of each species in these models, field layout diagrams were drawn, in which the within and between row positions of the longer-term species were first marked, and then the intercrop areas were allocated and their reduction over time as the framework species approached canopy closure were estimated.

5. Development, interpretation and comparison of financial models for each of the five MSA system models

The Excel workbook for each of the five selected agroforestry systems consists of a set of spreadsheets, including a first or summary sheet and a sheet for each individual species module. The species modules are adaptions of the financial models described above. Costs which are common across two or more species in an MSA system (shared costs, notably cost of leasing land, land preparation for planting, and tools, equipment and containers for use in harvesting food crops) and costs which are independent of the scale of planting, are treated as overhead costs and moved from the species modules to the summary sheet. Performance criteria in the individual species sheets are limited to the NPV and annual labour requirement, and no sensitivity analysis is provided, the focus of the analysis being on financial performance of the overall agroforestry system, not on individual components of it.

As illustrated in Table 3, the top section of the *summary sheets* list the tree and crop species in the mixtures, the years in which they are assumed to be grown, the areas (percentage of a hectare) allocated to each species, initial spacing within and between rows, and yield and price parameters. For species for which yield changes over time, *yield factors* rather than discrete values are applied. Yield factors are also used for species where a number of products are sold, notably sandalwood which can produce carving timber, heartwood for oil production, sapwood, fuelwood and edible nuts. This is referred to as a *site and management factor,* and can also be used to reflect the impact of planting site quality. Below these data are sections on common parameters (national minimum wage rate and the discount rate) and on shared costs. These are followed by annual net cash flows for each species in the mixture. Where the percentage of area for a species changes between rotations of that species during the life of the agroforestry system, the different rotations are treated like different species when combining cash flows in the summary table. The common costs and annual cash flows for each species in the mixture are summed, and the aggregate NPV and overall IRR are calculated.

Critical to performing the financial analysis of MSA is the transfer of data between workbook sheets. As illustrated in Figure 1, data in summary sheets (on areas planted, yields or yield factors, product prices, and the wage and discount rate) are referenced in individual species modules. In turn, the annual net cash flows and labour requirements derived in species modules are referenced by the summary sheets.

Screenshots of components of MSA financial models are presented in Tables 3 - 5. Some of the year columns in the screenshots (mainly those where there is little change in numbers between years) are hidden using the *Column Hide* facility, to ensure that the screenshop detail is not too small for convenient reading.

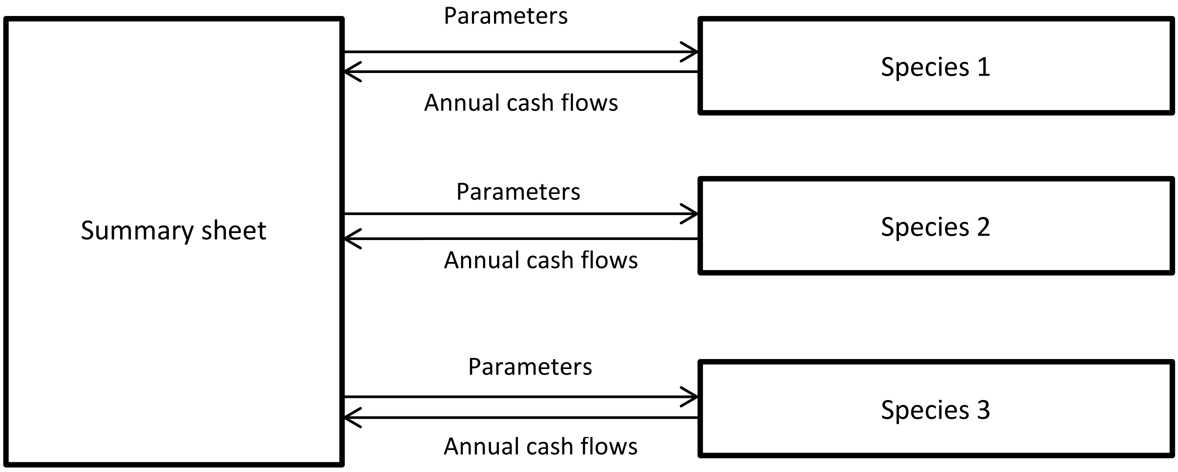

Figure 1. Passing data between the summary spreadsheet and species modules

As indicated in Table 3, mango is grown at a 9 m x 9 m spacing, and about 55% (5/9) of the area is intercropped with cassava for the first five years. The stocking density is 123 stems per hectare of mango and 16,000 plants per hectare for cassava. An aggregate NPV of F$ 122,123 is generated over the 15 year project life. The IRR estimate is not meaningful because the system is designed to minimize early capital outlays, and the small capital outlay leads to an exaggerated return on capital.

Table 3. Example of a summary sheet – the mango and cassava model

	A	B	C	D	E	F	G	H	I
1	**Summary sheet for mango and cassava MSA model**								
2									
3	**Tree or crop species mixture**	Area, year 1-5	Area, yield 6-15	Row spacing (m)	Spacing within rows (m)	Planting density (sph)	Yield quantity or factor	Yield unit	Product price ($/kg)
4	Mango (*Mangifera indica*)	100%	100%	9	9	123	1	Factor	1.75
5	Cassava (*Manihot esculenta*)	55.56%	0%	1	0.5	16000	20000	kg/ha	0.9
6									
7	**Shared costs**								
8	Land lease costs	1000			**Common parameters**				
9	Hand tools ($)	200			Wage rate (F$/day)		18.56		
10	Site clearing cost (F$)	37			Discount rate (%)		8%		
11	Knapsack sprayers ($)	300							
12	Containers - buckets, crates ($)	250							

14	**Annual net cash flows, mango and cassava**											
15	Year	0	1	2	3	4	5	6	7	8	9	15
16	Shared costs ($)	-1787										
17	Mango ($)	-978	-388	-1057	-1057	6193	12059	12059	12059	18464	18464	26851
18	Cassava ($)	-1556	6580	6580	6580	6580	8136					
19	Aggregate net cash flow ($)	-4321	6191	5523	5523	12772	20195	12059	12059	18464	18464	26851
20	Aggregate NPV ($)	122123										
21	Overall IRR ($)	150%										
22												
23	Labour requirement (days)											
24	Mango	5	6	39	39	26	102	102	102	149	149	161
25	Cassava	0	61	61	61	61	61					
26	Total labour requirement	5	67	100	100	87	163	102	102	149	149	161

A stability analysis of the mango-cassava model is presented in Table 4. Sensitivity analysis using the Excel *Data* then *What-If Analysis* menu options, with 20% pessimistic and optimistic variations in parameter values, reveals that mango yield and price and the discount rate have greatest effect on NPV. Breakeven analysis – using the *Goal Seek facility* in Excel to find the level of each parameter for which overall NPV is zero – is not useful because either species leads to an approximately breakeven financial performance. Scenario analysis – using the *scenario manager* in Excel is used to examine the impact on NPV when a number of parameters are simultaneously adjusted by 20% in pessimistic and optimistic directions – indicates that the NPV would be reduced to less than half if all six parameters simultaneously took pessimistic values. The pessimistic scenario is particularly useful for gaining an impression of how financial performance would deteriorate if there was a general downturn in prices, a destructive weather event or some other unforseen adverse circumstance.

Table 4. Sensitivity, breakeven and scenario analysis for the mango-cassava model

29	**Sensitivity analysis**	Pessimistic	Expected	Optimistic	**Breakeven**
30					**values**
31	Mango yield (factor)	0.8	1	1.2	-0.02
32		98152	122123	146093	
33	Mango price (F$)	1.4	1.75	2.1	0.08
34		96545	122123	147701	
35	Cassava yield (kg)	16000	20000	24000	-42700
36		114332	122123	129914	
37	Cassava price (F$)	0.72	0.9	1.08	-1.85
38		114137	122123	130109	
39	Wage rate (F$)	22.27	18.56	14.85	135.2
40		118237	122123	126009	
41	Discount rate (%)	9.60%	8%	6.40%	150%
42		107448	122123	139519	

Scenario Summary			
	Pessimistic	Expected	Optimistic
Changing Cells:			
G4	0.8	1.0	1.2
G5	16000	20000	24000
I4	1.4	1.75	2.1
I5	0.72	0.9	1.08
B8	22.27	18.56	14.85
B9	9.6%	8.0%	6.4%
Result Cells:			
B25	51849	122121	225364

Table 5 demonstrates the structure of a financial model for an individual species (mango), as parameter, annual cash flows and performance indicators. The annual net cash flows and labour requirements are referenced by the summary sheet.

Table 5. Financial analysis module for a single species – the mango spreadsheet

	A	B	C	D	E	F	G	H	I	J	P	Q
1	**Financial model for mango**											
2												
3	Land area planted (ha)	1.0		Expected yield, yr 4 (kg/ha)			4500					
4	Yield factor	1.0		Expcted yield, yr 5-7 (kg/ha)			9000					
5	Row spacing (m)	9		Expected yield, yr 8-11 (kg/ha)			13500					
6	Spacing within rows (m)	9		Expected yield, yr 12-15 (kg/ha)			18750					
7	Number of trees	123		Transport cost ($/kg)			0.11					
8	Land preparation cost (F$/ha)	614		Labour requirement, year 0			5					
9	Planting materials ($/seedling)	2.2		Labour requirement, yr 1 (days)			6					
10	Planting materials, year 0 ($/ha)	272		Labour requirement, yrs 2-3 (days)			39					
11	Fertilizer, yr 1-3 ($/ha)	103		Labour requirement, yr 4 (days)			26					
12	Fertilizer, yr 4 ($/ha)	412		Labour requirement, yrs 5-7 (days)			102					
13	Fertilizer, yr 5-7 ($/ha)	516		Labour requirement, yrs 8-11 (days			149					
14	Fertilizer, yr 8-15 ($/ha)	619		Labour requirement, yr 12-15 (days			161					
15	Crop protection, yr 1 ($/ha)	174		Mango price (F$/kg)			1.75					
16	Crop protection, yr 2-3 ($/ha)	236		Wage rate (F$/day)			18.56					
17	Crop protection, yr 4-15 ($/ha)	299		Discount rate (%)			8%					
18												
19	Year	0	1	2	3	4	5	6	7	8	14	15
20	Capital outlays ($)	885										
21	Fertilizer cost ($)		103	103	103	412	516	516	516	619	619	619
22	Crop protection cost ($)		174	236	236	299	299	299	299	299	299	299
23	Transport cost ($)					495	990	990	990	1485	2063	2063
24	Labour cost ($)	93	111	718	718	476	1887	1887	1887	2759	2982	2982
25	Total operating cost ($)	93	388	1057	1057	1682	3691	3691	3691	5161	5962	5962
26	Production (kg/ha)					4500	9000	9000	9000	13500	18750	18750
27	Revenue ($)	0	0	0	0	7875	15750	15750	15750	23625	32813	32813
28	Net cash flow ($)	-978	-388	-1057	-1057	6193	12059	12059	12059	18464	26851	26851
29	NPV($)	98136										
30												
31	Annual labour requirement (days)	5	6	39	39	26	102	102	102	149	161	161

Table 6 illustrates a more complex agroforestry system, in this case with four species, and with multiple rotations of plantain (a cooking banana species) and kava. Canarium cannot be planted until the second year when shade is available, and has a 30 year life, while Pacific kauri is not logged until year 40.

Table 6. Summary sheet of a more complex agroforestry system – canarium, plantain, kava and Pacific kauri.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	AG	AP
1	**AFM5 – canarium (*Canarium indicum*) + Pacific kauri (*Agathis macrophylla*) + plantain (*Musa balbisiana*) + kava (*Piper methysticum*)**															
2																
3	Tree or crop species mixture	Year 1	Year 2-6	Year 7-12	Yr 13-16	Yr 17-20	Row spacing (m)	Spacing within rows (m)	Planting density (sph)	Product yield	Yield unit	Product price (vt/kg)	Price unit			
4	Canarium (*Canarium indicum*)	0%	50%	50%	50%	50%	10	9	111	1.0	Factor	50	vt/kg NIS			
5	Plantain (*Musa balbisiana*)	50%	50%	20%	0%	0%	3	2	1667	1.0	Factor	50	vt/kg			
6	Kava (*Piper methysticum*)	0%	40%	70%	70%	0%	2	2	2500	2400	kg/ha	1800	vt/kg			
7	Pacific kauri (*Agathis macrophylla*)	50%	50%	50%	50%	50%	10	9	111	10	m^3/ha/yr	3000	vt/m^3			
8																
9	**Shared costs**				**Common parameters**				NIS means nuts in shell (but not husk)							
10	Land clearing labour (3 days)	4200			Wage rate (vt/hr)		1400		Kava roots are dried before selling							
11	Sundry tools (vt)	25000			Discount rate (%)		8%		Canarium timber is not included in the sensitivity analysis							
12	Crates and buckets (vt)	10000														
13	Knapsacks (vt)	25000														
14	Land lease fee (vt/ha)	83000														
15																
16	**Annual net cash flows**															
17	Year	0	1	2	3	4	5	6	7	8	9	10	11	12	31	40
18	Shared costs (vt)	-147200														
19	Canarium (vt)		-39456	-4856	-4856	-8094	-3238	-6475	-25345	23264	-27944	142848	202640	262432	433224	
20	Plantain, first rotation (vt)	-41785	337402	323515	317340	312567	304991	293913								
21	Plantain, second rotation (vt)							-16714	134961	129406	126936	125027	121996	117565		
22	Kava ,first rotation (vt)		-259520	-25280	-36480	-36480	-29200	600892								
23	Kava, second rotation (vt)							-454160	-44240	-63840	-63840	-51100	1051560			
24	Kava, third rotation (vt)												-454160	-44240		
25	Pacific kauri (vt)	-5390	-2406	-2406	-2406	-1604	-1604	-1604	-642	-642	-642	-642	-642	-642	-642	600000
26	Overal agroforestry system (vt)	-194375	36020	290973	273598	266389	270949	415851	64734	88188	34510	216133	921395	335115	432582	600000
27	Overall NPV, excl. (vt)	2775365														
28	Overall IRR (%)	86%														

Note: Plantain is a cooking banana species. Costs and cash flows in this table are reported in Vanuatu vatu

Comparison of performance of the five MSA systems

The aggregate NPVs for an agroforestry system provide an estimate of by how much the grower's wealth would change by adopting agroforestry systems, taking into account the predicted capital outlays, operating costs and revenue generated over the project life. A positive aggregate NPV indicates that the project (i.e. agroforestry system) is *financially viable*. The pattern over time of the aggregate cash flows reveals whether the agroforestry system is *financially feasible* or affordable. The aggregate labour profile reveals for example whether the system is *physically manageable* by the farm family or whether labour hire is required.

Table 7 provides a comparison of financial performance of the five agroforestry systems. Given that the planning horizon for the MSA systems depends on the greatest harvest age of the species included, the models differ with regard to project life, i.e. the number of years for which land must be committed to them. Hence as well as aggregate NPVs, the *land expectation values* (LEV) are reported. An LEV is the discounted sum of an infinite sequence over time of identical projects, and for forestry and agroforestry is known as the *site value*, i.e. what net return the land could generate if committed permanently to a particular agroforestry system. This provides a criterion for comparing MSA systems of differing durations. For very long rotations, the LEV differs little from the NPV. From Table 7 it is notable that models 1 and 3 provide the greatest return. The value of this information is limited in that the site productivity differs between the models; comparison by this criterion would be most useful for comparing returns for alternative species mixtures on similar sites.

Table 7. Financial performance estimates for the five agroforestry systems

Agroforestry system	**AFM1**	**AFM2**	**AFM3**	**AFM4**	**AFM5**
Species	Mango, cassava	Breadfruit, pineapple, cassava	Citrus, sandalwood, pigeon Pea	Cacao, sandalwood, sweet potato	Canarium, plantain, kava, Pacific kauri
Project life (yrs)	15	20	20	30	40
No. of species	2	3	3	3	4
NPV – local currency	122123	47105	230473	2693918	2775365
NPV in A$	75716	29205	142893	32327	33304
LEV ($A)	110573	37182	181925	35894	34911

DISCUSSION

Given the kind of information generated in the financial analysis, and particularly the net cash flows and labour requirement in the early years before much revenue is generated, it is possible to provide some policy guidance on what level of support might be required for landholders to be able to adopt particular types of agroforestry systems. This could be linked with the assessment of what form of assistance might be effective. Potential assistance measures might include: market-based instruments (MBI) including subsidies and grants, e.g. free seedlings, assistance with planting, payment for weed control, provision of minor equipment items; joint investment, e.g. plantation joint venture schemes for high-value species; moral suasion (publicising the private and social benefits of tree planting); and broad-based community forestry programs such as joint forest management (practiced in India), community forest user groups (CFUGs, Nepal) and community-based forest management (CBFM, Philippines).

In practice, free seedlings and some extension together with moral suasion are often used to encourage tree planting. In some cases, minor assistance will be sufficient to encourage forestry and agroforestry adoption. In a preliminary survey of agroforestry adoption in Efate, Vanuatu, Harrison and Aising (2015) found that when landholders were asked what type of assistance they would require to expand agroforestry, or adopt agroforestry if not currently engaged in this practice, about half mentioned provision of hand tools (the same numbers as reported financial support). However, for large-scale adoption it is likely that national or regional approaches involving community forestry programs which provide greater levels of organizational support and funding and property rights to some existing forest resources will be required.

Some Challenges for Evaluation of Agroforestry Systems and Suggestions for Further Research

A number of challenges have been encountered in this study. While financial modelling is well established for monoculture forestry and even mixed timber species plantings, modelling of mixed-species agroforestry systems including intercropping targeted at novel tree species for which little financial data are available becomes a much more complex task. There is a distinct lack of information available about the silviculture, harvest age, yield and farmgate timber prices of traditional tree species which have not been grown commercially. A Delphi survey as used for rainforest cabinet timbers in north Queensland (described in Herbohn et al. (1999) and Dayananda et al. 2002, pp. 241-243) could be used to obtain estimates of harvest ages and timber prices for novel tree species in Fiji and Vanuatu.

Some agroforestry costs were found to be particularly difficult to estimate in Fiji and Vanuatu, a notable case being land access costs (lease establishment fees and annual land rental costs), which apparently vary between customary land owners and between locations. As well, depending on the land condition at planting sites, the land amelioration cost can be highly variable, an extreme case being where the land requires a vegetation fallow for perhaps two years before agroforestry establishment can begin.

The MSA financial models which have been developed are deterministic models. While the sensitivity analysis is helpful in providing an indication of how variations in parameters (particularly yields and product prices) will affect financial returns, these do not address the risk of catastrophic agroforestry failure due to wildfire, extreme cyclones or severe pest or disease failure. Measures can be adopted which will minimize the risk of extreme damage, e.g. fire protection measures (described by Harrison and Harrison, 2015), inclusion of cyclone resistant tree species, and use of recommended crop protection measures. Landholders tend to minimize expenditures on these preventative measures. Harrison and Aising (2015) found that their survey respondents were negative about use of chemical fertilizers, but more inclined to use pesticides in their agroforestry.

The models discussed in this paper address financial impacts of agroforestry systems, but do not include non-market environmental and social values also relevant to decision-making. Planting could be undertaken for watershed protection, which would have relatively high cost but low yields, but could be valuable for control of soil loss and downstream flooding. Also, species could be grown which have high traditional values for special buildings, wood crafts or ceremonial events, as additional benefits. Research to estimate non-market values, to be combined with the financial values, would assist policymaking about environmental planting. In other words, to improve the modelling for policy support, it would be useful to supplement the financial estimates with non-market value estimates for environmental and social impacts. Various methods of non-market valuation are available for this purpose, of varying degrees of precision and varying costs. The simplest though somewhat imprecise method would be *benefit transfer*, drawing on databases of non-market values from other sites. A particularly useful overview of databases of environmental values has been provided by Van Landeghem (nd). It is noted that the Environmental Valuation Reference Inventory (EVRI) of Environment Canada has data from more than 1900 studies, and the Review of Externality Database of the European Commission more than 1200 studies. Details of a number of other environmental databases are provided.

MSA systems provide important benefits, but public sector support measures are required to promote them. While various government departments in Fiji have some responsibility for agroforestry, none are the lead agency for agroforestry. Hence development of national or regional agroforestry policy statement (with a similar role to national forestry policy statements which have been developed by many countries) may be warranted. A model on which this could be based is the newly developed Indian national agroforestry policy reported by CCAFS (2014).

Another suggestion for further research is that the financial modelling could be further developed into a *decision-support tool* for use in agroforestry extension. Further validation testing would be desirable for this application. Yield and price data could be refined using the Delphi survey approach as adopted for rainforest tree species in tropical north Queensland. Further validation efforts on the MSA models for Fiji and Vanuatu could be performed by undertaking *face validity* testing with forestry experts, particularly people familiar with mixed-species agroforestry systems adopted on farms or trialled in research projects. It would also be desirable to develop user-friendly input and output interfaces for MSA system models, perhaps including input screens and error trapping, silvicultural and plant protection recommendations, and tabular presentation of result of computer runs.

CONCLUDING COMMENTS

The method of financial analysis for mixed-species agroforestry systems developed in this paper is the result of much development effort on tree and crop financial models and much experimentation in spreadsheet development. The Excel workbook modelling approach involving a summary sheet and modules for each species has proved to be an effective format for the financial modelling. A remaining concern is that there has been insufficient validation opportunities for the MSA financial models and their parameter values. A number of opportunities are identified for improving on and extending the financial analysis of mixed-species agroforestry systems.

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Natural Resource Enterprises: Enhancing Landowner Incomes and Conservation in Forests in the USA

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ABSTRACT

Mississippi landowners were found to diversify incomes from forests through fee-access outdoor recreation, including hunting, angling, wildlife watching, and other nature-based activities (Jones et al. 2005). The Natural Resource Enterprises (NRE) program at Mississippi State University educates private landowners, resource agencies, and local communities about recreational enterprises, conservation and integration of these activities with sustainable forestry through educational workshops. Since 2005, over 75 landowner educational workshops have been conducted in 11 U.S. states and an estimated 4,500 landowners and community leaders have been trained in outdoor recreational business development and associated conservation practices**.** At events, participants learn how to start NRE businesses and ways to implement forest management and land and water conservation on their properties. Survey results revealed that our programming has initiated over 1,000 new outdoor recreational businesses and generated an estimated $12.6 million in supplemental annual family incomes on an estimated 4,700 ha in the U.S. NRE development on rural lands benefits landowners and local rural communities through income diversification on working forests and agricultural land while simultaneously enhancing ecosystem conservation and sustainability in the U.S.

Keywords: sustainability, forest management, landowners

INTRODUCTION

Outdoor recreation, including recreational hunting, angling, wildlife watching and ecotourism, is one avenue that incentivizes natural resource conservation and sustainable land-use practices on private lands in the United States (U.S.) while providing ecosystems services benefitting society at large. Demand for quality outdoor recreation is popular throughout the world. U.S citizens (87.5 million) spent over $145 billion (U.S. dollars) on wildlife-related recreation in 2011 (U.S. Department of the Interior 2011). Past research found that revenues collected in 1998 from fee-access hunting on private lands in Mississippi ranged from $2,964 to $5,254 on average per landowner who offered access to property, or $7.50-$14.28/ha, depending upon the region of the state evaluated. Net revenues averaged from $1,539 to $3,244 per landowner who provided hunting access, or $3.95 to $9.66/ha (Jones et al. 2005). During 2005-2008, outdoor recreation increased Mississippi rural property values by 52% or $1,615/ha and those tracts that were leased for recreational hunting averaged over $61/ha (Brashier 2014). Property characteristics that statistically influenced sales prices of rural tracts were hectares comprised of diverse land covers dominated by forested and agricultural lands. Expenditures for outdoor recreation (hunting, angling, wildlife watching, horse trail riding, and other nature-based outdoor activities) produced $2.7 billion in economic impact to Mississippi in 2008 (Henderson et al. 2010). Despite the economic and environmental benefits of fee-access outdoor recreation, only 10-14% of Mississippi private landowners participated in these businesses on their properties, primarily due to concerns about accident liability and perceived incompatibility with traditional forestry and agricultural land-uses (Jones et al. 2005). Similar trends in revenues and land values associated with fee-access wildlife and fisheries recreation have been documented in other southern U.S. states (Richardson et al. 1992, Richardson et al. 1996).

Marginal lands, such as agricultural field borders, wetlands and wetland forests, and forested riparian corridors along watersheds are often difficult to farm or manage for timber production due to flooding problems or regulatory restrictions (National Research Council 1992). However, these properties are ideal for conserving wildlife and fisheries habitats and can be readily enrolled in fee-access recreational businesses and governmental cost-share assistance programs. Revenues from fee-access recreation on private lands were substantially greater on forested and managed agricultural lands, particularly bottomland hardwood forests and forested riparian buffers along watersheds. This finding reveals that private landowners can generate income from conservation and restoration of lands that were marginal for forestry, agriculture or development (Jones et al. 2005, Jones et al. 2008). Additionally, these lands provided ecosystem services that benefit local and regional communities. This study also revealed that fee-access recreation and associated wildlife habitat conservation, often promoted by governmental cost-share assistance programs, were compatible with agriculture and forestry, thereby providing incentives to landowners to diversify natural resource enterprises on their properties that encourage land and water conservation.

Natural resource enterprises may include diverse outdoor activities, wildlife-related recreation, and associated amenities such as hunting, angling, wildlife watching, agritainment or farm tours, horse trail riding, and rural bed and breakfast accommodations. Establishing these types of enterprises on family forests and farms provide multiple benefits and ecosystem services that include the diversification of income streams for rural families, land ownership retention, conservation and stewardship of the land, improved watershed integrity, high quality habitats for wildlife and fish, reduced regulatory measures for environmental protection (state and federal wetland regulatory protection programs), and sustainable rural development (Jones et al. 2005, Jones et al. 2008).

NATURAL RESOURCE ENTERPRISES PROGRAM

The Natural Resource Enterprises Program (NRE) (www.naturalresources.msstate.edu) was established in the Department of Wildlife, Fisheries, and Aquaculture and Cooperative Extension Service at Mississippi State University to educate rural landowners in the U.S. about fee-access recreational business development, wildlife and fish habitat management on farm and forest lands, and compatible land-use practices. Historically in the U.S., educational materials for natural resource enterprise development, though available, have been difficult to locate. As a result, landowners may not be aware of training opportunities and resources available. Working with program partners, we have developed educational workshops, demonstrations, and resources to inform landowners, agency professionals, and community leaders about enterprise opportunities, wildlife habitat management, and sustainable land uses on private lands. The NRE Program partners with federal resource agencies and state land-grant universities, farm bureaus and agricultural trade organizations, U.S. state agencies, non-governmental organizations, and private-sector firms. Partners are actively trained in NRE and land management approaches and participate in workshops. Through these partnerships, we offer on-the-ground educational demonstrations and workshops to assist private landowners in outdoor recreational business development and conservation practices on their lands to enhance natural resources, including wildlife and fish and their associated habitats.

WORKSHOP PROGRAMMING

NRE workshops provide participants with the opportunity to learn from and interact with resource and agency professionals and existing operators of successful outdoor recreational businesses. We conduct workshops on properties that are currently in forestry or agricultural production and that also support a fee-access outdoor recreational enterprise.

During workshops, participants are given learning experiences including instructional lectures from resource professionals and field tours on properties with a fee-access recreational business. During lecture sessions, speakers from universities, resource agencies, and organizations discuss topics, such as revenue potential from outdoor recreational enterprises, business planning and management, legal considerations and liability reduction, governmental cost-share assistance, and habitat management considerations on the farm.

Participants tour properties that are hosting events during afternoon sessions to observe enterprise operations and wildlife and fisheries management integrated with forestry and farming practices. Each workshop attendee receives educational materials about enterprise operations, business management and marketing, liability reduction, wildlife and fisheries habitat management, cost-share assistance programs, and other topics pertinent to establishing and managing an enterprise.

PARTICIPATION

Workshops have been well received by past landowner, resource agency, and community leader participants. From 2005 to 2015, the NRE Program and partners have conducted over 75 landowner workshops and demonstrations in 11 U.S. states, including Alabama, Arkansas, Indiana, Louisiana, Michigan, Minnesota, Mississippi, Oregon, South Carolina, Tennessee, and Texas. Attendance at these events has been exceptional with nearly 4,500 landowners with ownerships located in 16 U.S. states. The program participated in a conference and series of workshops sponsored by Lunds University (Dr Marie Appelstrand) and the Swedish Forest Agency in 2009 to promote fee-access outdoor recreational enterprises within local communities in central Sweden.

To evaluate impacts from workshops, participants were mailed a comprehensive survey entitled Natural Resource Enterprises Landowner Survey that requested information about land-use practices, NRE businesses and conservation that have been implemented on farms since respondents attended a workshop, and additional information required to manage their properties. The Dillman Method of survey design and administration was used in construction and mailing of the questionnaire to workshop participants (Annual Review of Sociology 1991).

RESULTS

In June 2013 and 2014, questionnaires were mailed to attendees of past NRE workshops from 2011 to present. Respondents to this questionnaire mailing were pooled with respondents from a survey mailing conducted in 2011 to participants who attended workshops from 2008-2011. The survey was divided between sections with questions related to landownership, cost-share assistance program participation, types of NRE's initiated on private lands and revenues collected from new business start-ups, informational needs on land management, and respondent demographics. Overall, the questionnaire response rate was 34%, yielding an N size of 514 landowners (pooled from an estimated 30 workshops) who owned lands in 16 U.S. states.

Respondents reported that they frequently utilized the NRE website (www.naturalresources.msstate.edu) to acquire information about wildlife management on their properties, business resources for establishing an NRE business, and to learn about upcoming training events. Other methods preferred by respondents for learning about NRE establishment in addition to attending workshops were watching videos (75% viewed or were interested) and using a resource binder of educational materials provided to attendees at events (65% of respondents). Resource materials sought by respondents were those about wildlife management (82%), timber management (80%), legal issues surrounding NRE operations (76%), wildlife supplemental plantings (74%), agritainment enterprises (63%), fee hunting (62%), and NRE business planning (62%).

Most workshop attendees were landowners (91%) and had the following land uses on their properties: agriculture (78%), forestry (63%), personal recreation on property (61%), fee-access recreational businesses (22%), and vegetable and mushroom production for sale (18%). In terms of landownership, respondents (n=462) owned 220 hectares on average. Land covers on properties owned were primarily forested (mean = 148 hectares/respondent), followed by agriculture (mean = 79 hectares) and other lands such as fallow fields and wetlands (mean = 41 hectares). Agricultural lands ranged from row crops (mean = 79 hectares), pasture (mean = 26 hectares), and aquaculture ponds (mean = 5 hectares). Forested lands were dominated by planted pines and bottomland hardwood forests, 74 hectares and 59 hectares on average, respectively. Mixed pine hardwood forests averaged 44 hectares, followed by upland hardwoods (mean = 39 hectares), natural pine (mean = 20 hectares) and recently harvested cutover tracts averaged 14 hectares. Other lands owned by respondents consisted of wetlands and flooded fields (averaged 10 hectares), food plots for wildlife, roads, and rights of way (each cover type averaged 8 hectares), and fishing ponds (mean = 3 hectares).

Conservation practices were implemented by respondents (n=328) on an aggregate 5,856 hectares representing on average about 50 hectares per farm. Diverse practices were reported by respondents on their properties and included mowing (56%), wildlife plantings (50%), herbicide application (43%), land disking (34%), use of prescribed fire (30%), and forest management (29%). In terms of conservation practices information requested, respondents reported wildlife plantings, herbicide application, pond management, forest thinning, and prescribed burning were the subjects most sought. Over one-half of respondents reported that they had requested assistance from university extension staff, agency biologists, or other land management experts to implement conservation and land management practices on their properties.

Nearly one-half of respondents reported that they had lands enrolled in U.S. Farm Bill conservation cost-share assistance programs. On average, these landowners collected $7,146

(U.S. dollars) in annual contract payments, accounting for payments in excess of $1.25 million. Conservation Reserve Program was the most popular cost-share assistance program participated in, with 97 landowners reporting enrolments of 82 hectares on average per farm. The Wetlands Reserve Program had 29 farmers participating who averaged 57 hectares enrolled, followed by the Wildlife Habitat Incentives Program with 52 participants who averaged 19 hectares enrolled and the Environmental Quality Incentives Program with 49 landowners who averaged 15 hectares enrolled per farm.

One hundred and sixty-four respondents (30%) reported initiating an NRE business on their lands between 2011-2013 with 46 landowners establishing hunting leases, 40 fee-hunting operations, and 30 landowners starting fishing or agritainment operations. On average, landowners committed 329 hectares of their forests and farm lands to outdoor recreational businesses per farm, totalling over 54,000 hectares across all U.S. respondents. In terms of hunting species featured on lands, white-tailed deer (n=101) and wild turkey (n=62) were the most popular game species reported, followed by squirrel species, waterfowl, mourning dove, and rabbit. Landowners initiating NRE businesses collected on average $13,851 per farm, totalling nearly $2.3 million in aggregate cash flow from NRE's initiated (Table 1). Inferring these averages to the total number of landowners attending past workshops, an upper limit of new NRE business start-ups would equal 1,050 new NRE's established on an estimated 1.2 million hectares of forest and agricultural lands in the U.S., accounting for an aggregate cash flow of $14.5 million U.S. dollars. Overall, respondents (69%) reported that revenues met their income expectations. When asked reasons why landowners initiated these businesses, most reported income potential from NRE operations, land conservation management, recreational potential on their lands, improving wildlife and fish on their property, and for personal hobby and enjoyment.

Lastly, most respondents did not have a business plan for their NRE and needed assistance in drafting such a document. To meet this need, we have initiated more advanced workshop formats to train landowners in drafting business plans to better guide their actions in starting new NRE ventures. Respondents reported that their business clients consisted of adult hunters, families, and out-of-town guests who learned about their outdoor excursions offered through word of mouth. When participants were asked how they would prefer to learn about NRE business and land management opportunities in the future, most favoured attending workshops. The majority of respondents were male (63%), older than 56 years of age, over 90% Caucasian, college graduates, and slightly more than half lived on the property reported in the survey.

Table 1: Expected income of landowner respondents from natural resource enterprises developed on their properties in the U.S. from 2008-2013.

Expected income from enterprise development	**Number of responses (N=164)**	**Percentage (%) of total responses**
$0 – $1,000	76	45
$1,000 - $10,000	47	29
$10,001 - $25,000	17	10

$25,001 - $50,000	13	8
$50,001 - $75,000	6	4
$75,001 - $100,000	1	1
$125,001 - $150,000	1	1
Over $150,000	3	2

CONCLUSION

Past research has shown that private landowners earn additional revenues from their properties through fee-access outdoor recreational businesses. As a result, we have developed workshops to educate private landowners, state and federal resource agency staff, and elected and nonelected community leaders about fee-access outdoors recreational enterprise development and integrated conservation practices on rural properties. Survey findings revealed that workshop participants had become more knowledgeable about and had implemented successful natural resource enterprises and associated land conservation management on rural properties located in U.S. states. Landowners earned income from these businesses and earnings met landowner expectations. Consequently, natural resource conservation practices conducted on private lands and associated with NRE development enhanced environmental protection on these working properties and thus, provided viable ecosystem services to rural communities in the U.S.

As noted, response by landowners to the NRE Program's comprehensive 20-page survey was exceptional with a 34% response rate. Much of the information provided by landowners was financial in nature. Individuals, and particularly landowners, are often not receptive to supplying this type of personal information. The high response rate may have resulted from landowners developing personal relationships with program staff at training events and due to their appreciation for the educational resources and training received. Respondents knew that NRE staff were attempting to assist their businesses and increase the value of their properties and therefore were more inclined to complete questionnaires. It is recommended that where possible, an incentive should be offered to landowners to increase their likelihood of completing mail surveys. For completing and returning our survey, respondents received a compact set of binoculars. Landowner recipients often expressed their delight at receiving the complimentary set of binoculars. Additionally, a special effort was made to inform landowners that their responses would be anonymous and used to strengthen educational programming in the future. Researchers should consider factors affecting response rates to mail questionnaires and where possible design survey instruments, provide incentives, and effective communications with survey recipients to maximize questionnaire response rates.

In terms of providing outreach programming in the U.S., multi-state stakeholder collaboration among land-grant universities, state and federal resource agencies, conservation and agricultural trade organizations, and private-sector groups has been vital to designing and implementing educational programming to attract and educate forest landowners and agricultural producers. Outreach programming promoting fee-access recreation and conservation on privately owned U.S. lands can benefit landowners and local communities through sustainable economic development, environmental conservation, and land stewardship and retention. It is believed that this hands-on approach of participatory teaching, marketing, and information dissemination through workshop programming is effective at delivering quality land management training to landowners in rural America who often have difficulty in acquiring knowledge and skills. In this fashion, we can assist landowners in rural landscapes to diversify family incomes on their lands while enhancing land and water conservation, thereby strengthening local economies and providing ecosystem services and quality outdoor recreation on the U.S. land base that might not otherwise be provided if incentives were not present.

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Private Landowner Awareness of Their Conservation Alternatives: An Important Factor Affecting the Management of Small-scale and Community Forests

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Abstract

In landscapes where forests are predominantly owned by private families and individuals, the aggregate effect of their decisions over time can have a profound and lasting effect on land cover and the ecosystem services that result from a wooded condition. Previous research on family forest ownership in the USA shows that most owners do not have a professionally prepared management plan for their land guiding management over a long-term time frame, nor do they utilize the professional services or capacity of foresters when they sell timber at a discrete point in time. The result is often reactive decisions about their land, made in the absence of relevant forestry information or knowledge of their alternatives. An important precursor to making an informed decision about forest management is awareness about alternatives and knowledge of conservation programs and opportunities. The Conservation Awareness Index (CAI) is a rapid assessment survey tool to estimate landowner awareness and experience with four distinct conservation choices they commonly face in the northeastern USA, namely timber harvesting, property taxation, sale or donation of development rights, and estate planning for the next generation of owners. Analysis suggests landowners have relatively poor awareness of their conservation alternatives, and awareness varies significantly by community. This paper reviews the results of six applications of the CAI with hundreds of private woodland owners, and provides insight into relevance for small-scale and community forestry at the landscape level.

Keywords: Private landowners; conservation awareness

Introduction

In many countries, the predominance of forest is owned by private families and individuals. The decisions they make about their forest influences its condition into the future, and the cumulative effect of these decisions can have ecosystem-scale implications. Encouraging private forest owners to make informed decisions about the future of their land is often the goal of many extension and public outreach programs. One approach to assisting landowners with their management or decision-making is to encourage the development and adoption of forest management plans for their land. Many public agencies in the USA either provide the technical expertise to develop plans for owners, or provide the incentive through cost-sharing or subsidy to have management plans professionally developed for private lands. The underlying assumption of this strategy is that owners with professionally prepared management plans will have the knowledge and access to expertise to subsequently make conservation-oriented decisions both for the good of the owner[s] and the good of the forest. This in turn positively influences the extent of beneficial ecosystem services for the public.

This strategy for promoting conservation to private woodland owners is challenged, however, by the fact that most owners in the USA do not have management plans for their land, nor do they respond positively to various appeals, incentives, and marketing campaigns. In the six New England states in the northeastern USA (Maine, Massachusetts, New Hampshire, Vermont, Connecticut, Rhode Island), approximately 20% of all family forest owners (who own 10 or more acres), representing 39% of all family forest land, have management plans (Butler et al. 2015). According to Butler (2008), for the USA, "Four percent of the family owners, who own 17 percent of the family forest land, report having a written forest management plan". This low success or adoption rate is after decades of a wide variety of state and federal programs, incentives, and campaigns. The implication is that most landowners are not interested in professionally prepared management plans. While it is likely true that landowners with plans have more information for informed decision making, it is also true that most landowners do not have plans, and are not likely to be induced to have one, much less follow it.

Instead of equating conservation success at the landscape scale to the number of management plans or acres covered by management plans, is there another means by which landowner conservation can be estimated? Perhaps more important at the point of a landowner making a decision about their land is their relative awareness of conservation programs and alternatives, than whether or not they have a plan. Is there a way to estimate landowner conservation awareness?

Modeled after the Conference Board's Consumer Confidence Index (Conference Board), the Conservation Awareness Index (CAI) was developed in 2012 to be a rapid awareness assessment tool for private woodland owners. The instrument has 16 simple questions that assess landowner knowledge, awareness, and experience in 4 aspects of conservation relevant to New England: timber harvesting, current use property tax programs, conservation easements, and estate planning to pass land on to heirs. Respondents are assigned a score on the basis of their answers, with the maximum being 64 points, representing excellent awareness of conservation information and alternatives. The questions were developed after a series of structured interviews with conservation professionals asking what they wish landowners knew to make informed decisions. Draft questions were then tested through a series of focus groups with landowners, and a pilot instrument was likewise tested through the mail. The resulting instrument was first deployed in 2012 to several hundred landowners in western Massachusetts (Van Fleet et al. 2012). Figure 1 provides an example of the questions and format used in the CAI assessment tool.

The Study Site

Since it was first developed and tested, CAI has been deployed 6 additional times in different circumstances in the northeastern USA, in the states of Massachusetts, New York, and Connecticut. These states are heavily forested (i.e., 63%, 62%, and 58% respectively), and non-industrial private ownership dominates (63%, 65%, and 64%, respectively) (Smith et al. 2009). Ownership size is quite small, averaging 2.3, 7.4, and 3.6 hectares, respectively (Butler et al. 2015). They are also in the densely populated northeastern corner of the USA, and have high suburbanization, fragmentation, and parcelization pressures (Stein et al. 2009).

SECTION 2: Conservation Restrictions

5. How much would you say you know about Conservation Restrictions? Circle a number from the scale below:

Not heard of	*Nothing at all*	*Some*	*Quite a lot*	*A great deal*
1	2	3	4	5

6. Please indicate whether the following statements are true or false by circling *T* or *F*. If you do not know, circle *Don't know*:

A. Conservation Restrictions permanently limit development on my land.	*T*	*F*	*Don't know*
B. Conservation Restrictions must apply to my entire property.	*T*	*F*	*Don't know*
C. Conservation Restrictions require public access to my land.	*T*	*F*	*Don't know*
D. Land trusts hold Conservation Restrictions on private land.	*T*	*F*	*Don't know*

7. Have you or someone you know had experience with Conservation Restrictions? Circle *Yes* or *No* in the boxes below. If you do not know, circle *Don't know*:

A. I have considered a Conservation Restriction for my land.	*Yes*	*No*	*Don't know*
B. I have a Conservation Restriction on my land.	*Yes*	*No*	*Don't know*
C. Someone I know has considered a Conservation Restriction for their land.	*Yes*	*No*	*Don't know*
D. Someone I know has a Conservation Restriction on their land.	*Yes*	*No*	*Don't know*

8. Do you know a local land trust? Check *Yes* or *No* and provide any additional information that you can:

___ *Yes*: Specify their name(s):____

____

___ *No*: How would you find out about one:______________________________________

____

Figure 1. Example of CAI questions and format, that assess awareness (question 5), knowledge (question 6), and experience (questions 7 and 8).

Research Method

The CAI was originally developed following structured interviews with conservation experts, and focus groups with landowners to explore relevant questions and subjects. Once developed as a survey instrument, standard mail survey protocols have been followed (Dillman 2000), with multiple mailings of the instrument to randomly selected landowners of 4 or more hectares in targeted communities. When mailed to landowners in Connecticut or New York, some of the questions were modified to reflect state-specific programs, but the overall structure, length, content, and scoring heuristic did not change. A multi-wave mail survey format was used on 6 different occasions (Table 1), and the CAI was used once as the script for a series of structured interviews in a qualitative format. Response rates varied between 35% and 60% (Table 1), and comparison of respondent information (e.g., age, ownership size, ownership objectives) with known landowner characteristics by state suggests that respondents were representative.

Results

Overview of CAI Application

The Conservation Awareness Index (CAI) has been deployed 6 times between 2011 and 2014 in three different states in the northeastern USA. A total of 2,576 private landowners have responded, and response rates to the surveys have been strong, implying a representative sample. Average CAI scores range from 14.5 to 23.5 (Table 1) out of possible maximum score of 64. This implies that landowners are very poorly informed or unaware of the 4 aspects of conservation decision-making they may face. The CAI has been deployed in New York twice, and both times the mean score is meaningfully lower than scores in Massachusetts, implying less awareness of their conservation alternatives.

Similar to the meaningful difference between states, all applications of CAI in Massachusetts and Connecticut have shown significant difference in mean CAI by town. Some towns have landowners who are significantly more aware of their conservation alternatives than others. Kittredge et al. (2015) and Losey et al. (unpublished 2013) both positively and significantly related CAI to different estimates of local conservation social capital (e.g., presence of a local land trust; local conservation staff; trained Extension volunteers). Interestingly, Kittredge et al. (2015) found that conservation awareness did not vary according to the rural or suburban nature of the community.

Table 1: Summary of CAI results.

Study, year	**Mean CAI**	**Std dev / std error**	**n**	**Response rate (%)**	**Location**
Van Fleet et al. 2012[1]	20.4	12.6 std dev.	267	53	Western Massachusetts
Losey et al. unpublished 2013	23.4	12.6 std dev	409	52	Throughout Massachusetts
Kittredge et al. 2015[2]	23.5	0.7 SE	426	39	Eastern Massachusetts
LeClair et al. unpublished 2014	22.9	0.7 SE, 12.5 std dev	283	37	Central MA, NW Connecticut
Schnur et al. 2013[3]	14.5	8.7 std dev	271	60	Western NY
Van Brakle et al. 2015	15.8	10.5 std dev	920	35	Catskills, NY

Total = 2,576 respondents. 6 separate studies.

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Qualitative Application of CAI

The CAI survey instrument has also been used as a script in structured interviews with landowners. Spousal couples were interviewed jointly, and then separately their adult children were interviewed, to explore differences in conservation awareness between generations. As this was an exploratory and qualitative study, sample size was small (14 couples and 6 offspring), and it is difficult to generate coherent results and implications. Nonetheless, impressions from this work suggest that there is no difference in conservation awareness between the generations, for the participants in the study. Also, in the setting of structured interviews, it was possible to observe people interacting while they deliberated over a question. It was apparent to the research team that some questions or subjects (e.g., estate planning) evoked considerably more discussion or uncertainty than others. This observation lends nuance to the quantitative results that would otherwise equate different aspects of the CAI instrument. Uncertainty is difficult to detect when a mail instrument is used.

CAI as a Long-term Program Evaluation Tool

The CAI research developers cooperated with two non-profit conservation organizations to deploy the CAI instrument to estimate landowner conservation awareness in advance of targeted outreach campaigns. Both groups wanted to establish a baseline of landowner conservation awareness, with the intent of implementing outreach campaigns and assessing accomplishment in the future. The MassConn Forest Partnership (http://www.opacumlt.org/massconn/) operates in 38 towns in northeastern Connecticut and central Massachusetts with the goal to "collaborate on land protection efforts, promote sustainable forestry practices, and organize public outreach and education efforts in order to increase the pace and efficacy of conservation". MassConn deployed CAI in the spring of 2014, and will be using it again in two years to evaluate awareness.

The Watershed Agricultural Council (WAC: http://www.nycwatershed.org/) is a public-private partnership that "works with farm and forest landowners in the New York City Watershed region to protect water quality on behalf of nine million New York residents". The WAC developed a new website targeting private woodland owners, and planned a subsequent outreach effort for them in their watershed. WAC deployed CAI in the spring of 2015 to serve as a baseline of landowner conservation awareness, against which change in awareness could subsequently be estimated.

CAI as a Short-term Education Evaluation Tool

The Massachusetts Keystone Program (https://masskeystone.net/) is an outreach effort aimed at training local community leaders in conservation topics. Participants attend a 3.5-day training session where they learn both in the classroom and field about conservation, ecology, and communications. In return they agree to return to their communities to serve as spokespersons or advocates for conservation. Since 70% of all forest in Massachusetts is owned by private families and individuals, it is important to reach these owners with conservation information. This can often be more effectively done by local peer opinion leaders.

The Keystone Program is competitive, and 25 people are selected annually from an applicant pool of 75-100. This ensures that the volunteers are highly qualified and effective conduits for information. The CAI was used as an educational evaluation tool to estimate conservation awareness of participants before the 3.5-day training, and immediately afterwards. Not surprisingly, it was shown that participants were being selected who had high conservation awareness relative to landowners in general (e.g., mean CAI of Massachusetts landowners ranges between 20.4 and 23.5 (Table 1), vs. 32.1 before training(Table 2)). Importantly, however, conservation awareness was significantly improved by the end of their training (Table 2).

Table 2: CAI before and after Keystone training; 2011, 2012

	Mean CAI	Std error	n
Before training	32.1[a]	1.4	42
After training	39.7[b]	1.2	43

[a, b] Means with different superscripts are different at the 0.000 level. F= 16.931. p=0.000

The Keystone Program selects excellent people, well above average in terms of their conservation awareness, and improves their awareness significantly in 3.5 days.

Discussion

On the basis of 6 different deployments of CAI, and the responses of thousands of private landowners, it appears awareness of their conservation alternatives is quite low. It is also noteworthy that there are significant differences in conservation awareness by state and by communities within a state. In two specific instances, higher conservation awareness at the community level was related to local conservation social capital. It does not matter if the communities are rural or suburban, or heavily forested or developed. Conservation awareness relates more to the extent of conservation social capital.

The Conservation Awareness Index (CAI) is a simple instrument that is easy to deploy, and provides a relatively rapid assessment of landowner awareness of their conservation options. It thus represents a metric by which conservation progress or success can be estimated. Rather than promote the adoption of management plans, and estimating success by the number of plans and acres they represent, the CAI represents a means by which progress can be measured in terms of awareness, knowledge, and experience. Ultimately, when it comes to the promotion and implementation of conservation in landscapes dominated by private ownership, it is the awareness and knowledge of owners that will influence decision making, and not the presence or absence of a management plan, that owners may not even remember that they have. This sentiment was eloquently expressed by Aldo Leopold, who said: "The real substance of conservation lies not in the physical projects of government, but in the mental processes of citizens" (Leopold 1966).

Conclusions and Policy Implications

The conservation of forests is an important global issue due to the ecosystem services and greater social benefits they provide. In regions where most forests are owned by private families and individuals, the decisions they make about their forest will influence the future of the resource, and its capacity to continue producing benefits. A logical goal of forest conservation is that owners will make informed decisions about the future of their forest, based on a full awareness and understanding of their alternatives, instead of reactive decisions based on immediate need rather than a full understanding of alternatives and consequences. It thus seems logical that conservation programs should aspire to increase conservation awareness, knowledge, and informed decision-making, rather than the adoption of practices or the implementation of certain activities. As in any effort, it is important to estimate progress or relative attainment of success, and a rapid assessment tool like CAI provides a simple means to do this.

There are several policy implications associated with a concept like conservation awareness and a tool to assess it like CAI. First, as public or private organizations make decisions about conservation (e.g., where to invest funds to protect forests, where to invest staff and other resources), they would be advised to consider not only the biophysical conditions (e.g., biodiversity, rare species, productive soils, potential resilience to climate change, landscape metrics such as connectivity, large uninterrupted blocks of forest) but also the relative conservation awareness of owners of land. The result of landowner decisions represents a form of ecological disturbance that can influence forest conditions. Having a strong understanding of landowner conservation awareness sheds light on the relative likelihood of various landowner behaviors. Organizations that make conservation decisions without an understanding of landowner conservation awareness are not considering the implications of their collective decisions, cumulative effects, and the future possible trajectory of the landscape.

Another policy implication relates to how conservation is promoted or advanced. At least in the United States, conventional wisdom illustrated by the USDA Forest Service and the National Association of State Foresters is to advance forest conservation through the promotion of management plans and associated management practices through subsidy or outreach. Success is estimated by the number of plans and acres affected. It may be more realistic and effective to shift the emphasis from plans and practices to enhanced conservation awareness and informed decision-making. Instead of landscapes where success is measured by management plans, success would be estimated by significant increases in conservation awareness. The promotion of conservation via conventional means has had negligible success over the decades as most landowners do not find management plans or practices appealing. In spite of decades of subsidy and promotion, conservation awareness is rather poor. Shifting the policy emphasis from plans and acres to explicitly improving conservation awareness, through various means of outreach (e.g., peer networks) may yield more lasting and significant success.

Monitoring landowner conservation awareness with a tool like CAI will also enable outreach programs to be better tailored to address specific, relevant identified areas of low awareness and knowledge. Monitoring will enable spatial targeting of emphasis in certain communities with identified low awareness. Monitoring through a rapid assessment tool like CAI could also enable areas of high conservation awareness to be identified, and enable further exploration of those areas to determine underlying causes. What is it about certain communities that results in high awareness? Can these elements of success be applied in other areas? Finally, a rapid assessment tool like CAI can be used to easily measure conservation progress over time.

Lastly, the concept of a simple, rapid landowner awareness assessment tool is by no means limited to the conservation issues of the northeastern USA. Through relatively inexpensive and simple means of qualitative and quantitative research and development, a conservation awareness index tool could be developed for many different forest circumstances worldwide. To what extent are landowners aware of: markets for NTFPs? Sources of seedlings and planting techniques? Rare species habitats and their protection? Sustainable means to produce firewood? Potential of agroforestry to produce sustainable food and fiber? Efficient access to markets? Elements of effective forest restoration in degraded area? CAI could be developed for other countries and conservation situations. The concept of a rapid human awareness assessment tool has important relevance to guide small scale forestry outreach and policy.

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Clonal Capture of Mature *Tectona grandis* (teak) for Improved Germplasm Deployment in Papua New Guinea (PNG)

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Abstract

Teak (*Tectona grandis*) is a priority species for plantation development in Papua New Guinea (PNG), although expansion of the planted area is constrained by a lack of high quality seed sources. To address this problem, clonal methods were used for capturing selected plus trees within existing plantations (9 candidates) and an existing clonal seed orchard (20 candidates). Truncheon cuttings were collected from the lower branches of each of the 29 candidate trees. Truncheons were cool-stored for 5 days during transportation before being planted in a potting medium that was a mixture of coarse sand and forest soil (at ratio 1:1 by volume) and placed under intermittent mist. Adventitious root development in the truncheons occurred over a period of 5 to 6 months, and successfully rooted truncheons were planted in a hedge garden and used as a further source for cuttings. Subsequent cutting experiments using softwood single-node cuttings evaluated the effects of (i) rooting media (coarse sand vs a mixture of coarse sand and coconut husk) in the non-mist propagators, and in the mist system, coarse sand, fine sand, jiffypot (coco pellets) and a mixture of perlite and coconut husk, (ii) cutting length (6, 8, 10 and 12 cm), and (iii) rooting ability of clones. After 12 weeks a significantly greater rooting percentage was recorded in a mixture of coarse sand and coconut husk (78% ± 3.95se) compared to coarse sand alone (52.3% ± 2.85se) in the non-mist propagators. Rooting percentage variation did not differ significantly across the rooting media in the mist propagation system. However, a greater rooting percentage was attained in jiffypots (85% ± 0.05se) compared to in coarse (64.6% ± 0.07se) and fine sand (65.3% ± 0.06se). For the cutting length experiment, s significantly greater rooting percentage (94% ± 0.04se) was recorded with the cutting length of 10 cm compared with 6 cm (50% ± 0.09se) and 8 cm (53.1% ± 0.09se) cutting lengths. At week 12 after insertion of cuttings in jiffypots, no significant variations in rooting percentages were found among the clones. Low rooting percentages were recorded across all clones. Nevertheless, cutting survival of these clones was significantly higher without producing roots at week 12 after insertion in jiffypots in the mist house. Clones obtained from leafy stem cuttings were successfully acclimatized and would be used in teak clonal seed orchard (CSO) establishment to become a source of high quality germplasm for planting in PNG.

Keywords: clones, genetic materials, clonal seed orchard, cutting, rooting cuttings

Introduction

Tectona grandis (teak) is an exotic commercial timber species introduced into Papua New Guinea (PNG) during the German colonial period between 1890 and 1900s (Howcroft 2005).

It is native to India-Burma, Myanmar, Thailand and Lao (Kaosa-ard 1981), and from the 1850s onwards it has been introduced throughout the tropics (FAO 1957) in regions such as Asia, West Africa, East Africa, Central America, South America (Gartner 1956), and the Pacific Island nations (PNG, Fiji and the Solomon Islands) (Pandey and Brown 2000).

Teak has been subjected to domestication and utilised as a plantation species on both small and large scales, owing to its high value timber (considerably the stem quality being important). The species is amenable to being grown in plantations, but Kjaer & Foster (1996) reported that tree improvement efforts for teak can be hindered by (i) low seed yield per tree, (ii) low germination percentage of seed, (iii) control pollination being difficult, and (iv) a long period of juvenility (i.e. flowering after age 6). To circumvent these issues the PNG Forest Research Institute (PNG-FRI) commenced a clonal program for selection of elite trees identified around the country.

This clonal approach to domestication was undertaken to secure valuable genetic materials within a clonal archive. Branches were harvested from selected trees from three sites and brought to a PNG-FRI nursery and propagated as truncheon cuttings. Successfully propagated truncheons were then established as hedged plants in a clonal archive, which has become the source of vegetative material for further propagation. The bulking of clones by leafy stem cuttings has been carried out for three reasons. Firstly, to address the issue of using seeds from unclassified sources by increasing the number of available improved materials as planting stock. Secondly, the clones produced would be used to establish new teak clonal seed orchards (CSOs) to supply improved seed to tree farmers. And finally, to establish resources to investigate the genotype by site interactions so that selections can be identified for further breeding. Genetic gains through clonal deployment of superior genets or families is well recognised for several plantation species, for example, *Pinus radiata* in New Zealand (Carson et al. 1990) and Australia (Cotterill et al. 1989), and *Pinus elliottii* improved for plantings in South East USA (White et al. 1993).

The technical aspects of vegetative propagation of teak is widely reported in the literature (e.g. Goh and Monteuuis, 1997 and Monteuuis *et al*., 1995). This study uses an adaptive research approach to teak cuttings using locally-available materials. The present paper examines the effect of genotype, propagation media, cutting length and propagation environment in teak leafy stem cuttings. Two experiments are presented, the first combined experiments were rooting media tests using the mist and non-mist propagation systems, and second was cutting length.

Materials and Methods

Source genetic materials

The study site was at the PNG-FRI nursery in Lae, Morobe Province. A total of 29 unrelated parents were sourced from three sources: (1) Oomsis woodlot in Morobe Province, (2) Vunapaladig-Kerevat plantation in East New Britain Province, and (3) Kuriva plantation and CSO, in Central Province. Stems with a diameter of 1.8-2.0cm, a length of 40 to 50cm and with at least 2 dormant buds (truncheons) were collected from each of the selected trees. The ends of the truncheons were sealed with Vaseline immediately after harvest, before being wrapped together with sawdust in hessian bags. The preparation was well watered and packed in empty boxes, and transported over five days to the FRI nursery. During transport many of the dormant buds began to grow.

At the nursery the truncheons were planted into the plastic pots of 28cm width x 21cm length filled with a mixture of coarse sand and forest soil at a ratio of 1:1 by volume. Three truncheons were planted per pot with 10-15cm inserted into the potting medium. Potted truncheons were placed under intermittent mist for 5-6 months. Successfully rooted truncheons were transferred to nursery beds for a two-week sun-hardening and then transplanted in the clonal archive at a spacing of 2 x 2 m. These hedge plants (clones) were pruned regularly to promote multiple juvenile shoots suitable for cutting propagation.

Testing for Propagation Characteristics
Two propagation experiments were conducted with physiologically juvenile shoots harvested as single-node cuttings from the clonal hedge plants.

Experiment 1: 8 clones (4 cuttings per clone randomly assigned to two propagation media) and 2 propagation media (coarse sand and a mixture of coarse sand:coconut husk 1:1v/v) were examined. A total of 32 cuttings were set in a non-mist propagation system.

Experiment 2: 8 clones (4 cuttings per clone randomly assigned in the propagation tray containing one of the rooting media) and 4 propagation media (perlite:coconut husk 1:1v/v, coarse sand, fine sand and jiffypot) were examined. Jiffypot is a commercially prepared medium comprised of compressed cocopeat and was used to compare the performance of locally sourced propagation media. A total of 128 cuttings were set under an intermittent (10 seconds every 10 minutes) misting propagation system.

Experiment 3: 8 clones (4 cuttings per clone of each cutting length was randomly replicated twice in the propagation tray containing jiffypot) set in the misting system. A total 64 cuttings were set under an intermittent misting propagation system for 12 weeks prior to an assessment of rooting traits.

Response variables and data analysis
Cuttings in the three experiments were assessed 12 weeks after setting and the survival and rooted cuttings percentages were recorded. Data collected were collated into an excel spreadsheet, prior to processing using a Pivot Table. The rooting percentages were subjected to two-way analyses of variance (ANOVA) using the SPSS statistical software, version 17.0 (SPSS, 2007).

Results

Experiment 1
A significantly greater percentage of rooted cuttings were found in the coarse sand:coconut husk medium (78% ± 3.95se) compared to coarse sand alone (52.3% ± 2.85se) in non-mist propagators (Fig.1a).

Experiment 2
A significantly greater rooting percentage was attained in jiffypots (85% ± 0.05se) compared with all remaining media treatments. Rooting percentage in coarse (64.6% ± 0.07se) and fine sand (65.3% ± 0.06se) were found to be significantly greater than those set in a mixture of perlite and coconut husk (42%) (Fig.1b).

Experiment 3
Cuttings with a length of 10 cm had a significantly greater rooting percentage (94% ± 0.04se) than cuttings with a length of 6 cm (50% ± 0.09se) and 8 cm (53.1% ± 0.09se) (Fig. 2). Higher cutting mortality was also noted in the 6cm and 8cm cutting length treatments. Cuttings with

a length of 12cm had a rooting percentage (75%) found to be intermediate between, and not significantly different from, all remaining cutting length treatments.

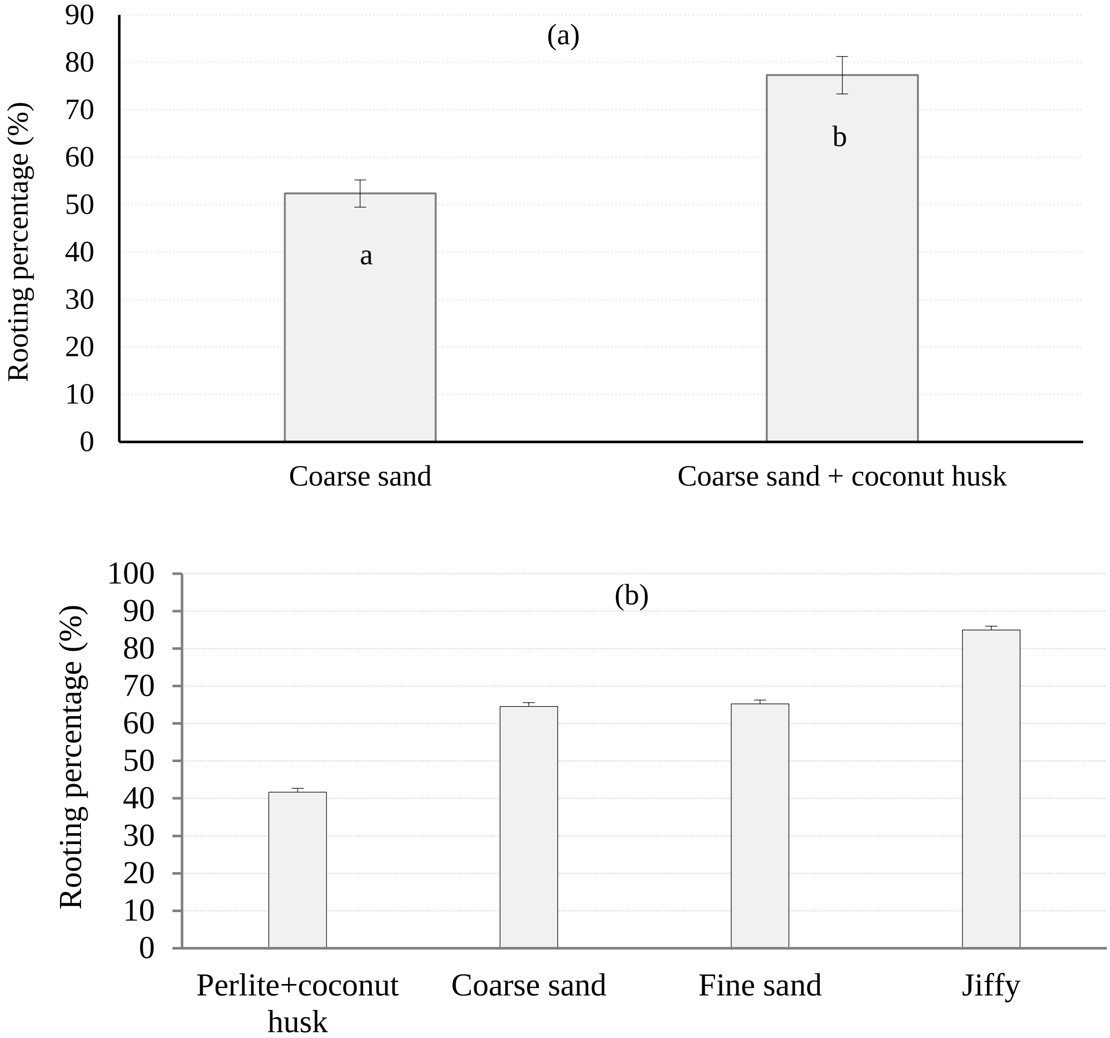

Figure 1. Effects of rooting media on rooting percentage of leafy stem cutting of *T. grandis* in non-mist (a) and (b) mist propagation systems at FRI-Lae, Papua New Guinea.

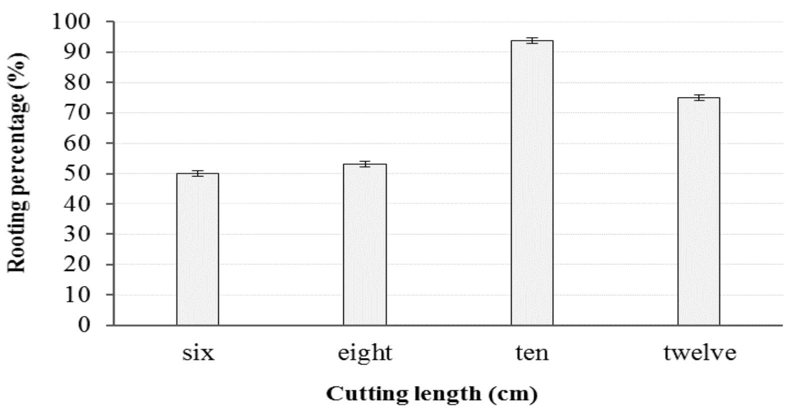

Figure 2. Effect of cutting length on rooting percentage (%) in leafy stem cuttings of *T. grandis* within mist propagation system

At week 12 after insertion of cuttings into jiffypots, significant variation in rooting percentages were shown among the clones (Fig. 3). Low rooting percentages were recorded across all clones, nevertheless, cutting survival of these clones were significantly higher without producing roots at week 12 after insertion in jiffypots in the mist house (Fig. 3).

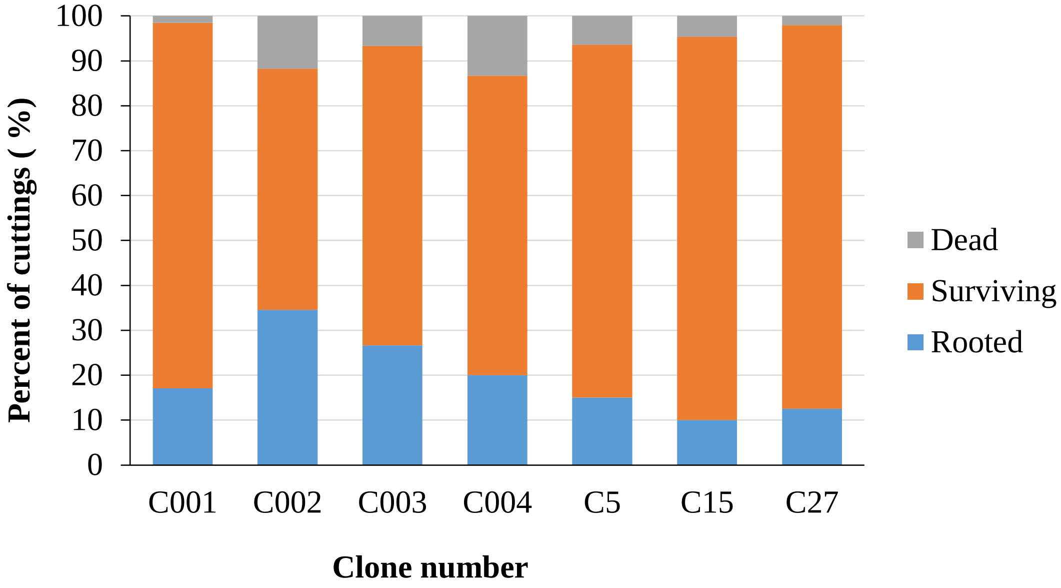

Figure 3. Clonal variation in percentage of rooted, surviving (but not rooted) and dead cuttings for *T. grandis* propagated in misting system after 12 weeks.

Discussion

Tree species differ in their stem cutting response to propagation media (Leakey *et al*. 1990). For example, in *Milicia excelsa* (Ofori *et al*. 1996) and *Irvingia gabonensis* (Shiembo *et al*. 1996), higher rooting percentages were recorded in sawdust than in the other media tested. This result is consistent with results obtained here with *T. grandis*, (i.e. higher rooting percentage (78%) in a mixture of coarse-coconut husk in the non-mist, and jiffypot (85%) in the mist propagation system). It is obvious that these rooting media provide sufficient water to prevent wilting of cuttings as a result of higher rates of water uptake in the cuttings (Loach 1986), consequently higher rooting percentages were attained.

In general, an optimum rooting medium is one with an adequate gas-filled pore space and oxygen diffusion rate sufficient for the needs of respiration (Andersen 1986). However, excess water may limit the diffusion of oxygen and thereby result in anoxia within the cutting base (Loach 1986). While rotting of the cutting base in the jiffypot and the mixture of coarse sand-coconut husk was observed in these experiments, it is clear that coconut husk can have a positive effect on rooting capacity provided it is not mixed with very light/coarse components such as perlite. The high percentage of cuttings surviving but not rooting by week 12 means that the propagation period is likely to be longer than conducted for this experiment. Further work with an extended propagation period is required to determine the true influence of the treatments in this experiment.

A cutting length of 10cm was found to have a higher rooting percentage (94%) compared with all cutting treatments and is recommended for further evaluation of cutting propagation in teak. Similar results were reported in *Triplochiton scleroxylon*, where long cuttings had a greater rooting percentage than short cuttings regardless of their position of origin (Leakey and Mohammed, 1985). In addition, single-node cuttings of *Hedera helix* with a stem length equal to the internode length recorded an increase in root number with increasing stem length (Poulsen and Andersen 1980). However, other factors such as interaction between leaf area and cutting length has to be considered as a cutting's carbohydrate content can influence rooting, as demonstrated in *Eucalyptus grandis* (Hoad and Leakey, 1993). Larger-leaved cuttings do require a greater stem volume for the storage of assimilates, as basal cuttings with a larger diameter had the greatest rooting percentage, demonstrating that cutting stem volume may in fact be more critical than length (Leakey et al. 1993).

One main factor influencing the induction of adventitious roots in cuttings is the clonal variation in rooting ability. In this preliminary study, there was no detailed investigation into this, as genetic effects are the least studied factors that control rooting by cuttings (Haissig and Riemenschneider, 1998). Clonal variation has effects on ramets' large scale multiplication for CSOs or planting programmes. The low rooting percentage recorded across all clones in this study is attributed to the duration of the experiment. It is possible that the assessment time needs to be extended to 16 weeks to allow for surviving cuttings (Fig. 3) to develop adventitious roots. Thus, the clonal variation in rooting ability recorded here was not easily explicable in the rooting percentages among the clones tested.

Conclusions

These results indicate that *T. grandis* is amenable to vegetative propagation using the techniques described. The rooting percentage of over 70% achieved in non-mist propagators using a mixture of coarse sand-coconut husk and over 80% rooting attained in jiffypot in the mist propagation system indicate that multiplication of planting stock (clones) for new teak clonal seed orchard establishment as well as satellite teak clonal establishment in PNG can be attained. The optimum cutting length was 10cm set in either mist or non-mist propagation systems. Propagation by stem cuttings can be an effective means of capturing plus tree clones. However, rooting ability varies between selected individuals, and a proportion may need to be discarded from subsequent clonal production because of propagation difficulties. This simple cutting propagation of teak is helpful in domesticating this species for the benefit of the PNG forest plantation sector.

Policy Implications

The establishment of the teak clonal seed orchard funded by the ACIAR projects in collaboration with the PNG Forest Authority (PNG-FA) will provide improved seed sources (e.g. from established CSO) so that improved seeds will be available for plantation forestry in PNG.

The following recommendations should be considered by the PNG-FA to attain the objectives as stipulated in the Vision 2050, in terms of planted forests expansion. Productive forest plantation with higher return depends on the quality of seed supply, thus PNG-FA should consider:

- Reviewing its policy on encouraging the use of improved seeds from selected plus trees in teak plantations or CSO for plantation development in the country;

- Reducing the proportion of plant materials derived from unimproved sources (e.g. any trees that are accessible to collect seeds or on forest floor);
- Including the introduction of teak genetic material from overseas origin to add genetic diversity to the local materials in the country;
- Providing sufficient resources to increase the number of CSOs not only for this exotic species but also other commercial timber species; and
- Producing and disseminating information on propagating mature teak to clients for woodlot and plantation development.

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The Potential for a Small-Scale Biomass Energy Industry on the Sunshine Coast Based on Locally-Available Waste Wood

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ABSTRACT

Small, community-based biomass energy systems (up to 1MW of thermal or electrical energy capacity) sourcing feedstocks from local waste wood streams are common in many northern hemisphere countries and are increasingly deployed in New Zealand. In both urban and rural settings throughout these countries, many of these woody biomass energy systems are building an excellent track record of efficient and reliable application in businesses, schools, universities, hospitals and a range of other community facilities. These system deployments generate many socioeconomic and environmental sustainability benefits for investors and local communities. In Australia, small-scale biomass energy systems remain a vastly underutilised renewable energy technology. Using multiple data sources, this paper aims to raise awareness and understanding of small-scale biomass energy systems and their potential for application in the Sunshine Coast region of south-east Queensland. The research highlights opportunities and challenges for industry development in this region. There are numerous suitable local business and community facility applications, and supplies of waste wood from local hardwood plantations, woody weed control programs, landfill diversions and arborist and timber processing businesses are potentially available for use as bioenergy fuel. However, integrated supply chains for the economically viable delivery of these feedstocks in suitable forms to local plants require further research and development.

Keywords: small-scale bioenergy systems, eucalypt plantations, resource audit, woody biomass, regional economic development

INTRODUCTION

Throughout the developed world, there is growing interest in using woody biomass for energy. Governments, industry sectors, businesses, and local communities are increasingly realising the many environmental and socioeconomic benefits of applying traditionally waste woody biomass as feedstock for renewable energy. Historically, the direct combustion of roundwood in wood-stoves or furnaces has been the simplest, cheapest and most commonly applied renewable energy option from woody biomass. Significant advancements in wood combustion technology over the past decade (i.e. the development of Advanced Wood Combustion (AWC) systems, as defined in Richter et al. 2009) has stimulated enhanced interest in the potential of this renewable energy option at a range of scales. Policy-makers and investors are showing increasing interest in the potential of small-scale AWC bioenergy systems (BERC, 2010; Valente et al, 2011, Stucley et al 2012). These systems feature high efficiency, low pollutant emissions and automated operation. They can combust woodchips or compressed wood pellets and can be thermal (i.e. heat) energy plants, combined heat and power (i.e. CHP) cogeneration plants or tri-generation (i.e. heating, cooling, power) plants.

CHP and tri-generation plants produce electricity through a Steam Rankine Cycle (SRC) or an Organic Rankine Cycle (ORC) turbine attachment.

'Small-scale' AWC bioenergy systems, as referred to here, are plants of up to 1MW of thermal or electrical energy generating capacity. Compared with substantially larger systems that generate tens to hundreds of MW's of energy for large industry or base-load power stations, small-scale AWC bioenergy systems of less than 1MW have the advantage of being able to be unobtrusively distributed throughout a community. These small plants are also often developed as a form of community-owned infrastructure. For these reasons they are often described as 'community-scale' or 'community-based' bioenergy systems (BERC, 2010; Clarke and Chadwick, 2011; Coote, 2012). These systems, and particularly those of less than 500kW capacity, are now commonly deployed in local communities throughout the United Kingdom, Europe, North America, and in New Zealand. In these settings, small-scale AWC bioenergy systems are widely embraced as a proven sustainable, cost-effective and low-carbon renewable energy option.

Most of the small-scale AWC bioenergy systems deployed overseas are thermal energy plants supplying heat for space or process heating, steam for industrial purposes, and cooling/refrigeration (via the absorption cooling method) for a range of local community applications. Cogeneration CHP plants and newly emerging tri-generation plants are currently less common but are increasingly deployed or being considered as the technology rapidly develops. Existing and potential community-based applications of these small-scale AWC bioenergy systems include residential apartment complexes, municipal buildings and facilities, schools, universities, hospitals and businesses across a range of sectors. Experiences from the successful deployment of these bioenergy systems in overseas settings suggests they have many standout environmental and socioeconomic sustainability benefits for investors, local communities and surrounding regions.

In Australia, recent years have seen a small number of new small-scale AWC bioenergy systems installed or being considered by forward-thinking businesses and local governments for applications including sawmills, greenhouses, hospitals and other community buildings such as sports and aquatic centres. However, despite the high potential evident from overseas experiences and an array of local deployment opportunities, small-scale AWC bioenergy systems remain a vastly underutilised technology in Australia. There is generally minimal awareness and understanding of the technology among politicians and policy-makers, industries that could benefit from the technology, and the broader public who will be a key stakeholder in supporting the industry's development. This low level of awareness and understanding can lead to scepticism and misrepresentation of the small-scale AWC bioenergy industry. Overseas experience suggests this is often based on the relative newness of today's AWC energy technology, and includes concerns about the capital costs of building or converting to an AWC bioenergy system, the sustainability of the required feedstock supplies, and beliefs that burning woody biomass will be cumbersome to operate and dirty or air polluting (BERC, 2010).

Using multiple data sources, this paper aims to raise awareness and understanding of small-scale AWC biomass energy systems and their potential for application in the Sunshine Coast region of south-east Queensland. Characteristics of these distributed renewable energy systems and the opportunities and challenges for the development of a small-scale biomass energy industry on the Sunshine Coast are outlined. Four sources of potentially locally-available waste wood feedstocks are briefly reviewed including discussion of important measures to ensure the feedstocks could be sustainably supplied to local bioenergy plants in a suitable form. Two case studies of successful small-scale AWC bioenergy systems recently installed in community facilities in southern Australia, with potential for replication in the Sunshine Coast region, are then briefly described. Some concluding comments follow. Findings from this research can help inform the decision-making of policy-makers and forestry and bioenergy industry investors on the Sunshine Coast.

RESEARCH METHOD

Multiple data sources were used for this research. These included literature review, media analysis (i.e. review of on-line news and reports accessed via regular bioenergy industry e-bulletins) and personal communication with a range of bioenergy industry stakeholders. Interviews and informal discussions were held with bioenergy system investors, installers, project managers and operators, plus local forestry and natural resource management professionals, Local and State Government staff, and managers of local arborist and timber processing businesses. Site-visits to observe bioenergy system operations and waste wood supplies at businesses in the Gympie region adjacent to the Sunshine Coast were also undertaken. An audit of the Sunshine Coast's hardwood plantation resource involved personal communication with local farm forestry practitioners, analysis of existing plantation databases and targeted plantation inventories.

RESULTS AND DISCUSSION

Key Questions About Small-Scale AWC Bioenergy Systems

Key questions about the characteristic features and benefits of small-scale AWC bioenergy systems were identified and factual responses determined. The responses are based on the current state of the technology and the operational experiences of investors, project managers and operators of installed systems.

Are small-scale AWC bioenergy systems a viable investment?

Small-scale AWC bioenergy systems require a substantial up-front capital expenditure and also incur on-going operating and maintenance costs. Initial investments vary widely depending upon the size and type of the adopted unit, and local availability. Costs are reported to range from a few thousand dollars for an efficient residential pellet heater to tens - hundreds of thousands of dollars and upwards for larger thermal or CHP systems (i.e. 75kW – 1MW+) supplying renewable energy to small-large buildings, campuses or communities (for examples see McCallum, 1997; Prest and Simpson, 2009; Coote, 2012a; Stucley et al. 2012; WSFWAS, 2008). Other factors influencing the system's installation and operating costs include whether it is for a new building construction or a retro-fit, the type of biomass feedstock required, and the need for associated feedstock storage and handling infrastructure. Although these costs mean small-scale AWC bioenergy systems will be more expensive to install than fossil-fuel systems, their running costs are proving to be cheaper over the long-term.

The costs of fossil-fuel derived energy has increased rapidly over recent years and this trend is anticipated to continue. In comparison, the cost of woody biomass feedstocks are expected to remain relatively stable and much lower than fossil-fuels into the future. Small-scale AWC bioenergy systems are therefore proving to be viable, cost-effective investments that offer long-term energy cost savings and relatively short payback periods. Although dependent upon the initial investment, the payback period is typically reported as no more and often better than 7 - 10 years. In many cases, government grants or incentives for renewable energy investments have helped to shorten payback periods and increase the attractiveness of investment.

Are small-scale AWC bioenergy systems difficult to install and operate?
Small-scale AWC bioenergy systems are considered relatively simple to install and operate, although complexity varies across differing sites and system types and sizes. Specialist technicians are required to appraise a site's suitability to small-scale bioenergy, and if deemed viable, design and install an appropriately matched system. Specialist technicians are also recommended to undertake scheduled servicing of installed systems. With expert assistance, problem-free installations, including plumbing and electricity grid connections, are commonly achieved in both new building constructions and existing facilities. The 'modular' and 'distributive' capability of small-scale AWC systems means they can be containerised and relatively simply and unobtrusively 'dropped-in' to existing facilities. This means they can also be easily relocated if needed. Investors must also consider the space requirements for feedstock storage and handling and how this differs between semi-automated and fully-automated systems. Semi-automated systems will require on-site machinery or manual labour for regular feeding of bulk fuel bins and occasional ash cleaning whereas fully-automated systems include self-feeding mechanisms and automatic ash removal.

Regardless of the level of automation, small-scale AWC bioenergy systems are largely hands-off operations. Staff members will require training to have a basic understanding of the plant and its operation, and to identify any potential problems. Some more complex system functions do require closer monitoring and modern systems are typically mobile phone or web linked to automatically notify staff and maintenance contractors of any problems associated with these functions. In Australia, although small-scale AWC bioenergy systems technology is relatively new and operational experience is therefore limited, a substantial and growing resource of overseas technology and experience is increasingly available to local investors. For example, there are many well-known, high quality and reputable system manufacturers and suppliers in European countries such as Austria that have successfully installed thousands of thermal energy units. Other highly experienced operators also exist in the United States and increasingly in New Zealand. Some long-standing overseas-based bioenergy companies now have local agents available to support local investors. These companies can design and install imported turn-key small-scale bioenergy solutions customised to any suitable local business' needs and site characteristics.

Are small-scale AWC bioenergy systems efficient and reliable?
Compared to older wood stoves and boilers, modern small-scale AWC bioenergy systems are highly sophisticated, reliable and efficient. Thermal energy plants typically have efficiency levels of 80-90% which is comparable with the best fossil fuel boilers. For CHP plants that use the generated high-quality heat for electricity production, the key to achieving similarly high levels of efficiency (and system cost-effectiveness) is the capture and use of the by-product low-quality heat in applications such as space or water heating. Small-scale AWC bioenergy systems are also most efficient and reliable when running continuously (aside from scheduled maintenance interruptions) and when the feedstocks consistently match the system's specifications. Different types and sizes of AWC bioenergy systems have differing feedstock specifications and tolerances, although increasingly, systems can be designed to handle and tolerate a more flexible range of feedstocks. This is particularly the case with larger systems (i.e. larger than 1MW), whereas systems of less than 500kW capacity typically require stricter adherence to feedstock specifications. These small-scale systems operate most efficiently and problem-free when woody biomass feedstocks are consistently clean (i.e.

uncontaminated) and dry (i.e. 20-30% moisture content) with a particle size of around 40mm diameter. Woodchip feedstocks present system operators with the greatest challenges for ensuring this consistency. Supply contracts therefore require strict parameters for feedstock consistency, and deliveries require close monitoring to ensure agreed-to standards are met.

Dry and consistently sized woody biomass feedstocks greatly enhance combustion efficiency. This is because the particles will have a consistent burn rate and a greater proportion of the energy from burning the wood goes into useful heat, rather than converting moisture in the wood to steam. Consistent particle size is best achieved with a drum chipper and is important for reducing the presence of sticks and other oversized pieces that can cause clogging or jamming problems for a system's in-feed mechanism. Too many fines can also cause efficiency problems and potential health hazards for workers. Clean materials are also highly important because foreign objects such as soil, rocks, metals and plastics will damage equipment and cause operating problems and unnecessary breakdowns. Despite the high reliability of small-scale AWC bioenergy systems when operated to manufacturers' specifications, it is prudent and common practice for investors to have fossil-fuel energy systems in place to cover peak loads and as back-ups for when the bioenergy systems are off-line for maintenance.

Will small-scale AWC bioenergy systems be a source of carbon and other pollutant emissions?

Modern small-scale AWC bioenergy systems are recognised as a low-polluting renewable energy technology. When operated to manufacturers' specifications, these systems produce no visible emissions or odours and emit far less particulate matter than older-technology wood-stoves and boilers or the combustion of fossil fuels. This is due to their controlled and sophisticated combustion chambers that burn wood cleanly and completely. They also typically contain state-of-the-art flue-vent emissions reduction equipment that captures the majority of particulate and other gaseous emissions. Minimising the carbon and other pollutant emissions from small-scale AWC bioenergy systems is however dependent upon an efficiently operating system, which again highlights the importance of consistently sized, clean and dry feedstocks. Dry waste wood feedstocks of a consistent particle size will be completely combusted and generate insignificant levels of carbon dioxide and other pollutant gas (e.g. oxides of nitrogen and sulphur, methane) or particulate emissions when compared to the traditional disposal of waste wood in landfill, burning in open fires, or being left to rot on the forest floor. Importantly, feedstocks should also be free of chemically treated or painted waste wood and timbers containing other contaminants such as plastics to avoid toxic emissions that may pose community health hazards and drive community opposition to bioenergy installations. As a rule, all emissions from an AWC bioenergy system should be closely monitored and controlled to comply with local regulations.

Although the combustion of waste wood in small-scale AWC systems generates some carbon emissions, it is generally accepted as a 'closed-cycle' carbon neutral process (for example see BERC, 2010; WBA, 2012). That is, the carbon dioxide released is already a part of the continuously recycling natural carbon cycle that exists between forests and the atmosphere. In comparison, the carbon dioxide released through the combustion of fossil fuels (i.e. coal, oil, gas) has been geologically sequestered for tens of thousands or millions of years and becomes a new addition to the carbon cycle. Even when the carbon emissions resulting from operations including the harvesting, transport and processing of feedstocks, and the construction and commissioning of new AWC bioenergy systems are accounted for, the use of waste woody biomass for energy is recognised as a 'carbon lean' process, with the net effect being very little new carbon dioxide is added to the atmosphere. Significant reductions in overall carbon emissions are achievable when compared to burning the fossil fuels required to generate an equivalent amount of energy. For example, the combustion of wood fuels emits 25g of CO_2/kWh, whereas gas emits 194g/kWh, oil 265g/kWh and coal 291g/kWh (WFSWAS, 2008).

Can the woody biomass feedstocks required for small-scale AWC bioenergy systems be sustainably supplied?

Small-scale AWC bioenergy systems require comparatively small quantities of woody biomass feedstock. As a general rule, small-scale plants require between 100-200t/annum of dry clean wood for every 100kW of energy capacity. The viability of a small-scale AWC bioenergy system depends upon its required feedstocks being available on demand, and both economically and environmentally sustainable. Economic sustainability means the feedstocks must be reliably-available low- or no-cost materials that are unsuited to a higher-value use and available within short transport distances. Timber processing businesses (particularly sawmills) that generate a waste wood product and have high on-site heat and power demands are therefore ideal sites for small-scale AWC installations and there are many examples of these sustainable bioenergy applications across the world. Timber processing businesses are also often a supplier of sustainable feedstocks to other local bioenergy installations. Other sources of potentially suitable low-value waste wood that are typically available in adequate quantities in local communities include municipal landfills, the construction and arborist industries, and rural land management including forestry operations. Provided supply chain costs are acceptable, applying the waste wood from these sources to bioenergy in small-scale AWC systems is a preferable and more environmentally sustainable use when compared to traditional disposal methods.

Where new wood for bioenergy projects are proposed, a common fear among local communities is that the new market for wood will lead to increased forest clearing and other unsustainable harvesting practices. Ensuring the environmental sustainability of forestry-sourced feedstocks requires close monitoring by local authorities and the enforcement of best-practice management that does not degrade forest health and productivity. Such sustainable forest management will utilise thinnings (i.e. small-diameter trees) and other harvest residues (i.e. low grade or defective logs, undersized tops, large branches) for bioenergy while retaining adequate levels of nutrient-dense leaf, twig and bark on-site to avoid long-term soil nutrient depletions and reductions in soil moisture-retention capacity (Stucley et al. 2012; Berger et al. 2013). System operators will need to assure local communities of the sustainability of their forestry-sourced feedstocks as a means of gaining and maintaining a social licence to operate. Supply chain issues can also impact this social sustainability of bioenergy installations. An advantage of small-scale AWC plants is that their comparatively small feedstock requirements can equate to short and non-intrusive supply chains (i.e. small numbers of truck movements) and this can greatly assist with community support.

What are the environmental and socioeconomic sustainability benefits of small-scale AWC bioenergy system installations?

A bioenergy industry based on distributed small-scale AWC systems can deliver substantial environmental and socioeconomic benefits for local communities and surrounding regions. System deployments create new markets for woody biomass that can help to reduce local waste streams and relieve growing pressures on limited landfill space and associated local government and community costs. Using waste woody biomass in small-scale AWC bioenergy systems can help to reduce the consumption of fossil fuels and contribute to national-level greenhouse gas mitigation and renewable energy targets. This can also help to reduce other pollutant emissions that can be harmful to human health, resulting in cleaner air and a healthier environment for local communities.

Small-scale AWC bioenergy system installations can help to reduce business operating costs, and support local and regional energy resilience and economic diversification. Using locally-sourced waste wood in small-scale community-based bioenergy systems has great potential to develop local jobs and economies and a level of energy independence and security. Sustainable bioenergy can be created and paid for locally as opposed to importing fossil fuel-derived energy and exporting local energy money to regions afar.

Small-scale AWC bioenergy system deployments can also provide opportunities for the improved management and utilisation of rural land in areas like local woody weed management and forestry operations. New bioenergy markets for local forestry thinnings and other harvest residues can be created, enhancing the viability of forestry investments and potentially stimulating new investment in local forestry. The increased utilisation of forestry thinnings and other harvest residues can have long-term forest health and productivity benefits including enhanced growth rates and biodiversity values, and substantially reduced bushfire hazards.

Opportunities and Challenges For a Small-Scale Biomass Energy Industry on the Sunshine Coast

Despite the Sunshine Coast's mild sub-tropical climate – in contrast to the cool temperate climes of most of the overseas countries where small-scale AWC bioenergy systems are widely deployed – opportunities still exist for local system deployments for business, institutional and community applications. Potential applications include space or process heating, hot water and steam, cooling/refrigeration, or combined heating, cooling and power generation for facilities within the agriculture, manufacturing, health, education, recreation, tourism and hospitality industries. The region also appears to have a range of waste woody biomass resources available that are potentially suitable as feedstocks for local small-scale AWC bioenergy systems. However, challenges remain in terms of developing efficient and cost-effective supply chains for these locally-available feedstocks.

Importantly, the Sunshine Coast also has an established local government policy setting that appears supportive of a small-scale biomass energy industry. Using the region's waste wood resources in small-scale bioenergy applications is a potential match to the Sunshine Coast Council's sustainability and economic development agendas. A small-scale biomass energy industry on the Sunshine Coast would help to achieve many of the environmental sustainability objectives and desired outcomes of the Council's Corporate Plan 2009-2014, Waste Minimisation Strategy 2009-2014, Energy Transition Plan 2010-2020, and Climate Change and Peak Oil Strategy 2010-2020. Small-scale AWC bioenergy systems deployed throughout the Sunshine Coast could be one component of a desired diversified mix of local decentralised renewable energy technologies in the region, reducing reliance on large-scale centralised sources of fossil fuel-derived energy and assisting the Council achieve its goal of zero timber waste in the region's landfills. This would help to reduce greenhouse gas emissions and contribute towards the Council's goal of being a carbon neutral organisation.

Small-scale AWC bioenergy systems deployed throughout the Sunshine Coast would also help to achieve the underpinning vision of the Council's Regional Economic Development Strategy 2013-2033 - encouraging and developing new high-value industries based on clean and innovative technologies. Investments in local small-scale biomass energy systems would help to generate new employment opportunities associated with these system's installation, operation (including feedstock supply chains) and maintenance. In sum, the development of a small-scale biomass energy industry on the Sunshine Coast could help the Council respond to the region's sustainability challenges and opportunities relating to waste minimisation, local energy transition, climate change, and regional economic development. The creation of a new renewable energy market for the region's waste wood can foster the type of environmental, energy resilience and socioeconomic development benefits for local communities and the region that are sought after by the Sunshine Coast Council.

Locally-available feedstocks

Hardwood Plantations

A recent study has provided analysis of the Sunshine Coast's hardwood plantation estate and its potential to supply woody biomass to local small-scale AWC bioenergy plants (see Meadows et al. 2014). The region's 1,120ha of private farm forestry (~600ha), HQPlantations-owned (~310) and Joint Venture (~210ha) hardwood plantations are predominantly small-scale (<20ha) Gympie Messmate (*Eucalypts cloeziana*) monocultures. The vast majority of these plantations are now aged between 12-18-years. The management of the HQPlantations-owned and Joint Venture plantings has involved early pre-commercial thinning to waste and no further harvests are planned until these plantations reach clearfall age (~25-years) (Last, 2013). In contrast, most of the private farm forestry plantings appear to have had minimal or no thinning. This is often because there is a lack of local markets for small-diameter hardwood logs and many landholders are reluctant to thin to waste. These farm forestry plantations require thinning to maintain and enhance their long-term health and productivity.

The previous research by Meadows et al. (2014) has used the plantation age-class and corresponding area, productivity and management history findings and informed harvest-related assumptions to underpin a 20-year forecast of biomass yields from a harvest schedule suggested for the region's hardwood plantation estate. The forecast biomass yields are underbark stem-wood quantities assumed to be un-merchantable for higher-value solid-wood products. The forecast of potentially available woody biomass in GMt is provided in Figure 1. The forecast shows there is an opportunity for reasonable yields (~9,000GMt) from the immediate needed thinning of private farm forestry plantations. Minimal yields are then predicted to be available until a substantial spike in around 10-15-years when most of the region's hardwood plantations reach maturity and are available for clearfall harvest. Future thinning (at age 12-years) and clearfall harvests (at age 25-years) are expected to provide minimum woody biomass yields of 30-40 and 100-120GMt/ha respectively. Closer to 200GMt/ha may be available from clearfall harvests of poorly-managed farm forestry plantations.

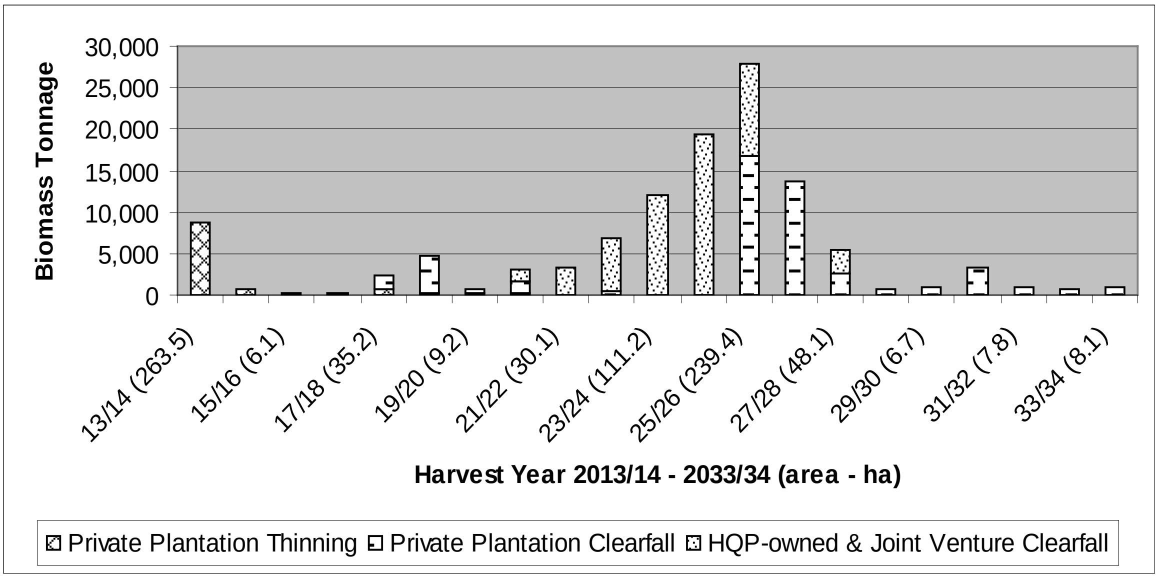

Figure 1. Potential biomass for energy yields (GMt) from future harvesting of the Sunshine Coast's hardwood plantations. Source: Meadows et al. (2014)

Hardwood plantation harvesting and supply chains are pioneering processes on the Sunshine Coast, particularly for the region's farm forestry plantations (Meadows et al. 2014). Further research is therefore required to understand better the likely product mixes and available volumes of biomass for energy from the region's hardwood plantations, and to test for efficient biomass harvest and supply chain systems for the sizes and terrains that are characteristic of these plantations. Suitable systems could be adapted from the knowledge and experience developed in both pine and hardwood plantations located elsewhere in Australia (see Ghaffariyan et al. 2011; Walsh et al. 2011) and throughout Europe (see Karha et al. 2005; Laitila, 2008; Ghaffariyan, 2010; Valente et al. 2011; Magagnotti et al. 2011, 2012). An integrated harvest with higher-value products and short transport distances are keys to the efficient and economic utilisation of woody biomass for energy. As noted above, it is also critical that a sufficient proportion of the harvested forest's most nutrient-dense materials are recycled on-site to maintain soil health and site productivity for successive rotations. Different sites can require differing levels of retention, but overall, a balance in biomass retention is needed and this balance should be underpinned by scientific analysis and managed appropriately.

Woody Weed Control Programs

A number of environmentally-significant exotic woody weeds occur on large areas of public and private land throughout the Sunshine Coast. These include Privet (*Ligustrum spp.*), Chinese Elm (*Ulmus parviflora*), Chinese Celtis (*Celtis sinensis*), Broad-leaved Pepper Tree (*Schinus terebinthifolius*) and Camphor Laurel (*Cinnamomum camphora*). The Class 3 declared pest plant Camphor Laurel (State of QLD, 2011) is one of the region's most prolific environmental weeds and arguably offers the most potential as a local bioenergy feedstock. State-level mapping has identified a widespread occurrence of Camphor Laurel infestations throughout the Sunshine Coast (QLD Government, 2009). It occurs as large single trees or clumps in paddocks and public spaces in both urban and rural settings, dense roadside corridors and near-monoculture infestations of riparian zones, gullies and hillsides (see Figures 2 and 3). Particularly severe infestations are known to exist in the Noosa hinterland and the headwaters of the Maroochy River system (Burrows, 2013). To better understand the extent and densities of the region's Camphor Laurel infestations, an investigation into methodologies for producing finer-scale, local-level mapping is underway, with an initial focus on producing detailed maps for the Nambour and Buderim districts (Fitzpatrick, 2014).


Figure 2 (left). A large schoolyard Camphor Laurel tree at the Old Mooloolah School, Mooloolah (**Source:** Fitzpatrick, Spatial 3i Pty Ltd, 2005)**. Figure 3 (right). A Camphor Laurel riparian infestation in the North Maroochy River region – the light green trees snaking across the landscape at left are Camphor Laurel** (**Source:** SEQCatchments, 2011)**.**

Small areas of Camphor Laurel are currently harvested and the merchantable timber processed locally at small sawmills such as the Cooroy-based Sunshine Coast Camphor Laurel Timber Initiative Inc.[6]. There appears much potential for the current levels of harvesting to be increased and for the residues unsuited to high-value sawn or wood-turned products to be directed to local bioenergy applications. Previous research undertaken in dense wild and planted Camphor Laurel stands in India (Sing and Negi, 1997 cited in Stubbs et al., 1999) and Japan (Satoo, 1968 cited in Stubbs et al., 1999), and in infestations in northern New South Wales (Stubbs et al., 1999) suggest between 200-400 GMT/ha of standing above-ground biomass are likely to be harvestable from the type of dense infestations commonly found throughout the Sunshine Coast hinterland. However, local fieldwork is required to verify these estimates and such fieldwork could be incorporated into the ground-truthing work required for the current local-level mapping project.

A program for the widespread removal of Camphor Laurel from the Sunshine Coast's rural landscape should be encouraged for the many environmental and biodiversity-related benefits this could provide. Importantly, this includes providing opportunities for new ecosystem restoration and farm forestry plantings. The weed tree's removal must, however, also be carefully managed. The species commonly infests steep and otherwise sensitive riparian sites and its prolific nature means it does currently provide some important habitat resources for some local wildlife, while also arguably helping to facilitate some natural regeneration of local rainforest communities. Where necessary, staged removals and the on-site retention of a proportion of woody biomass as logs or standing dead trees for erosion control and fine and coarse woody debris habitat and soil health functions should be considered.

[6] The Sunshine Coast Camphor Laurel Timber Initiative (SCCLTI) is a community-operated sawmill established in 2006. The organisation currently saws around 300t/annum of Camphor Laurel logs sourced from public and Council lands and some private properties, and has a strong interest and capacity to increase this throughput (Ryan, 2013). Large high-quality logs are utilised and all other harvest residues (which often comprise the majority of the tree) are currently left on-site whole or chipped and spread as mulch, but the organisation is interested in utilising this material and the mill's processing residues for bioenergy (Ryan, 2013).

Landfill Diversions

The Sunshine Coast Council's waste transfer stations currently receive around 10,000tonnes/annum of miscellaneous wood waste from public depositors. This wood waste consists of used milled timbers, timber composites and manufactured timber products. Until around five years ago, these waste materials were disposed of in landfill with all other general waste. Council now has a goal of diverting this waste wood stream to alternative, better uses and has begun a process of improved product segregation and stockpiling. Additionally, the Council recently (June 2014) commissioned a study to investigate the physical and chemical characteristics of the waste wood resource and its potential for more effective use in a range of applications including bioenergy (see Eales and Clark, 2014). Depositors of waste wood are now required to segregate CCA-treated and laminated timbers from other general wood waste. From this general waste wood mix, some high quality wood and timbers and processed products are recovered for reuse and sale through the 'Tip Shop'. The remaining materials comprise the current waste wood resource that has potential application for both bioenergy and soil enhancement. The other processing currently performed on this material, primarily to reduce its bulk for stockpiling, is course mulching/shredding using a large contracted timber grinder. This process results in a product of approximately 90% sub 50mm particle size.

A summary of the wood waste's post-shredding physical characteristics is provided in Table 1, and an image of the pre- and post-shredded materials is displayed in Figure 4.

Table 1. Summary of SCC Wood Waste Physical Characteristics

Composition	**Post-Shredding Materials**
Natural timber	42.8%
Treated timber	0%
Clean manufactured boards/products	24.8%
Laminated manufactured boards/products	8.5%
Contamination	3.6%
Material <6mm	20.3%
Density	
Gross density	0.38kg/l
Apparent bulk density (at field moisture)	0.98kg/l
Apparent bulk density (37.7% moisture content)	0.61kg/l
Grading	
>50mm	9%
<50mm >25mm	39%
<25mm >12mm	13%
<12mm >6mm	17%
<6mm	20%

Source: Eales and Clarke (2014, p.7).

The physical analysis indicates the shredded product comprises a wide range of materials and particle sizes, both of which may pose problems for use of the product in small-scale AWC bioenergy systems. The compositional analysis was restricted to particles greater than 6mm. Contaminants identified or considered likely to be found within the product include rocks/stones, sand/dirt, plastics, glass, affixed laminates, nails, screws, metal connectors and other ferrous products, textiles, cardboard and some chemically treated materials. Limited chemical analyses of the product have also been undertaken. The product's ash content at 550 degrees Celsius was found to be 14.3% and the composition of major and minor elements within the ash have been reported (for results, see Eales and Clarke, 2013). Council notes the product's moisture content is generally relatively dry, with most components being of aged timbers (Emmerson, 2014). Scientific analysis of the moisture content along with the product's total C, H, N, S and Cl proportions, and calorific value, is required.

Figure 4. Pre- and post-shredded wood waste at the Sunshine Coast Council's Caloundra Waste Transfer Station. Source: Emmerson (Sunshine Coast Council), 2014.

The post-consumer, self-haul presentation nature of the Council's waste wood product makes it difficult to ensure consistency in material quality. Physical and chemical contaminants exist in the processed product due mainly to fixtures and fittings attached to old furniture (Emmerson, 2014). In response to the findings of Eales and Clark (2014), Council has implemented new product segregation requirements for depositors. Some additional segregation measures are also being employed by Council staff. These new measures are primarily to remove chemically-treated and laminated timbers from the waste wood stream together with any furniture with cloth coverings or metal frames. This will improve the potential for both a future bioenergy application and its interim application for soil enhancement (Emmerson, 2014). This is a critical step for ensuring the materials can be safely combusted in bioenergy plants at a range of scales. It is also critical for gaining and retaining public acceptance of waste wood combustion in bioenergy systems. Despite this, further segregation, grading and processing methods will be required to match the material to the feedstock requirements of any future local small-scale AWC bioenergy systems. Enhanced product screening and the use of magnet technologies to remove ferrous and other contaminants, and different chipping machinery and undercover storage to improve particle size and moisture content consistency are likely required.

Arborist and Other Timber Processing Industries

The Sunshine Coast's waste transfer stations currently receive at least 5,500 green metric tonnes (GMt) per year of clean woodchip materials that are delivered by Council's roadside vegetation maintenance contractor or other arborists (Straker, 2013). This material has been excess to the Council's mulching needs and may be a suitable bioenergy feedstock. Other arborists on the Sunshine Coast also generate substantial volumes of potentially suitable woodchips. For example, the region's largest contractor (Eastern Tree Services) that undertakes an annual powerline maintenance program for Energex generates on average 9,500GMt/annum of woodchip (ETS, 2013). These materials are currently provided as garden mulch to willing landholders located near the day's worksite. There is both internal company and external interest in using this material for renewable energy (Wedel, 2013).

A small number of other large arborist contractors and many smaller arborist companies also operate on the coast. The Tree Felling and Tree Surgery sections of the Classified Index within the Sunshine Coast's 2013 Phone Directory lists 88 local arborist businesses (Local Directories, 2013). Other sources suggest there may be 'hundreds of small and micro-scale operators' who mostly dispose of chipped materials for use as garden mulch, or by any other legal means to avoid landfill fees (Cherry, 2013; Wedel, 2013). The region's arborist industry evidently produces a source of woody biomass that could be better-used for bioenergy, however, amended field practices will be required to segregate suitable logs and large branches from the leaves, twigs and other potential organic contaminants commonly contained within bulk 'chipped green waste'. Segregated materials would need to be separately transported to storage facilities for drying and subsequent chipping and delivery to a local bioenergy plant.

Timber processing businesses on the Sunshine Coast also generate waste wood that is potentially suitable as bioenergy feedstocks. These businesses include a range of small-medium enterprises across the sawmilling, woodturning, timber supply and manufacturing (i.e. floors, blinds, doors, furniture, roof trusses and frames) sectors. The Classified Index within the Sunshine Coast's 2013 Phone Directory lists more than 250 timber-using businesses under these categories (Local Directories, 2013). There has been no detailed regional analysis of the amount of wood waste generated by these businesses and where these materials end up (Breust, 2013). However, discussions with the owner of one of the region's larger timber manufacturing businesses has provided some insights (Petrie, 2013). This business produces around 1,500m3/annum of dry (8-12% moisture content) used pallets and miscellaneous timber off-cuts and shavings. Disposal currently costs the business up to $150,000/annum. Around 60m3/fortnight is collected and processed at a local shredding facility before being delivered to a bioenergy plant in Rockhampton.

Further research is required to accurately quantify and characterise the waste wood resource that could be supplied for local bioenergy from the region's arborist and timber processing businesses. Further work is also required to gauge these business operators' interest and willingness to participate in a local bioenergy industry, and to determine the most viable supply chain systems required for the processing and delivery of suitable feedstocks to local small-scale AWC bioenergy plants.

Case studies of small-scale AWC bioenergy system installations in southern Australia

Mount Gambier Aquatic Centre Biomass Boiler, South Australia

The Mt Gambier Aquatic Centre is an outdoor community pool facility that was constructed by the Mt Gambier City Council in the 1980s. The Centre is open 7 days/week for 6-months of the year (Oct-March) and includes three pools (totalling 1.38ML), two of which are heated to between 27-32 degrees Celsius. These pools have always been heated by a biomass boiler, with the Mt Gambier City Council being the first local government in Australia to implement such heating methods. However, after 30-years of service the original boiler had become unreliable and difficult to operate and needed replacing. Various replacement options for the Centre's heating needs were thoroughly investigated in a triple bottom-line assessment and the standout winner was a new biomass boiler.

The new boiler was installed in September 2013 and is a 650kW Binder AWC thermal energy system that was manufactured in Austria. This sophisticated unit is highly responsive to changes in heat demand (which are influenced by the weather) and features remote monitoring and operation, and an automatic ash removal mechanism that significantly reduces maintenance costs compared to the older system. The $360,000 unit (an additional $40,000 was spent on upgrades to the in-feed system) has been designed to run on dry feedstocks, with the ideal moisture content being 20-30%. By tapping into the local plantation forestry industry's existing supply chains feeding local mills, a reliable long-term supply of dry pine (*Pinus radiata*) woodchip has been secured. Up to 10m3 of woodchips are used per day and it is anticipated the system will require approximately 2,150m3 (550 tonnes) of chips over the six-months that the pool is open each year. The chips are purchased for $40/t (delivered to the nearby Council depot), and although more expensive than the fresh sawdust that was previously used in the old boiler, the chips have a higher energy content and provide numerous operational advantages compared to a wet fuel including better turn-down, easier ignition and less tars produced upon cool-down.

Chipped waste logs and branches (segregated and dried for 6-12 months) sourced from the Council's Waste Transfer Station have also been trialled and have proven to be a good fuel. However, in contrast to the pine chips, this fuel source was not screened and the many oversized pieces caused substantial jamming problems in the in-feed system.

Despite some minor teething problems with installing the replacement system and the change of fuel from sawdust to woodchips, the new boiler has functioned well and is meeting expectations. Its use will save approximately 58 tonnes of greenhouse gas emissions per year and because of its high efficiency and the low moisture content of the fuel, no smoke and negligible particulate emissions are produced. The system's anticipated payback period of 4-years is on-track, and this may be even shorter if natural gas prices (the most likely alternative heating source was a straight gas boiler) do increase significantly in the next few years as predicted. In recognition of its innovativeness and environmental sustainability merits, the Aquatic Centre's new biomass boiler was awarded the 2014 South Australian Aquatic Innovation Award.

Beaufort Hospital Biomass Heating System, Victoria

The Beaufort Hospital in the Pyrenees Shire local government area of western Victoria installed a biomass-fuelled heating system in February 2013. The project arose out of the Victorian Central Highlands Agribusiness Forum's (CHAF) active interest and investigation into the potential for local bioenergy applications. CHAF identified the Beaufort Hospital as a suitable site for a needed biomass heating demonstration project because the hospital had an ageing and inefficient gas boiler system that needed replacing. The installation was not undertaken on a commercial basis and required state government funding to support it because the knowledge and technology for the bioenergy installation was not readily available. The idea behind the funding was that once a demonstration biomass boiler was developed, it would help to raise awareness of the energy source and enable easier replication without the pioneering expenses incurred at Beaufort.

The new boiler is a containerised 110kW Hargassner AWC thermal energy system that replaces two 150kW condensing gas boilers. The system is housed within a 12m shipping container that includes a fuel store and filling system, and is web-linked to automatically notify staff and maintenance contractors of any operating problems. Operating the fuel store filling system requires the attendance of a hospital staff member. The unit cost approximately $208,000 to supply and install, with an additional $230,000 incurred for other installation and infrastructure costs including project management, construction of the boiler house, and the fuel handling and feeding system. The system runs on dry (i.e. 20-30% MC) hardwood woodchips with a reliable supply having been secured through an agreement with a local (i.e. 10km distant) sawmill. The sawmill will supply the system's required 300m3 (100-120t) of woodchips per year (derived from mill residues) and the agreement includes specific chip quality criteria to ensure they are clean, within the required moisture content range and are stored separately undercover. The woodchips are proving to be of a very high quality and are purchased for $110/tonne delivered. Various boiler maintenance tasks are required but these are minimal, and are undertaken every 6-months at a cost of around $4,500 per year.

The biomass boiler has taken over most of the hospital's heating load, with an LPG system only operating as a back-up for boiler maintenance and to cover peak loads. Initial estimates predicted use of the system will reduce the hospital's LPG expenditure by around $55,000 per year and deliver a financial benefit of around $35,000 per year through reduced energy (heating) costs. In addition, the system will reduce the hospital's greenhouse gas emissions by around 140t per year. The payback period for the installation is expected to be 12-years based on 2013 LPG prices and this does not include the system's other co-benefits such as fuel security and hospital reputation. While the installed cost of this boiler was expensive, the project manager contends that other institutions or organisations installing a similar plant could now do so for a considerably lower amount. To date, the system has performed exceptionally well, and the 'demonstration' outcome of this project has been important for providing a 'blue-print' for the method to be replicated by other interested parties. Over a 12-month operating period (to March 2015), the system's heat production and LPG offsets were closely monitored and assessed to provide a detailed report on actual operating costs and any operational issues encountered. Preliminary outcomes indicate that to date the system has performed well above initial expectations, with heating needs being met using less woodchip fuel than budgeted for and a shortening payback period as a result of the better than planned performance and increasing gas costs.

Potential applications in the Sunshine Coast Council region

Examples of potential sites for small-scale AWC bioenergy system installations on the Sunshine Coast include timber processing and food manufacturing businesses; university, technical college and other educational campuses; hospitals or other large medical facilities; public swimming pools and other aquatic and indoor leisure centres; hotels and resorts; and theme parks. Investment in a small 'pilot plant', preferably in a community facility, could help to kick-start a local small-scale bioenergy industry in the region. Such plants can be valuable and trusted demonstration sites, and are important first steps to help accelerate the installation and operational learning curve, develop feedstock supply chains and drive down costs for future local installations at a range of scales and in both public and private facilities.

One potential standout location for accommodating a small-scale community-based biomass energy pilot system on the Sunshine Coast is the University of the Sunshine Coast's Sippy Downs campus. A pilot plant R&D project at this site would provide the campus' researchers and students with a convenient opportunity for undertaking intensive investigations into the operation and benefits of a small-scale biomass energy facility. The research could provide valuable local-level insights to underpin the development of a sustainable small-scale bioenergy industry on the Sunshine Coast.

The above-noted Sunshine Coast Camphor Laurel Timber Initiative Inc. (SCCLTI) sawmill also presents a standout opportunity to accommodate a small-scale community-based biomass energy pilot system. The SCCLTI mill is now located within the Noosa Shire near the town centre of Cooroy and on land owned by the Noosa Council. The mill site has a long timber industry history and the sawmills that previously operated on the site were important businesses for the local community and economy. The site also now accommodates a restored and heritage listed wood boiler house. The SCCLTI's business plan has included a bioenergy facility as an integral component of the organisation's long-term development. The organisation's goal is to utilise their Camphor Laurel sawing residues and much of the other woody biomass that is currently left at the tree removal sites, plus other locally-available waste wood resources, to generate enough thermal energy and electricity to power the mill's sawing and kiln-drying operations and potentially export surplus power to the grid (Ryan, 2013). The mill is favourably centrally located to receive various waste wood feedstocks from the Noosa and adjoining Sunshine Coast and Gympie regions. A new small-scale bioenergy facility at the SCCLTI site has much potential to increase activity at the mill and once again contribute socioeconomic benefits to the Cooroy community and surrounding Sunshine Coast and Gympie districts.

CONCLUDING COMMENTS

Small-scale AWC bioenergy system deployments can generate multiple socioeconomic and environmental sustainability benefits for investors and local communities. However, these benefits can only be realised when woody biomass feedstocks are responsibly sourced, with due consideration of the impacts on lifecycle carbon emissions, land-use change, and soil, water and air quality, and also the living conditions of those involved in or affected by the feedstock supply chain and the bioenergy system's operation. Sourcing locally-available waste wood fuels is critical to minimising carbon emissions and maximising local economic development opportunities. Key requirements for the efficient and sustainable (i.e. problem-free) operation of small-scale biomass energy systems are contaminant-free fuels that are consistent in particle size and moisture content. Another critical key to the success of system deployments is gaining and maintaining a local social licence to operate. Investors should facilitate discussion amongst the general public about their planned AWC renewable energy system and its sustainability benefits. This is particularly important for installations in public facilities. Post-installation, the provision of information displays and public viewing or tour opportunities at the facility can have beneficial on-going community educational impact. These measures will help to raise the current low level of community awareness and understanding of small-scale AWC bioenergy systems and counter any misunderstanding, scepticism and even misrepresentation of these systems that can exist in some sectors of the community.

While there are currently no small-scale AWC bioenergy systems known to be operating on the Sunshine Coast, this preliminary research has identified much potential for industry development in the region. The local policy context appears favourable, there are numerous suitable local industry and community facility applications, and some potentially suitable waste wood feedstocks appear available. However, the necessary integrated supply chains for the economically viable delivery of these feedstocks in suitable forms to local plants remain undeveloped. Thermal (i.e. heat only) plants are the simplest, cheapest and most commonly deployed type of small-scale biomass energy system internationally (and to a much lesser extent elsewhere in Australia) and there are hundreds of published case studies of successful deployments available to guide potential investors (for examples see BERC, 2010; www.usewoodfuel.org.nz/case_study.html; www.usewoodfuel.co.uk/using-woodfuel/case-studies.aspx); www.forestry.gov.uk/website/forestry.nsf/byunique/infd-7s3fql). A small 'pilot' thermal energy system, preferably installed in a prominent Sunshine Coast community facility, would help to 'kick-start' a new small-scale bioenergy industry for the region. In developing such a plant, much can be learnt from the planning, installation and operating experiences of the owners and managers of similar systems deployed elsewhere.

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Inventories and Significance of the Genetic Resources of an African Mahogany Species (*Khaya senegalensis* (Desr.) A. Juss.) Assembled and Further Developed in Australia

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Abstract

The forest tree species *Khaya senegalensis* (Desr.) A. Juss. occurs in a belt across 20 African countries from Senegal-Guinea to Sudan-Uganda where it is a highly important resource. However, it is listed as Vulnerable (IUCN 2015-3). Since introduction in northern Australia around 1959, the species has been planted widely, yielding high-value products. The total area of plantations of the species in Australia exceeds 15,000 ha, mostly planted in the Northern Territory since 2006, and includes substantial areas across 60-70 woodlots and industrial plantations established in north-eastern Queensland since the early-1990s and during 2005-2007 respectively. Collaborative conservation and tree improvement by governments began in the Northern Territory and Queensland in 2001 based on provenance and other trials of the 1960s–1970s. This work has developed a broad base of germplasm in clonal seed orchards, hedge gardens and trials (clone and progeny). Several of the trials were established collaboratively on private land. Since the mid-2000s, commercial growers have introduced large numbers of provenance-bulk and individual-tree seedlots to establish industrial plantations and trials, several of the latter in collaboration with the Queensland Government. Provenance bulks (>140) and families (>400) from 17 African countries are established in Australia, considered the largest genetic base of the species in a single country outside Africa. Recently the annual rate of industrial planting of the species in Australia has declined, and R&D has been suspended by governments and reduced by the private sector. However, new commercial plantings in the Northern Territory and Queensland are proposed. In domesticating a species, the strategic importance of a broad genetic base is well known. The wide range of first- and advanced-generation germplasm of the species established in northern Australia and documented in this paper provides a sound basis for further domestication and industrial plantation and woodlot expansion, when investment conditions are favourable.

Keywords: provenance, clone, progeny, seed orchards, conservation, woodlots

Introduction

The African mahogany forest tree species *Khaya senegalensis* (Desr.) A. Juss., (hereafter referred to as Ks), occurs naturally within 20 African countries in a seasonally-dry belt from Senegal-Guinea in the west to Sudan-Uganda (see Figure 1) in the east (Orwa et al. 2009, IUCN 2015-3, Sexton et al. 2015) (see Figure 1). It is rated 10th among the world's 20 most widely used and prioritised tree species suitable for development of forest industries and planted forests (FAO 2014). The species is well known in global wood markets and is an important multi-purpose resource across its range (Nikiema and Pasternak 2008, Orwa et al. 2009, Sexton et al. 2010). However, it is classified as Vulnerable by the IUCN due to loss of habitat and over-exploitation, and effective regeneration is generally poor (Sokpon and Ouinsavi 2004, Nikiema and Pasternak 2008, Fremlin 2012, Sexton 2013, IUCN 2015-3).

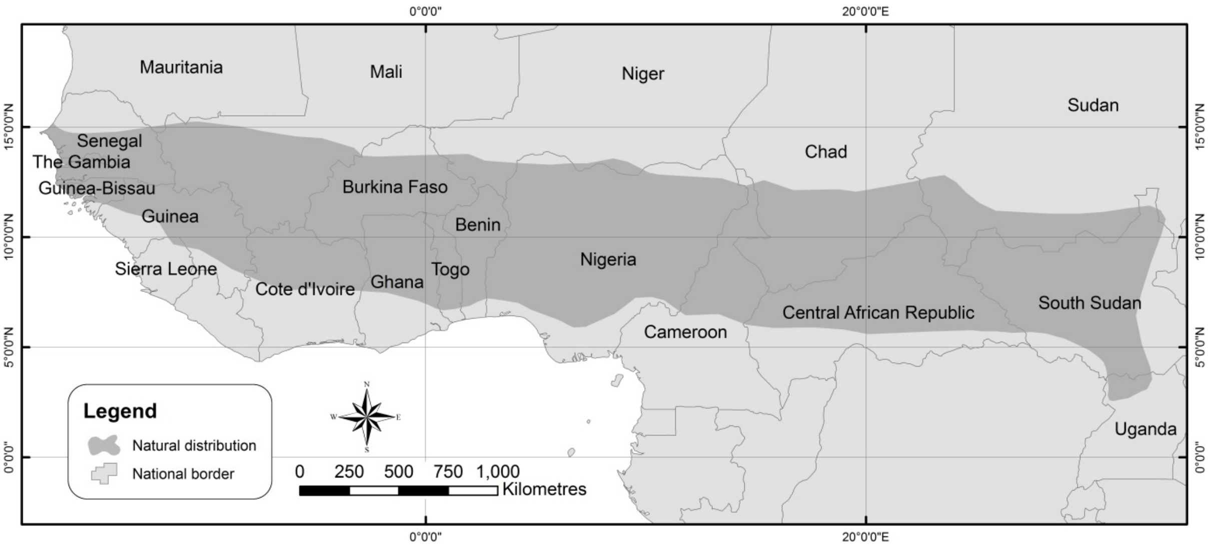

Figure 1. Approximate natural distribution of *Khaya senegalensis* within 20 countries in Africa.

In northern Australia, defined for this paper as north of latitude 20° S, vast tracts of land are climatically suitable for this species (Arnold et al. 2004, Figure 2 of Nikles et al. 2008). Since introduction to the region around 1959, Ks has been planted widely for amenity, research trials, woodlots, rehabilitation of mined areas and industrial plantations. The total area of the species planted in northern Australia exceeds 15,000 ha (Penfold 2015) with more than 13,000 ha of industrial plantations established in the Douglas Daly, Northern Territory (NT) (see Figure 2) since 2006 (Miller 2013) and 386 ha north of Cooktown in north eastern Queensland (Qld) between 2005 and 2007 (Nikles 2015a) (see Figure 2). Trials established in Western Australia (WA) in 1987-1999 and industrial plantings of 2006-2009 (ca. 100 ha) (Dumbrell et al. 2011, Dumbrell 2014) have been harvested commercially mostly as veneer logs (Fremlin 2015). More than 250 ha of woodlots across 60-70 ownerships have been established in north-eastern Queensland, mainly between Ingham and Bowen, since the early-1990s (Dickinson and Nikles 2011). A significant area of stands of the 1960s-1980s and trials of the mid-2000s remain on mined land at Weipa (Qld) (Annandale 2015a, b). Plantation trees yield high-value wood products (Armstrong et al. 2007, Nikles et al. 2008, Zbonak et al. 2010). For example, timber from 32-year-old NT plantation-grown Ks trees supplied to various industry assessors in eastern Australia in 2004 was judged to have 'good prospects on the domestic market in the future, and could conservatively be retailed for between \$3,000 and \$5,500/m^3 for dried, dressed Medium Feature to Select grade timber' (Armstrong et al. 2007, p viii; and see pp 36-40). Furniture crafted from the plantation Ks timber has won state and national awards (Nikles et al. 2008).

New hardwood plantation establishment in southern Australia has been in steep decline since 2006-2007 and by 2012-2013 the total area across hardwood and softwood resources recorded a net decrease (ABARES 2014). In contrast, industrial planting of Ks began in northern Australia in the mid-2000s and annual planting has only recently declined from 1500 ha/year to 400 ha/year (Penfold 2015). Anecdotal information indicates several thousand hectares of new commercial plantings of Ks are proposed for the NT and Qld.

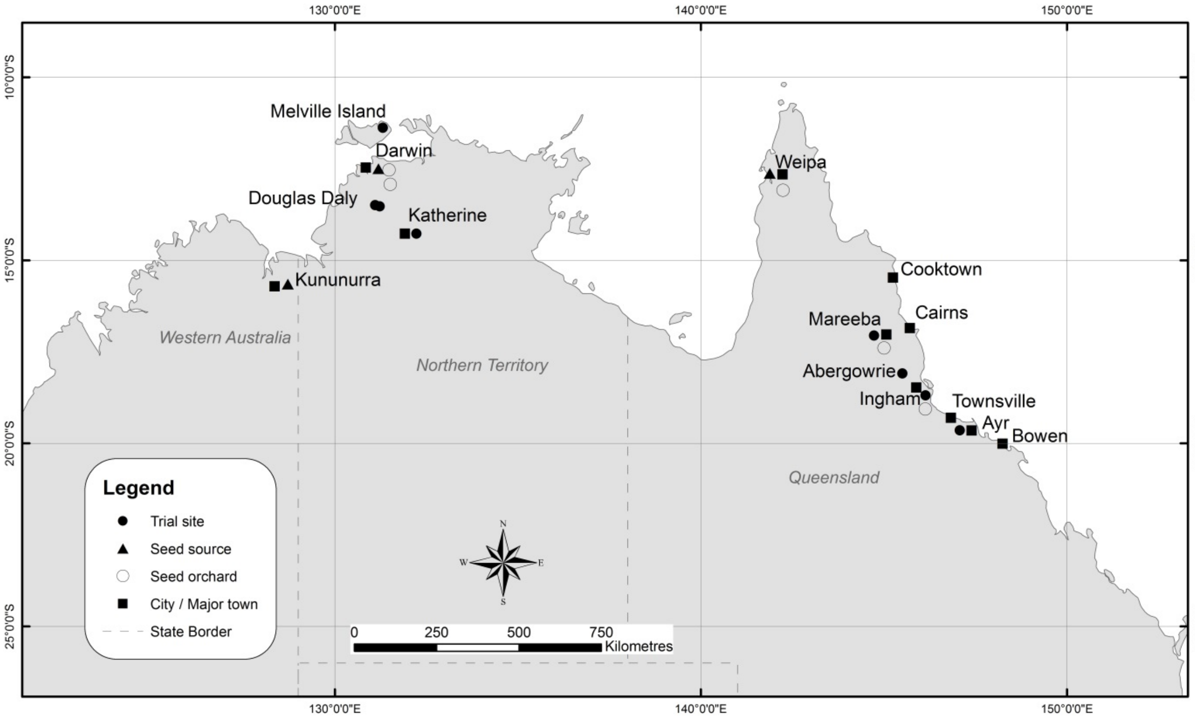

Figure 2. Locations of genetic resources plantings of *Khaya senegalensis* in northern Australia that include industrial plantations in the Douglas Daly and near Cooktown and Kununurra.

Collaborative conservation and tree improvement of Ks by Governments began in the NT and Qld in 2001 (Nikles 2006, Nikles et al. 2008). The initial base population in the NT comprised small stands planted near Darwin in the 1960s–1970s representing 21 provenances from 10 African countries, unknown African sources and three provenances from New Caledonia ex Ivory Coast. Stands of two unidentified African provenances formed the base at Weipa, Qld (Bragg et al. 2004). Trees combining good growth and/or form were selected mostly during 2001 to 2003 (143 around Darwin and 36 at Weipa). Small clonal seed orchards (CSOs) and hedge gardens were established in the NT and north-eastern Qld between 2001 and 2005 (Nikles et al. 2008); and a CSO, hedge garden and seedling seed orchard were planted at Weipa in 2004 (Bragg et al. 2004). Orchard seed and other seedlots have enabled establishment of advanced-generation progeny and clone trials since 2005, some planted collaboratively on lands of the private sector (Nikles et al. 2014). The status of Ks domestication, R&D outcomes and challenges have been documented in Workshop Proceedings (Bevege et al. 2004, 2006), Reilly et al. (2006), Nikles et al. (2008) and in Abstracts of a Forum (Dickinson et al. 2011). Additional collaborative research was undertaken in Qld and the NT on clonal technologies, efficient phenotyping and molecular diversity under the National and International Research Alliances Program, Smart Forests Alliance Queensland and detailed results have been reported (see Wallace et al. 2012). The status of domestication in 2014 was outlined by Nikles (2015b). Investment in Ks R&D by governments ceased in 2011 due to changed priorities; and it has been scaled down recently by industry (Fremlin 2015).

Since the mid-2000s, private growers have introduced large numbers of new provenances as bulk and individual-tree seedlots to establish industrial plantations and trials (Dickinson et al. 2009). This paper updates the inventory of 2009 and includes details of the clonal seed orchards, hedge gardens, and provenance, clone and progeny trials established by January 2013. It also describes the significance of the genetic resources assembled and further developed in Australia, considered to be the largest genetic base of the species in a single country outside Africa.

Genetic Resources of Ks Assembled in Australia

There are primary and advanced-generation resources. Locations of plantings of genetic resources of Ks in northern Australia and nearby towns or cities mentioned in the text are shown in Figure 2.

Primary Genetic Resources

Plantings established almost wholly from imported seed took place in several phases reflecting successive periods of establishment of the species in various types of plantings in northern Australia. The main phases and purposes of the plantings can be described as follows based on Dickinson and Kelly (2006), Nikles et al. (2008) and Dickinson et al. (2009):

1. Mid-1960s to early 1970s – silvicultural and provenance trials near Darwin, NT;
2. Mid-1960s to mid-1980s – taxa and silvicultural trials and extensive mine-site rehabilitation at Weipa, north western Cape York, Qld;
3. Early-1990s to early 2000s – trials and woodlots in north-eastern Qld; and
4. Since mid-2000s – industrial plantations in the NT, Qld and WA; provenance trials in the NT and Qld; and a family-in-provenance trial in Qld.

In phases 1-3, provenances were not identified precisely to specific geographic coordinates of locations within known country of origin, nor were the numbers of seed parents per provenance provided by the African suppliers of seed. Stands established from seed of all phases remain, though some are diminished to varying degrees by fire, land redevelopment and partial harvesting at Weipa, Qld; cyclone and land redevelopment near Ingham, Qld; and land redevelopment in the NT.

Provenances Represented in CSOs

Tree selection between 2001 and 2003 in stands from seed importation phases 1 and 2 contributed above-average trees for growth and/or form for CSO establishment as follows:

a. One hundred and thirty-six clones from trees selected in trials in the Darwin region, NT tracing to 21 known provenances from 10 African countries across the species' range plus three provenances from New Caledonia (thought to have originated in Ivory Coast);
b. Thirty-six clones from trees selected at Weipa in stands of two African provenances (Bragg et al. 2004) considered to be different from those of (a).

Six clones from trees selected in Qld woodlots likely of Burkina Faso origin were added to the program later. After Tropical Cyclone Yasi (2011, Category 5), 24 trees were selected in a families-in-provenances trial of 17 provenances from six African countries planted near Ingham, Qld in 2008 by a private grower: he established grafts of these trees in a CSO (Sexton 2013, 2015). Table 1 has details of the five CSOs developed – Berrimah, Howard Springs, Walkamin, Weipa and near Ingham - that incorporate a total of 202 unique clones.

More than one tree was selected in most provenances (Table 1), so there could be a level of co-ancestry among CSO clones from such provenances and some inbred seedlings among the progeny. Anecdotal observations of CSO progeny suggest that Ks seedlings exhibiting severe symptoms of inbreeding are rare. The first substantial collection of orchard seed was from the NT CSOs in 2008 (age 7.5 years). Families from 40 of these clones are established in progeny trials described below in the section Second-generation Genetic Resources. There is potential to establish progeny trials of a further 162 orchard clones.

Table 1. Number of provenances and grafted clones from trees selected near Darwin, Northern Territory and in north Queensland and established in the Northern Territory and Queensland Governments' collaborative clonal seed orchards by country of provenance origin, orchard, year of first planting and area[a]

Country of origin	Number of provenances	Number of clones Berrimah, near Darwin, NT 2001, 0.4 ha	Number of clones Howard Springs, near Darwin, NT 2001, 1.2 ha	Number of clones Walkamin, near Mareeba, Qld 2003, 1.3 ha
Benin	1	2	1	0
Burkina Faso	2	13	13	14
Central African Republic	1	6	6	4
Chad	1	3	3	0
Ghana	1	10	10	5
Ivory Coast	2	5	5	4
New Caledonia[b]	3	12	13	4
Nigeria	2	11	11	5
Senegal	4	31	31	15
Sudan	2	10	11	4
Togo	1	6	6	4
Uganda	4	17	17	9
Unknown	NA[c]	8	9	6
Total	24	134	136	74[d]

[a] Modified from Dickinson et al. (2012). A fourth clonal seed orchard (CSO) of 36 clones was established at Weipa, Qld in 2004 through collaboration between the Queensland Government, the Napranum Land and Sea Management Centre and the company COMALCO (Bragg et al. 2004). Identities of the two African provenances represented are unknown. [A seedling seed orchard planted at Weipa in 2004 (Bragg et al. 2004) has been lost]. A fifth CSO was established privately near Ingham in 2011-2012 with 24 clones of 17 provenances from 6 African countries (Sexton 2015)

[b] Three seedlots from New Caledonia ex Ivory Coast origin

[c] Not available. Possibly included among the known provenances

[d] Includes a 68-clone sub-set of the 136 clones of the Howard Springs orchard and six (6) clones from trees selected in Queensland. The total number of unique clones across all five orchards is 136+ 6 + 36 + 24=202.

Seed from the NT and Walkamin CSOs is expected to exhibit high quantitative and molecular genetic diversity because of the diverse parental provenances and the observation that flowering times among the clones are essentially synchronous (Dickinson et al. 2012). Hence much of the CSO seed could represent inter-provenance crosses. Supporting these expectations are high variation in progeny trials (see the section **Exhibit High Genetic Variation**), and studies of nuclear and chloroplast loci, that included samples from CSO clones, which revealed high genetic diversity, especially in material of western-region provenances (Karan et al. 2012, Sexton et al. 2015).

Provenance Bulks and Individual-tree Seedlots Introduced During Phase 4

Dickinson et al. (2009) reported that 116 unique provenance bulk seed collections were represented across the domestication program of the NT and Qld Governments and the commercial and R&D programs of Great Southern Limited. The inventory showed 15 African countries had been sampled and three seedlots obtained from New Caledonia of Ivory Coast origin. Additional provenances were introduced in the 2000s by other companies [African Mahogany Australia (Fremlin 2014) and Northern Tropical Timbers (Nikles 2007)] and by a private grower (Sexton 2013, 2014). Numbers of provenance bulks established in the field to the end of the 2012-13 planting season are documented in Table 2.

Most of the seed for these plantings was from the western region[7] of the range in sub-Saharan Africa, especially Mali, Burkina Faso and Senegal (Table 2). Almost all bulks were from 25 or more parent trees. The seed used for plant production for the industrial plantations was a mixture of known provenances that were available at the time (Fremlin 2008).

The total number of provenances established in Australian plantings, representing 17 African countries, now stands at over 142 (Table 2) as the plantings near Ingham, Qld since Oct., 2008 may have additional material (Table 3). It is assumed that introductions of the 1960s and early 1970s, for which precise provenance details are not available, were from different provenance populations from those introduced more than 30 years later, i.e. in 2001 and, mostly, after 2004. Though Guinea Bissau, Mauritania and Sierra Leone are not represented, occurrences of Ks in those countries are relatively minor and provenances from neighbouring countries are well represented in Australia. The inventory of established provenances represents a decline from the 181 introduced due to the recent loss of 39 unique provenances through redevelopment of land on which a trial of 71 African provenances was planted in the NT in 2009 (Fremlin 2014). Another loss of provenance material occurred in 2014 through redevelopment for agriculture of a trial planted in 2008 near Abergowrie, Queensland. This trial had suffered major damage in February 2011 from Tropical Cyclone Yasi (Category5). Fortunately all 38 provenances included in this trial remain represented in companion trials in the NT (Table 3).

Table 2. Approximate inventory of provenances of *Khaya senegalensis* introduced from 17 of the 20 countries where the species occurs naturally in Africa and established in Australian plantings to 2012-13.

Country of origin	NT–Qld Government program [a]	Commercial growers[a, b]	Total
Benin	1	5	6
Burkina Faso	9	21	30
Cameroon	0	9	9
Central African Republic	1	2	3
Chad	1	1	2
Gambia	0	1	1
Ghana	1	4	5
Guinea	0	4	4
Guinea Bissau	0	0	0
Ivory Coast	5 [c]	0	5
Mali	0	60	60
Mauritania	0	0	0
Niger	0	8	8
Nigeria	2	2	4
Senegal	4	16	20

[7] Defined here arbitrarily as west of longitude 0° (the approximate western edge of the Dahomey Gap, an hypothesized barrier to gene flow – Karan et al. 2012, Sexton et al. 2015). Other regions suggested here are: central - 0° to 20° E; and eastern - east of 20° E.

Sierra Leone	0	0	0
Sudan	1	1	2
South Sudan	1	10	11
Togo	1	2	3
Uganda	6	2	8
Totals	33	148 (109 net) [d]	181 (142 net) [d]

[a] Updating of Dickinson et al. 2009. Assumes introductions of the 1960s and early 1970s were from different provenance populations from those introduced more than 30 years later, i.e. since 2000

[b] Most of these provenances were introduced after 2004. The status of stands of 70 additional provenances established near Ingham beginning in Oct., 2008 is yet to be assessed (Table 3, Sexton 2015)

[c] Three seedlots of secondary origin (New Caledonia)

[d] Provenances (39) lost to land redevelopment before trees could be selected and grafted were from: Benin 4, Burkina Faso 4, Mali 20, Niger 6 and Senegal 5. Hence the net total for column 3 is 109 and the net total for column 4 is 142 – subject to revision upwards when results of the assessments of [b] are available

Individual-tree seedlots have also been introduced - from Burkina Faso (22 seedlots across several provenances), several African countries (ca. 400 seedlots across many provenances) and South Sudan (19 seedlots across two provenances) [respective records of Department of Agriculture and Fisheries (DAF), Brisbane; Sexton (2013); Fremlin (2014)]. The suites of first-generation families derived from these importations were mostly incorporated in progeny trials together with advanced-generation families. For convenience, families of all generations are documented together in Table 4. All the progeny trials include families from different provenances planted together. Since it has been observed that flowering of CSO clones of widely different provenances is essentially synchronous (Dickinson et al. 2012), it is likely that seed collected within the progeny trials would include inter-provenance crosses.

Of special interest is the trial of about 375 individual-tree families established as families-in-provenances by GJ Sexton near Ingham, Queensland, in 2008 (Sexton 2013). This trial was also struck by Tropical Cyclone Yasi and consequent flooding. However, a few families exhibited a reasonable degree of wind firmness and individuals within them that had previously shown superior growth and form were selected and established in a clonal seed orchard (see Table 1, footnote a). Felling severely damaged trees at ground level and subsequent reduction of coppice to a single leading stem resulted in successful stand re-establishment (Sexton 2013; GJ Sexton, University of Qld, 2014, pers. comm.).

Inventory of Recent Provenance Trials

Table 3 documents Ks provenance trials established in northern Australia during 2001- 2013.

Table 3. Inventory (2014) of *Khaya senegalensis* provenance trials ordered by month and year of planting in the Northern Territory (NT) and Queensland (Qld) since 2001 at approximate locations shown in Figure 2

Trial location	No. of African provenances[a]	Month, year of planting	Plant owner, Land owner	Approx. net area (ha)
Walkamin, near Mareeba, Qld	5	Mar., 2001	Public, Public	0.7
Douglas Daly, NT	9	June, 2006	Private, Private	4.9
Douglas Daly, NT	11	Mar., 2007	Private, Private	2.3
Melville, Is., NT[b]	25	Jan., 2008	Private, Private	6.4
Douglas Daly, NT	38	Jan., 2008	Private, Private	7.7
Douglas Daly, NT	38	Mar., 2008	Private, Private	8.9

Abergowrie[c], near Ingham, Qld	38	Apr., 2008	Private, Private	8.5
Near Ingham[b], Qld	70	Oct., 2008 and later	Private, Private	13.0
Douglas Daly, NT[d]	71	Feb., 2009	Private, Private	10.4
Douglas Daly, NT	12	Feb., 2011	Private, Private	5.0
Douglas Daly, NT	11	Jan., 2012	Private, Private	5.0
Douglas Daly, NT	6	Jan., 2013	Private, Private	4.9

[a] Numbers given are accounted for in Table 2 except for provenances planted near Ingham since Oct., 2008
[b] Status of trial/s to be assessed
[c] Trial lost due to land redevelopment in 2014 after severe damage from Tropical Cyclone Yasi in 2011; all provenances remain elsewhere
[d] Trial (including 39 unique provenances) lost due to land redevelopment in 2013

Almost all provenance bulks included in the trials were from 10 or more than 25 parent trees. The initial numbers of trees of each provenance planted in these replicated trials commonly ranged from 150 to 240. In such trials, substantial numbers of trees are available for screening to select superior trees for conservation and tree improvement. For example, the trial planted in the Douglas Daly, NT in January 2008 contained 8,880 trees initially, across 37 African provenances each represented by 240 trees (Dickinson et al. in prep.).

Although full pedigrees of selections made in these stands would be unknown, methods of pedigree reconstruction (Isik 2014) might be used to determine co-ancestry among selected trees and allow decisions on how to use related trees effectively in a breeding context. Meanwhile, a simple tactic to limit co-ancestry in seed orchards would be to select a restricted number of trees per known provenance.

Advanced-Generation Genetic Resources

Many plantings of trials and woodlots since the late-1980s were from seed of Australian trees, commonly from trees around Darwin, with full details of sources unrecorded. Here, most attention is given to trial plantings of seedlings, cloned progeny or clones derived from trees selected in Australia, mostly of known provenance (Tables 1, 4, 5).

Hedge Gardens

A hedge garden was initiated at the Berrimah Research Farm near Darwin (NT) in 2004 with the planting of diverse seedlings and, later, rooted cuttings from stump coppice of a few of the trees selected for CSOs of which 38 were felled in 2003 for a study of log and wood properties (Armstrong et al. 2007). Still later, more clones from stump coppice and material from other sources were added.

For the NT clone trials described below, a variable number of cuttings (commonly 2-6 per hedge) were taken from among the following 536 hedges.

a. Seedling progeny of 11 of the trees selected near Darwin for CSOs: 350 hedges
b. Bulked seedling progeny of ca. 20 of the 36 CSO trees selected at Weipa: 112 hedges
c. Bulked wildling seedlings (Controls), of an estimated 10 seed parents different from those of (a), many uplifted from within stands where most of the 136 trees had been selected for the NT CSOs; and six seedlings from a Katherine, NT nursery: 66 hedges
d. Rooted cuttings from stump coppice of three Darwin select trees (two not represented by progeny in the hedge garden) and from one rooted cuttings tree: 8 hedges.

From the above, it is estimated that hedges 1 to 536 trace to 44 parental genotypes - 41 with seedling progeny and three with ramets from stump or branch coppice. Across these hedges, seven provenances are represented from Burkina Faso, Ghana, Senegal, Uganda and Ivory Coast via New Caledonia. Subsequent additions to the Berrimah hedge garden included: a further 10 clones ex stump coppice of Darwin select trees; seedlings from 10 families of a South Sudan provenance (Kagelu); and seedlings from a locally-produced controlled cross and open-pollinated seedlings from one of the parents. None of these additional hedges, accounted for in the 630 hedges of Table 4, has been incorporated in clone trials.

A subset of the Berrimah hedges (the top 220 based on 6-month heights in clone trials planted in the NT in 2005), was also established as rooted cuttings clones in potted hedge gardens in Qld, initially at Gympie in 2006 then transferred to Mareeba; ultimately 153 hedges were planted in the field at Walkamin in 2009 (Table 4). If required, all or sub-sets of the hedges in the NT and Qld could be rejuvenated by basal coppicing.

Table 4. Inventory (2014) of *Khaya senegalensis* hedge gardens and clone and progeny trials established by month and year of planting in the Northern Territory (NT) and Queensland (Qld) at locations shown in Figure 2.

Hedge garden or Trial type (plant type)	Location	No. of Entries (excluding Control bulks)	Month, year of first planting	Plant owner, Land owner	Approx. net area (ha)
Hedge garden[a] (seedlings, ramets)	Berrimah, near Darwin, NT	630	Mar., 2004	Public, Public	NA[b]
	Walkamin, near Mareeba, Qld	153 (sub-set of above)	Dec., 2009	Public, Public	NA
Clone trial (rooted cuttings clones)	CPHRS[c], Darwin, NT in adjacent trials A and B	A – 336 B – 188	Jan., 2005 Feb., 2005	Public, Public	3.0
	Katherine Research Station,NT	238	Jan., 2006	Public, Public	1.1
	Douglas Daly Research Farm (RF), NT	63	Feb., 2006	Public, Public	0.4
	Douglas Daly, NT	197	Mar., 2007	Public, Private	1.4
	Near Ayr, Qld	153	Aug., 2007	Public, Private	1.6
	Abergowrie[d], near Ingham, Qld	56	May, 2008	Public, Private	1.0
	Douglas Daly, NT	320	Dec., 2008	Public, Private	1.7
	Near Mareeba, Qld	48	June, 2009	Public, Private	0.9
	Douglas Daly RF, NT	141	Jan., 2010	Public, Public	0.7
	Near Mareeba, Qld	54	Jan., 2011	Public, Private	4.0
	Douglas Daly, NT	21	Jan., 2012	Public, Private	2.0
Progeny trial (seedling families)	CPHRS, Darwin, NT (within clone trials)	A – 11 B – 9 (sub-set)	Jan., 2005 Feb., 2005	Public, Public	0.6
	Near Ingham, Qld	ca. 375[e]	Oct., 2008	Private, Private	8.0
	Near Mareeba, Qld	12, 10 ex 10 CSO clones	June, 2009	Public, Private	0.6
	Near Katherine, NT	38, ex 30 CSO clones	Feb., 2010	Public, Public	2.6
	Near Ayr, Qld	42, ex 30 CSO clones	May, 2010	Public, Public	1.2
	Douglas Daly	14, ex 13 CSO	Dec., 2010	Public, Public	2.0

Research Farm, NT	clones			
Douglas-Daly, NT	42 [e], 14 ex 13 CSO clones	Jan., 2011	Public, Private	2.2
Douglas Daly, NT	17 [e]	Jan., 2011	Private, Private	0.6
Douglas Daly, NT	90 [e], 15 ex 15 CSO clones	Jan., 2012	Public and Private, Private	1.9
Near Ingham, Qld	44[e], 13 ex 13 CSO clones	May, 2012	Public, Private	0.6

[a] A hedge garden from bulked seed of local selected trees established at Weipa, Qld in 2004 was lost to land redevelopment

[b] Not available

[c] CPHRS – Coastal Plains Horticultural Research Station

[d] Trial lost due to land re-development in 2014 after severe damage from Tropical Cyclone Yasi in 2011

[e] These Entries are or include first-generation families from African seed

Clone Trials

Clones were developed as rooted cuttings from sub-sets of hedges 1 to 536, either in the NT or Qld, for establishment of clone trials planted in the NT (8) and Qld (4) during 2005–2012 on government land or collaboratively on private and company lands (Table 4). Within-clone replication in the NT trials increased over time as proliferating shoots on hedges yielded more cuttings, the number reaching eight ramets per clone for 50 clones of the 320-clone trial planted in the Douglas Daly in December 2008 (Table 4). Trials in Qld, being derived from several hedges per clone, had higher replication – commonly more than10. Among trials, numbers of clones vary from 21 to 336 (Table 4). Low numbers of clones and of replications for some clones partly reflected clonal variation in rootability (Reilly et al. 2011). Approximately 400 clones are under test across the NT and Qld trials, the latter including a clone of a Qld select tree. Almost all 44 parents of hedges are represented in clone trials.

Progeny Trials

Progeny trials were established on government, company or other private land between 2005 and 2012 (Table 4). They generally incorporate first- and advanced-generation families; for convenience families of all generations are documented together in Table 4. All the progeny trials are of open-pollinated families, either from seed of African or Australian ortets (original parents), or ramets (CSO grafts) of Australian selects. Families from open pollination of ortets (OPO) are from selected trees as follows: 11 Darwin, 3 Qld and 40 Kununurra trees (Table 5). These 54 families trace to at least five known provenances from Burkina Faso, Ghana, New Caledonia and Senegal and provenances of unknown origin.

CSO seedlots collected from the NT and Walkamin CSOs have been incorporated into seven progeny trials deployed across the NT and Qld during 2009-2012 (Table 4). This seed, referred to as 'open pollinated from ramets' (OPR), was kept separate by individual ramets. Across the trials, a total of 40 CSO clones are represented (Table 5). One parent tree is represented by both OPR and OPO families. There is scope for progeny testing of many more of the 162 untested CSO clones (see Table 1).

Across the OPO and OPR progeny trials a total of 93 unique families are deployed (Table 5). They trace to 16 known provenances across the species natural range representing nine African countries (Burkina Faso, Central African Republic, Ghana, Ivory Coast, Nigeria, Senegal, Sudan, Togo and Uganda) and three from New Caledonia and unknown (Table 5).

Summary of Advanced-Generation Genetic Resources

Progeny trials include families of a net 93 unique, selected Australian trees – 54 as OPO families and 40 as OPR families (with one select tree represented as both OPO and OPR families) (Table 5). Additional unique parents are represented in clone trials as: cloned seedling progeny of an estimated 30 parents of unknown pedigree (ca. 20 Weipa trees and ca. 10 Darwin trees); plus clones of three Darwin trees and a single Qld select tree, for an estimated total of 34 additional unique parents. Overall therefore, advanced genetic resources of Ks in Australia comprise seedling or cloned progeny from an estimated 127 unique parent trees from 16 known provenances of 9 African countries (listed above), unknown African provenances and three from New Caledonia (Table 5). There may be a level of co-ancestry among these genotypes, e.g. where more than one first-generation parent had been selected in a provenance. Tactics potentially available to limit co-ancestry in new breeding and deployment populations were mentioned above under ***Inventory of Recent Provenance Trials***. Secondary resources could be broadened by establishing trials from seed of the 162 orchard clones not yet represented in progeny trials, and seed of new selections.

Table 5. Numbers of parents of advanced-generation Australian families from open pollination of local ortets (OPO) or of ramets (OPR, within clonal seed orchards) by country and provenance represented in progeny trials

Country	Provenance[a]	Location of stand/s of parent tree selection	OPO families	OPR families
Burkina Faso	D416	Darwin, Northern Territory	1	1
Central African Republic	D391	As above		2
Ghana	D500	As above	2	1
Ivory Coast	S10050	As above		3
Nigeria	D480	As above		4
	D486	As above		3
Senegal	D417	As above	3	3
	S9392	As above		3
	S10066	As above		1
Sudan	S9368	As above		1
	S9687	As above		1
Togo	D411	As above		2
Uganda	D407	As above		3
	D408	As above		1
	S9620	As above		2
	S10053	As above		2
Unknown (Africa)	Unknown	Burdekin Agricultural College, near Ayr, Queensland	3	
	As above	Darwin, Northern Territory	1	2
	As above	Kununurra, Western Australia	40	
New Caledonia (ex Ivory Coast)	D477	Darwin, Northern Territory		1
	D487	As above	3	1
	D522	As above	1	3
Totals	19 + Unknown		54[b]	40[b]

[a] Alpha-numeric names are the seed accession labels given to the seedlots on arrival in Australia – D for those received at Darwin directly, S for those received via CSIRO's Tree Seed Centre, Canberra; details of geographic origins of the provenances in Africa and numbers of parent trees sampled not provided

[b] One parent has both OPO and OPR families. Hence the total number of unique parents is 93. An estimated 34 additional unique parents are represented as cloned progeny bringing the grand total to an estimated 127 unique Australian parents represented in advanced-generation progeny trials in Australia

Significance of the Genetic Resources of Ks in Australia

Include Range-Wide Provenance Collections Difficult to Replicate

The primary genetic resources of Ks established in Australia since the 1960s, mainly in the mid- to late-2000s, are from seed collected across the natural range of the species representing more than 142 provenances from 17 of the 20 countries in which it occurs naturally (Table 2). This large *ex situ* collection of germplasm is important because it has become difficult to secure range-wide provenance collections due to human conflicts in several African countries. Also, the genetic resources of Ks in Africa continue to be depleted through habitat loss and over exploitation reducing the gene pool available for new sampling.

Are Relatively Secure

While there is risk of further loss of genetic resources of Ks in northern Australia due to fire, cyclone or land redevelopment, it is mitigated by a number of factors. The 202 clones (Table 1) are distributed among five CSOs at disparate locations in the NT and Qld (Figure 2) giving a degree of security against loss of all clones. Many of these first-generation selections are also represented in clone and progeny trials on government, private or company land that is protected from fire within larger estates; this also applies to the progeny trials of more than 400 families from African seed (see Table 4). While the provenance trials are deployed more narrowly, the largest and several smaller ones remaining are located within the well-protected industrial plantations of the Douglas Daly, NT where cyclones are rare.

However, losses have occurred as described in earlier sections of this paper and there could be further losses. Hence there is a need to safeguard elements of the broad-based resources remaining. The challenge is to undertake wise management of the Ks germplasm established in Australia. We consider this is most likely to succeed via a collaborative, recurrent selection breeding program that provides improved material primarily for commercial deployment (Dickinson 2011). Incorporation of selected trees, from across the whole range of the genetic resources of Ks in Australia, as grafts in CSOs and as progeny in seedling seed orchards that are cycled over time, would most likely be components of such a breeding program that may be rekindled when investment conditions are favourable. Ideally, establishment of such seed orchards would pre-empt the next phase of commercialisation of Ks in Australia thus likely reducing the lag time to availability of improved seed.

Exhibit High Genetic Variation

Data analysis of clone trials to age 7.4 years show significant differences among clones for all traits measured (unpublished reports of J De Faveri, DAF, Mareeba). For example, among the 153 clones in a trial near Ayr, Qld, mean diameters at age 7.4 years ranged 7.7–18.1 cm, a 135% difference (Lindsay 2015a). Most clone trials included a bulk seedlot from Darwin street trees and an African provenance as Controls the latter performing better than the former for most traits. While ‘all clones’ means exceed the African Control for most traits, the means for the ‘top 10%’ of clones invariably surpass the African Control. Results of clone trials have enabled tentative identification of promising clones that could be considered for inclusion in new CSOs and breeding populations. However, outstanding clones are difficult to determine (Reilly et al. 2011).

Results of assessments of an advanced-generation progeny trial near Mareeba, Queensland (on a very poor site) at age 5.5 years indicate much variation among the 12 families for all traits assessed. Mean diameters of the families ranged 5.6– 7.4 cm, a 32% difference (unpublished data). In a trial near Ayr, Queensland (on a poor site) measured at age 3.3 years, mean diameters of the 41 CSO families ranged from 5.7– 8.1 cm, a 42% difference (unpublished data). In both trials, the ‘all families’ means surpassed the African Control for most traits while the ‘top 10%’ of families did so invariably. Means for DBHOB and height of the 10 families with seed parents originally of western-region provenances (Burkina Faso, Ghana, Ivory Coast and Senegal) were similar to those of the 15 families from far-eastern original sources (Sudan and Uganda), but the western-provenances families had better bole length, straightness and Value index (defined as $DBHOB^2$ x bole length x straightness score). These and other progeny trials have enabled tentative identification of diverse superior families (and hence the better CSO clones to target for re-collection of seed) and of promising individual advanced-generation trees. Promising parents and superior individual trees in both OPO and OPR progeny trials could be considered for inclusion in next-cycle seed orchards and breeding populations.

High provenance variation is demonstrated by results of two large trials established in the NT and Queensland in 2008 (38 provenances from Burkina Faso, Cameroon, Guinea, Mali and Senegal plus Australian Controls), and of another trial planted in the NT in 2009 (71 provenances from Benin, Burkina Faso, Cameroon, Mali, Niger and Senegal). These provenances span a wide range of environments in Africa: elevations (9m‒543m above sea level), mean annual rainfalls (500mm‒ 1,300mm) and geographic distributions (10°N in Cameroon to 14.75°N in Mali and 16.5°W in Senegal to 16.5°E in Cameroon). All the several economic traits assessed[8] at ages 3 years and 4.3 years respectively exhibited statistically significant and economically important differences among provenances (Dickinson et al. in prep., M. and S. Carson 2014, Fremlin 2014). For example, provenance means for diameter in the 2008 Queensland trial ranged from 6.9 cm for a Mali provenance to 9.3 cm for a Burkina provenance, a 35% difference. While particular Australian and African provenances were equally good for height, diameter and disease incidence, best Australian provenances were inferior to the best African provenances in straightness, branch size, axis persistence and wind firmness. In the 2009 NT trial the range in diameter was from 6.0 cm for a Niger provenance to 8.6 cm for a Burkina Faso provenance, a 43% difference. Photographs in Fremlin (2012) illustrated great differences in growth and tree form between provenances grown in the NT.

Confirming Australian results, significant provenance variation was exhibited for tree volume, axis persistence and stem form at 3.5 years of age in a trial planted in Sri Lanka in 2008 with a 21-provenance sub-set (Senegal to Niger) of the 71 provenances in the 2009, NT trial, with far-western provenances the more promising (Bandara 2014, Kangane 2014).

Include Large Numbers of Promising Provenances and Individual Trees for Screening
Most of the promising provenances for growth and tree quality traits in both the Australian and Sri Lankan provenance trials mentioned above were from the western region of the Ks range in Africa. One hundred provenances from across this western region are established in Australian plantings representing seven countries - Burkina Faso, Gambia, Ghana, Guinea, Ivory Coast, Mali and Senegal (Table 2). However, individual trees combining good growth and stem quality have been observed in all provenances (Fremlin 2014).

Furthermore, at older ages when additional biotic and abiotic factors may have impacted the populations available for domestication, indications of relative performances of provenances may change. Therefore, it would be wise to select trees for future conservation and breeding populations from a wide range of provenances to assure high diversity in these populations.

Large numbers of individuals from high performing populations with high diversity are needed for sustainable domestication (White et al. 2007). Within most of the provenance trials, substantial numbers of trees are available for screening to select superior trees for conservation and tree improvement. Our experience shows that large numbers of trees have

[8] Traits assessed in one or more of the Australian trials included diameter, height, stem straightness, branch thickness, axis persistence, wind firmness, diseased trees (‘pink’ disease) and ‘tree value index’

to be screened to identify superior trees meeting the criteria of the tree improvement objectives for Ks defined by Dickinson et al. (2009). In relation to veneer production, they stated (p 5): 'The straighter, the larger in diameter and the lower the incidence of knots in logs, the greater the recovery of high-value veneers'. (These criteria should also include 'the lower the log taper'). It is fortunate there are very large numbers of trees across the provenance and other trials and commercial plantings of Ks in Australia, allowing high selection intensity.

While the Australian provenance, clone and progeny trials together cover more than 100 ha of plantations (Tables 3, 4), and phenotypic selection is expected to be relatively accurate within the clone and progeny trials (half-pedigrees mostly known), there are far greater numbers of trees across the industrial plantations and woodlots which would enable very intensive selection. Although pedigrees of trees selected in these plantings would be unknown, decisions on how to use potentially-related trees effectively might be made as mentioned above under ***Inventory of Recent Provenance Trials***. Such knowledge would also provide a partial basis for restricting co-ancestry when considering thinning existing clone and progeny trials to develop seed orchards.

Allow Identification of Promising Parents, Clones, Families and Individual Trees in Trials

First-generation progeny trials of more than 400 African trees and advanced-generation clone or progeny trials of an estimated 127 unique local parent trees are established in northern Australia (Tables 4, 5). All of the economic traits assessed in several advanced-generation trials at ages 7.5 years and 5.5 years exhibit statistically significant and important differences among clones and families (unpublished reports of J. de Faveri, DAF, Mareeba). This has enabled identification of promising clones, families and individual trees at specific trial sites. However, the impact of genotype-by-environment interaction for these promising materials is currently unknown. These progeny and clone trials allow greater accuracy of individual tree selection for the next cycle of breeding and deployment than is possible in the provenance trials and industrial plantations where pedigree is not known. Such promising material warrants inclusion in future breeding and seed producing populations that are large enough to allow culling of, for example, genotypes exhibiting unfavourable environmental interaction.

Provide a Good Base for Genetic Improvement and Plantation Expansion

"Genetic diversity is widely recognised as the key component for long-term survival of most tree species" (Gapare 2014, p 312). In domesticating a species the strategic importance of a broad base of genetic resources including high-performing provenances is well known, e.g. White et al. (2007), Dvorak (2012). There is great variation among the diverse clones, families and provenances of Ks in respective Australian trials (see the section **Exhibit High Genetic Variation** above). Such high genetic variation, and the high phenotypic variation observed between individual trees (e.g. Lindsay 2015b, Slide 16), bodes well for further domestication, including via establishing 'seed production areas' ; collecting seed from superior phenotypes, proven CSO clones and 'best clones' in trials; and establishing new seed orchards. [One replication of the provenance trial planted in the Douglas Daly in January 2008 (see Table 3) has been converted to a 'provenance seedling seed orchard' (*sensu* Nanson 1972) that is being managed by thinning and irrigation (Fremlin 2015)].

However, repeated cycles of selection narrow the genetic base and may eliminate some genes that are needed later (Libby 1973). This problem may be addressed by retaining a fairly broad range of genotypes in breeding populations and a more select group in deployment seed orchards (White et al. 2007). Local availability of a broad genetic base of a species under domestication enables responsiveness to changes in selection goals in tree improvement when, for example, pest and disease issues arise, or abiotic changes occur, or new products are sought by consumers. The large, diverse and high-performing genetic resources of Ks in Australia should enable future challenges to be met successfully.

Constitute a Potential Source of Germplasm for Other Programs and Possible Re-introduction

As well as serving local domestication efforts, the genetic resources of Ks in Australia could potentially contribute germplasm for infusion into existing or founding new programs elsewhere. For parts of the natural range in Africa where genetic resources of Ks have been very severely eroded, Australian material of known provenance could be considered for re-introduction and refreshment of those depleted resources, conditional on appreciation that most open-pollinated Australian seed could represent inter-provenance crosses. Re-introduction of genetic material of some *Pinus* species to Central America and Mexico has been undertaken by CAMCORE (Dvorak 2012) and similar action is under consideration for return of some provenances of *Eucalyptus urophylla* to Indonesia (Dvorak et al. 2008).

Conclusions

Large areas and numbers of African provenances and families of Ks have been established in northern Australian plantations, and numerous advanced-generation clones and families have been derived from the early introductions. This resource is likely to comprise the broadest genetic base of Ks in a single country outside Africa. It includes large numbers of provenances from the western region of the range of the species in Africa which are generally the more promising at sites in northern Australia. The great genetic variability for economic traits within these resources, shown by the results of trials mentioned in the present paper, and their high molecular diversity, together with the vast numbers of Ks trees present in northern Australia, should enable local selective breeding and conservation to proceed successfully.

Since some loss of genetic resources of Ks have occurred in Australia, there is a need to safeguard elements of the broad-based resources remaining through wise management. Based on other experience we suggest that a collaborative, recurrent selection breeding program that provides improved material primarily for commercial deployment should be considered for implementation by stakeholders as soon as possible.

The genetic resources described could also serve as a large *ex situ* reservoir of the germplasm of the species for infusion into existing programs elsewhere or initiation of new programs, or even conditional re-introduction to parts of Africa. In the Australian context, the wide range of primary and advanced-generation germplasm established in northern Australia and documented in this paper, provides a sound basis for further domestication and industrial plantation and woodlot expansion, when investment conditions are favourable.

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Obstacles to the Spread of Forest Certification Schemes on Small-scale Forestry in Japan

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Abstract

Forest certification is not yet popular in Japan even though 15 years have passed since the first Forest Stewardship Certification (FSC) forest certification scheme was introduced in this country. The area of FSC-certified forest in Japan is 393,000ha or 1.6% of the total forest area, and that of the Sustainable Green Ecosystem Council (SGEC), a Japanese certification scheme, is about 1.26 million ha or 5.0%. The authors conducted a survey about forest certification with employees and forest workers in nine forest owners' cooperatives in Shikoku Region (total number of respondents were 178), and an opinion survey of consumers about wood products and forest certification (total number of respondents were 228). Lack of short-term economic benefits was found to be the most important reason why many forest owners are not interested in forest certification. On the other hand, there are positive reactions by consumers about the impact of forest certification on sustainability of forest productivity. Showing future prospects as well as providing facilitative policy measures by local governments may be keys to increased adoption of forest certification by small-scale forest owners in Japan.

Keywords: Forest certification, FSC, price premium, SGEC

Introduction

As an effective tool to achieve sustainable forest management in the world, forest certification is becoming popular. Today, certified timber and wood products are common in European countries. On the other hand, forest certification is not very popular in other parts of the world including Japan.

The first Forest Stewardship Council (FSC) certified forest in Japan appeared in 2000. Since then, the area of FSC certified forest gradually expanded and reached about 393,000ha as of September, 2015. In addition, Japan's original forest certification scheme named the Sustainable Green Ecosystem Council (SGEC) was founded in 2003. Total certified forest area of SGEC is about 1.26 million ha. Even after fifteen years of introducing forest certification schemes, the total certified area is less than 7% of the total forest area of 25 million ha in Japan.

Traditionally, wood has been one of the most important and popular natural resources for Japanese people. Presently, most of the houses are made still by wood. Japanese forestry is suffering a plight being pushed by imported timber, but domestic timber production is maintaining about 20 million m^3 of volume per annum and forestry is an important industry in many of the mountain villages. Under such circumstances, why is forest certification not popular in the Japanese forest sector?

This paper aims to analyse the reasons of unpopularity of forest certification in Japan by conducting 1) a questionnaire survey of employees in forest owners' cooperatives in Shikoku Region, and 2) an internet-based consumer survey about wood products and forest certification.

Method

The authors conducted a questionnaire survey of employees, including managers, office staff and forest workers, in nine forest owners' cooperatives in Kochi, Ehime and Tokushima Prefectures in Shikoku Region. Three of the cooperatives were FSC certified as forest manager, another three were SGEC certified as forest manager, and the remaining three were not certified by any forest certification scheme. The authors visited all nine cooperatives and distributed questionnaires, and the responses were collected by the return envelope.

A consumer survey about wood products was conducted by using an internet research site. The survey was conducted to target different age group and gender categories to acquire the broad general opinion of the public. After explaining forest certification systems, the questionnaire asked about the consumer's willingness to pay for FSC certified wood products.

Results

Questionnaire survey of employees in forest owners' cooperatives

Questionnaires were distributed to nine forest owners' cooperatives as shown in Table 1. The number of questionnaires distributed depended on the number of employees in each cooperative. The authors visited all the cooperatives and requested management staff to distribute the questionnaires. The questionnaires were then later returned by an enclosed return mail envelope. The survey was conducted between December 5, 2014 and February 28, 2015. In total, 337 questionnaires were distributed and 178 were returned. Recovery rate was 52.8%.

Table 1: Number of distribution and return of the questionnaire for forest owners' cooperatives in Shikoku Region

Certification	Cooperative (Prefecture)	Number of distribution	Number of return	Recovery rate (%)
FSC	A (Kochi)	30	10	33.3
	B (Kochi)	50	22	44.0
	C (Ehime)	30	29	96.7
SGEC	D (Tokushima)	30	9	30.0
	E (Tokushima)	30	2	6.7
	F (Tokushima)	51	26	51.0
Non-certified	G (Tokushima)	30	15	50.0
	H (Ehime)	66	59	89.4
	I (Ehime)	20	6	30.0
Total		337	178	52.8

A few questions relating to forest certification were asked. For the employees in the forest owners' cooperatives that were certified by FSC or SGEC, the question was asked "what do you think about the significance of FSC (or SGEC) forest certification to your cooperative?" For the employees in the forest owners' cooperatives that were not certified by any forest certification scheme, the question was 1) "Do you know of forest certification?" and 2) "What do you think about the significance of forest certification in forest management in the case of your cooperative becoming certified?"

The results of the question for FSC certified groups is shown in Table 2. About 39% of the respondents were positive, while 21% were negative. Some positive and negative opinions in the free description column are as follows: "*FSC is good because of contribution for the environment*", "*We are proud of being certified by internationally renowned scheme*", "*It's very complicated and I don't know it well*", "*Philosophy of FSC is good but it's not well known*", "*It's too expensive*", and "*There is no economic return*".

Table 2: What do you think about the significance of FSC forest certification to your cooperative?

Point	Answer choices	Number	%
5	Very significant	7	11.5
4	Significant	17	27.9
3	Neither significant nor insignificant	24	39.3
2	Insignificant	6	9.8
1	Very insignificant	7	11.5
Total		61	100.0
Average point		3.48	

The result of the question for the SGEC certified groups is shown in Table 3. About 16% of the respondents were positive, while 43% were negative. Some positive and negative opinions in the free description column are as follows: "*Appropriate forest management has done after certified*", "*Managing forest with environmentally friendly manner is a matter of course*", "*I don't know much about forest certification*", "*People doesn't realize the importance of forest certification*", "*SGEC is not recognized by the people at all*", and "*Is there any merit for forest certification*?".

Table 3: What do you think about the significance of SGEC forest certification to your cooperative?

Point	Answer choices	Number	%
5	Very significant	1	2.7
4	Significant	5	13.5
3	Neither significant nor insignificant	15	40.5
2	Insignificant	10	27.0
1	Very insignificant	6	16.2
Total		37	100.0
Average point		2.59	

The result of the question for the uncertified groups is shown in Tables 4 and 5. A majority of the respondents didn't know of forest certification. Of the respondents who knew of forest certification, about 31% provided a positive answer and 20% provided a negative answer.

Table 4: Do you know of forest certification?

Answer choices	Number	%
I know it well	17	21.3

I have heard about it a little	18	22.5
I don't know	45	56.3
Total	80	100.0

Table 5: What do you think about the significance of forest certification in forest management in the case of your cooperative becoming certified?

Point	Answer choices	Number	%
5	Very significant	4	11.4
4	Significant	7	20.0
3	Neither significant nor insignificant	16	45.7
2	Insignificant	5	14.3
1	Very insignificant	3	5.6
Total		35	100.0
Average point		3.11	

Consumer survey about wood products

The questionnaire survey was designed so that the age structure and gender ratio of respondents would be equally distributed. The survey was conducted through a Japanese internet consumer survey site on January 27 and 28, 2015. Table 6 shows the attributes of the respondents.

Table 6: Consumer survey respondent's age-class and gender attributes

Age Class	Male	Female	Total
20-29	23 (10.1%)	22 (9.7%)	45 (19.7%)
30-39	23 (10.1%)	21 (9.2%)	44 (19.3%)
40-49	22 (9.7%)	25 (11.0%)	47 (20.6%)
50-59	22 (9.7%)	22 (9.7%)	44 (19.3%)
60-	22 (9.7%)	26 (11.4%)	48 (21.1%)
Total	112 (49.1%)	116 (50.9%)	228 (100.0%)

Several questions about forest certification were asked. Firstly, we asked about awareness of forest certification. While not surprising in Japan, more than 86% of the respondents had never heard about forest certification (see Table 7).

Table 7: Recognition of forest certification

Choice of the answer	Number	%
"I know it."	5	2.2
"I have heard about it."	26	11.4
"I never know it."	197	86.4
Total	228	100.0

Before the next question, the authors showed information about forest certification with pictures and figures, and asked the following question: "Do you have some interest in forest certification?" The answers of the respondents are shown in Table 8. About 44% of respondents said that they were interested in forest certification, while 25% said they were not interested.

Table 8: Do you have some interest in forest certification after getting the information?

Choice of the answer	Number	%

“Yes, I am interested in it.”	13	5.7
“Yes, I am slightly interested in it.”	88	38.6
“Neither yes nor no.”	66	28.9
“No, I am not much interested in it.”	31	13.6
“No, I am not interested in it at all.”	25	11.0
No response	5	2.2
Total	228	100.0

Consequently, the next question asked: “In case you purchase a wood product with forest certification, what price premium (%) are you willing to pay?” The answers of the respondents are shown in Table 9.

Table 9: What price premium (%) are you willing to pay for certified wood products?

Choice of the answer	**Number**	**%**
0%	61	26.8
Less than 5%	70	30.7
Between 5 and 10%	23	10.1
Between 10 and 15%	8	3.5
Between 15 and 20%	2	0.9
Between 20 and 25%	1	0.4
Between 25 and 30%	1	0.4
Over 30%	0	0.0
I don’t know	62	27.2
Total	228	100.0

Lastly, the authors asked about the impression of the forestry-related companies and shops who are dealing with certified wood products. The answers of the respondents are shown in Table 10.

Table 10: What is your impression about a company who is dealing with certified wood products? (multiple choice)

Choice of the answer	**Number**	**%**
“I agree with the efforts of the company.”	109	47.8
“I can trust the company.”	87	38.2
“I will prefer to buy the products of the company.”	74	32.5
“Nothing changes with this matter.”	43	18.9
“I don’t support the efforts of the company.”	8	3.5
Others	4	1.8
Total	228	100.0

Discussion

Results of the questions for FSC and SGEC certified groups showed that the effect of forest certification was not very significant on their management. In particular, the evaluations for SGEC certification were poor. Only 16% of the employees had positive answers but 43% had negative ones. The major reason of such poor evaluation was a low recognition of the scheme. In addition, a lack of economic return is another major reason. These two reasons are intimately related, because a forest certification system deeply depends on consumer choice in the market based on their environmental awareness and the popularity of the certification scheme.

SGEC was founded in 2003 as an initiative of the domestic forest sector. To compare with FSC, SGEC was established later and it was designed to enable easier granting of certification. Therefore, total area of SGEC certified forest is 1.26 million ha and this is three times more than that of FSC. This is because the scheme is led by the forest industry and many companies intended to follow the trend of the industry sector to facilitate SGEC. However, credibility of the scheme is not strong among forest owners. That is why few of the questionnaire respondents showed a positive impression of the SGEC.

In the case of FSC, evaluation by employees in forest owners' cooperatives is better than that of SGEC. However, FSC certified forests have the same problem as SGEC certified forests – that of inadequate economic return because of the scheme's low recognition. The average cost for assessment and annual audits of FSC is higher than that of SGEC. Therefore, employees of FSC certified forest owners' cooperatives must be more sensitive for economic return. The largest obstacle to the spread of forest certification in Japan is that the system of forest certification is not well known by the public, and this is common to both of the certification schemes operating in the country.

Results of the consumer survey clearly indicated the low recognition of forest certification systems. Only 2% of the respondents knew about forest certification and another 11% had heard about it, while the remaining 86% had never heard of it. This result is not surprising because certified wood products are not popular and are hard to find in home centres and timber retailers. Consumers have not had many opportunities to know about forest certification up until now. Forest certification is a market oriented strategy to distinguish environmentally sound wood products from other sources. It is therefore critical that the public know more about forest certification systems.

After reading the explanation about forest certification, more than 40% of the respondents showed an interest in it. This was nearly twice as many as those who had no interest. In addition, more than 30% of the respondents expressed that they would purchase certified products with less than 5% of a price premium and about 10% of the respondents expressed they would purchase certified products with between a 5 and 10% price premium. In total, 46% of the respondents accepted a price premium for certified products and this coincided with the figure of 44% who showed an interest in forest certification on the previous question.

As a result of two different surveys, the authors found that a low recognition of the certification systems is the largest obstacle to the spread forest certification throughout Japan. In other words, if certification becomes more popular among the society, many people would purchase certified wood products even though they would have to pay a price premium for them.

Subsidies provided by local government for acquiring forest certification is one facilitative measure to spread certification to forest owners. There are some examples of such policy measures around the country. However, helping a few advanced local forestry organizations and/or forest owners to attain certification is not an efficient way to use public money, and actually forest certification has not been spread enough in this fifteen years. It would be more effective to use money for advertising forest certification to the public. Many Japanese people do not even know about environmentally sound forest management, where timber production and environmental functions can coexist in harmony. This concept and that of a forest certification system, which is a sincere endeavour for pursuing such environmentally sound forest management, should be widely promoted.

The Japanese government has enacted a law on the promotion of the use of wood in public construction in 2010. It is a strong policy measure to boost domestic forestry and the timber industry as well as to facilitate a low-carbon society. On the other hand, the Japanese government has no effective policy measures to tackle illegal timber harvest and trade. The authors consider that both national and local governments should propagate forest certification systems as a tool of environmentally sound forest management and also promote the utilization of certified wood products in public construction. Subsidies should be paid for the users of certified wood products as well as their producers.

Conclusions

The importance of sustainable forest management is universally recognized. In Japan, the environmental awareness of the people is growing and utilization of wood is expanding. Therefore, forest certification is likely to be widely accepted by the Japanese public but increasing the recognition of forest certification is necessary. SGEC is currently in the process of mutual recognition with PEFC (Programme for the Endorsement of Forest Certification), and this process should be completed within a couple of years. This provides a good opportunity to promote to the public the forest certification systems available to the forest industry with support of the government. Considering the European situation, sooner or later certified wood products will be more common in Japan. In order to recover the market share of wood products in Japan, domestic forestry and the forest industry need to make further efforts toward expansion of forest certification.

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A Participatory Approach to Inventory and Extension to Improve the Management and Quality of Smallholder Woodlots in Papua New Guinea

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Abstract

Smallholder and community interest in planting trees to supply essential products and services is high in areas where local forest resources have been harvested or access is limited. Smallholders are commercially focused hence the species of interest are often those with high market value so they can be used for local as well as commercial purposes. The market value of the trees from these woodlots will depend on the quality of the end-products, which in turn is dependent on woodlot management effects on tree growth and form. Inadequate establishment and silvicultural management of these woodlots is widespread and leads to low quality trees and low yields. The effect is two-fold, namely a reduction in the products available for local use and sale, and diminished interest in continuing tree planting. Many of the practical issues of woodlot management can be addressed through targeted extension, although in PNG and many other developing countries extension services are severely limited. This paper reports a study of the use of a participatory approach to extension by engaging with lead smallholder farmers, becoming known locally as enumerators. The approach included targeted training and participatory demonstration plantings, but also smallholder engagement in inventory operations. The engagement in inventory activities was seen to provide the enumerators with insight into the outcomes of various woodlot management approaches. This paper explores the variation in effectiveness of enumerators to perform inventory activities, the utility of the inventory data to quantify woodlot performance, and the effect of the participatory inventory approach on enumerators' understanding of the outcomes of management methods and their capacity to play an informal extension role within their communities.

Introduction

Opportunity exists in Papua New Guinea (PNG) to develop a vibrant rural economy through the production of high-value forestry species. The PNG government has increased its commitment to expanding the planted forest sector in co-operation with customary landowners (Kavanamur 2010). While smallholder farmers are eager to pursue opportunities in planted forestry, they are often limited by a lack of knowledge of appropriate silviculture for their situation. Conventional modes of delivering silvicultural extension to these farmers are constrained by a lack of government and institutional resources as well as prescriptions that may not be compatible with the social and community features of smallholder producers in PNG. The development of peer-mediated learning may be an appropriate avenue for addressing both the resource and information compatibility constraints to forestry extension in PNG.

Peer-mediated learning is based on the concept that peers exert a significant influence on others' adoption of new practices (Kueper et al. 2014). It recognizes that innovations, regardless of their origin, are often diffused horizontally through social connections, where users modify them to suit individual circumstances (Rogers 2003). Peers may be defined as friends, habitual associates, or unfamiliar people with similar interests and/or experiences (Shiner 1999). Ma et al. (2012) proposes that such facilitated peer learning in a forestry context is characterized by making information accessible to participants and assisting dialogue and learning among all peers. Participants in these authors' pilot program were receptive to this interactive and participative approach, which offers an alternative to conventional expert-directed extension.

Participatory research is related to peer learning whereby the beneficiaries of the research are actively involved in its planning and implementation (Norman 2015). Participatory research recognises that uptake of research results (external knowledge) depends on it being relevant to the target users (local knowledge). The integration of external and local knowledge can enhance relationships between contributors (Emery 2000), research and environmental outcomes (Klooster 2002; Kaschula et al. 2005), and the sustainability of both external and local knowledge systems (Mercer et al. 2010; Munyua and Stilwell 2013). The participatory research approach has been used effectively in the Pacific to incorporate local knowledge to address community development and environmental issues (Addinsall et al. 2015).

The present study is part of a wider project to establish locally-adapted seed stands and silvicultural information for Teak (*Tectona grandis*) and other important local priority forestry species. The aim of this study was to combine the use of participatory research to build the capacity of progressive farmers to monitor Teak woodlots and potentially influence peer-mediated learning.

Methods

Study Area

The study was conducted in the island province of East New Britain (4.23°S, 142.27°E) in Papua New Guinea. Focal villages were located on the Gazelle Peninsula which is characterised by deep, fertile volcanic soils and an equatorial climate. The study was a component of a wider ACIAR-funded research project aimed at developing Teak for smallholder forestry. A total of four communities participate in the project and were selected based on their active participation in another development project for dryland rice production.

Enumerator Selection and Training

Local NGO OISCA, who has developed strong links with the focal communities over many years, conducted the selection of enumerators. A total of 7 enumerators were selected based on their demonstrated level of interest in tree planting, as well as their active participation within their respective communities. OISCA has two forestry technical officers that provided the main point of contact for the enumerators. Enumerators participated in two single-day workshops with the first covering silvicultural practices for establishing and maintaining woodlots and the second covering tree measurement, data collection and critical thinking. All enumerators were then involved in the measurement of 12 yield plots in a larger planting (OISCA). Yield plots were measured as outlined below in the inventory section.

Site Selection
Enumerators conducted a census of all smallholder Teak plantings within each of the four focal communities. The census included basic information related to owner, occupation locality, timing, and number and spacing of trees planted. In consultation with the enumerators, woodlot owners were categorised into one of three broad occupational categories i) community leader, ii) employed or iii) farmer. The results of the census were used to apply a random sample of six sites per community stratified for socioeconomic category with 2, 1 and 3 sites for community leader, employed and farmer respectively.

Inventory
Enumerators were responsible for conducting an inventory of the six plots in each of their respective four communities (n=24 plots). Enumerators were paid a stipend for six months, which equated to a total of 24 days paid work (i.e. 1 day per week). Each yield plot consisted of 20 trees (four rows of five trees) located randomly at least two rows from the edge of the woodlot. Total tree height (m) bole length (m) and stem diameter over bark at 1.3m (DBHOB) were measured for all trees. Stem form and branch size were assessed for trees over 2m following the classification system outlined for Teak in Keiding (1986) (Table 1). Site suitability was assessed according to the appropriateness for growing teak and grower management of trees and classified according to a simplified three-point scale (1-low, 2-Med, 3-High).

Table 1: Stem form and branch size classification system for Teak (Keiding et al. 1986) used to assess the 36 yield plots in this study

Variable	Description
Persistence of axis	**The total height of the tree is divided visually into 4 equal portions. The length of unbroken axis is scored according to the quarterly section to which it can be followed.**
Class	Description
1	Double or multiple stem from ground level
2	Axis (single stem) branches out in the lowest quarter of tree
3	Axis branches out in 2nd quarter of tree
4	Axis branches out in 3rd quarter of tree
5	Axis branches out in 4th quarter of tree
6	Complete persistence
Straightness of stem	**Straightness is only recorded for persistence classes 4-6, because judgement of bends on that relatively small portion of stem in classes 1-3 is considered irrelevant.**
Class	Description
1	Crooked - more than 3 serious bends
2	Crooked 1-2 serious bends
3	Slightly crooked, many bends
4	Slightly crooked, few bends
5	Straight
Branch Size	**The classification of branch "coarseness" is a relative measure of branch size in proportion to the stem at the foot of the branches.**
Class	Description
1	Very heavy: branches from ½ - ¾ of stem
2	Heavy: branches about ½ of stem

3	Medium: branches between ½ and ¼ of stem
4	Light: branches around ¼ of stem
5	Very light: branches less than ¼ of stem

Data Analysis
The effects of the grower socioeconomic and site suitability categories on survival and diameter were evaluated using a General Linear Model (GLM) (Minitab v.17). Pairwise differences (at 0.05 level) between the treatments were tested using Tukey-Kramer method of multiple comparisons. Statistical correlation between height and diameter was determined using Pearson's correlation coefficient. A site suitability index was calculated according to Equation 1.

Equation 1: Site suitability index (ssi) for each grower socioeconomic category (Community Leader, Employed, Farmer and Non-Government Organisation - NGO).

$$ssi = \sum_{c=3} c \times f$$

where c = site suitability category (1, 2 or 3); and f = the percentage of yield plots within site suitability category.

Stem form and branch size measures were conducted on trees with a height of greater than 2m, which resulted in a high proportion plots categorised as low suitability being omitted. Indicative results for these measures are presented for site suitability, but not grower socioeconomic categories since the omission of low suitability sites had a disproportionate effect on the Community Leader and Employed growers where 37.5% and 25% of plots were of low site suitability.

Results

The census revealed a total of 118 smallholder Teak plots with an average of 65.8 trees/plot for a total of 7572 trees planted across four communities. The relative proportion of the three socioeconomic categories were 33% Leaders, 17% Employed and 60% Farmers. The trees ranged in age between 1 to 3.75 years. Enumerators participated in the measurement of the 12 yield plots in the OISCA planting and survival, but all were not able to implement the measurement of their six plots independently. The yield plots were measured and recorded by enumerators when accompanied by a scientist. After an initial training refresher before measuring the plots, every effort was made by the scientist to not influence the measurement and recording activities undertaken by the enumerators. The height and diameter data collected by enumerators were highly correlated with a correlation coefficient (R2) of 0.92 (Figure 1).

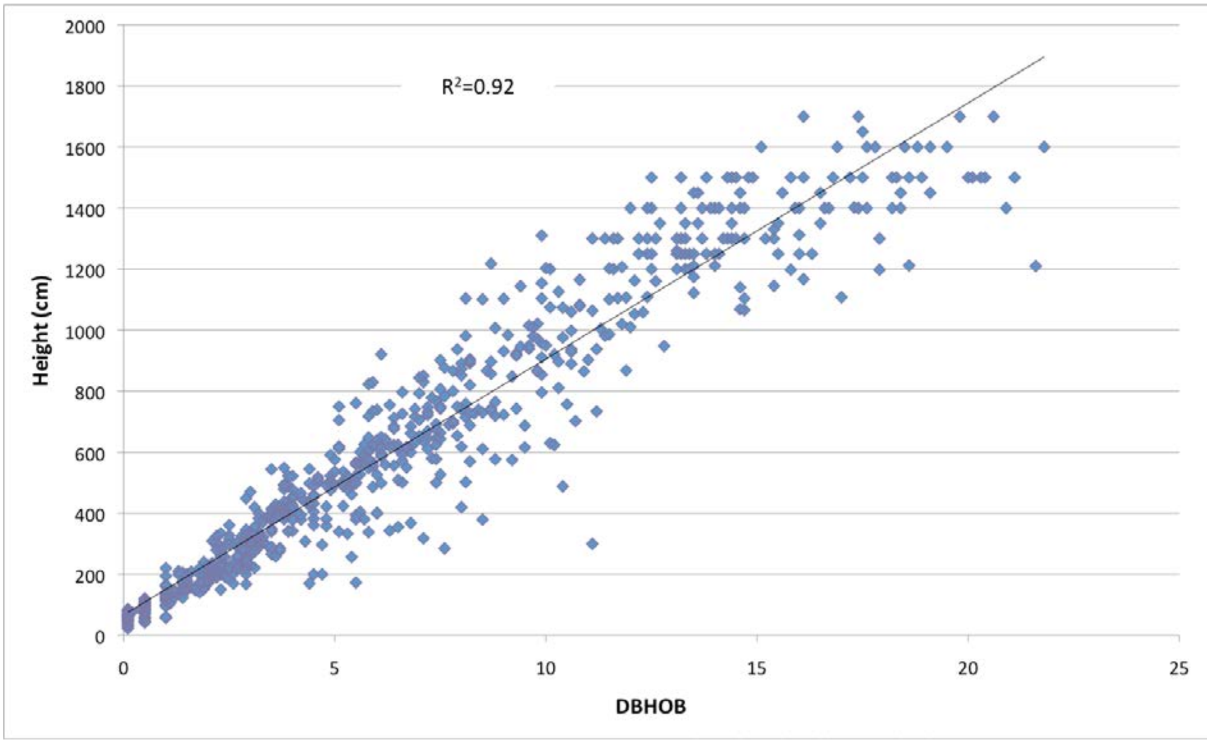

Figure 1: Relationship between tree height and stem diameter (DBHOB) for the trees measured by enumerators in this study.

Site Suitability

The site suitability index was greatest for the NGO grower category (3.0) and lowest for Community Leader (2.0) (Table 2). While the Farmer (2.58) and Employed (2.5) growers were intermediate for site suitability index, they contrasted in their distribution. Employed growers were found to have a skewed bimodal distribution whereby 75% of growers were categorised as having high (3) site suitability 25% as low (1). All Farmer growers had sites considered to be of either High (3) or Moderate (2) suitability.

Table 2: The percentage of plots categorised by their site suitability (1-Low, 2-Moderate, 3-High) for growing trees within each grower socioeconomic category (Community Leader, Employed, Farmer and Non-Government Organisation - NGO). Site suitability index (ssi) was calculated using Equation 1.

Grower Category	**Site suitability**			
	1	**2**	**3**	**ssi**
Community Leader	37.5%	25%	37.5%	2.0
Employed	25%	0	75%	2.5
Farmer	0	41.7%	58.3%	2.58
NGO	0	0	100.0%	3.0

A total of 36% of sites had no identified issues and were categorised highly suitable for growing Teak. In order of importance (number of yield plots) the identified site suitability issues were weed competition (32%), planted in an old garden area (16%), planted in highly competitive conditions such as under cash crops (8%) or secondary regrowth (4%), site affected by fire (4%) and site affected by poor drainage/waterlogging (4%).

Tree Survival

Percent survival was significantly ($P<0.05$) greater in the NGO (91%) and Farmer (86%) yield plots compared with both Community Leader (68%) and Employed (68%) plots (Figure 2). Percent survival was also found to be significantly greater ($P<0.05$) in sites of high (87%) and moderate (81%) suitability compared with that of low (55%) suitability (Figure 3). No statistical interactions were found for survival between grower socioeconomic category and site suitability.

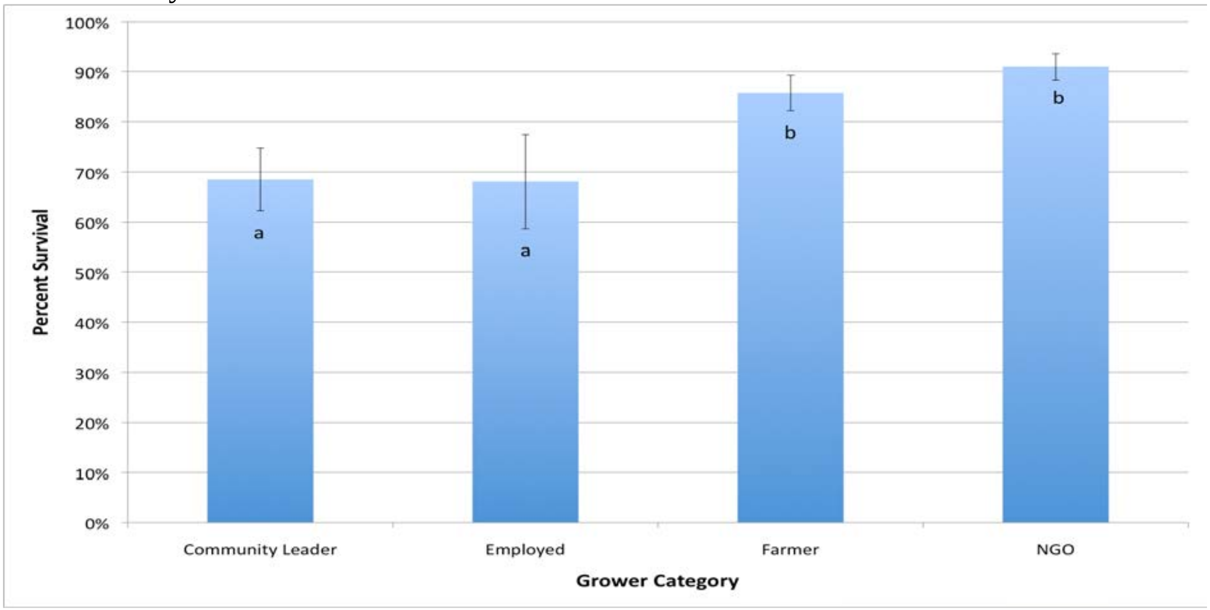

Figure 2: Percent tree survival measured in 36 yield plots across four grower socioeconomic categories (Community Leader, Employed, Farmer and Non-Government Organisation - NGO). Vertical error bars represent standard errors of the mean. Grower categories that share lower case letters are not significantly different (0.05 level).

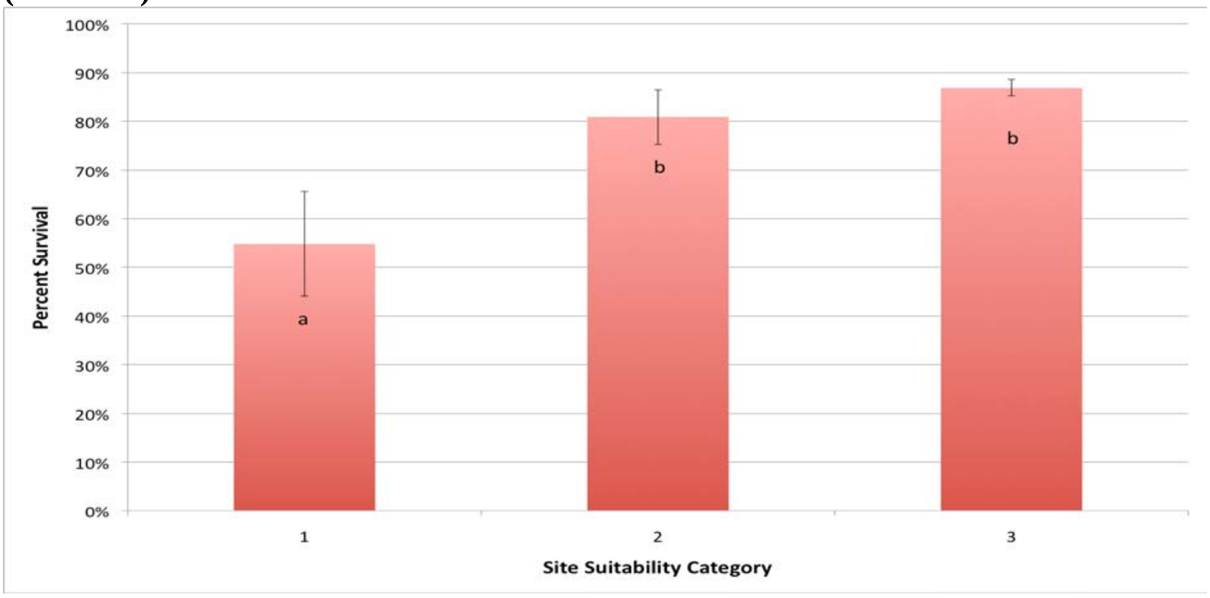

Figure 3: Percent tree survival measured in 36 yield plots across three site suitability categories (1-Low, 2-Moderate 3-High). Vertical error bars represent standard errors of the mean. Site suitability categories that share lower case letters are not significantly different (0.05 level).

Annual Diameter Increment

Annual diameter increment was significantly ($P<0.05$) greater in the NGO (4.5cm) yield plots compared with all remaining plots. Farmer (3.2cm) plots had a significantly ($P<0.05$) greater annual diameter increment than Community Leader (2.6cm) plots, with Employed (2.9cm) being intermediate between and not significantly different from either (Figure 4). Annual diameter increment was found statistically ($P<0.05$) different between all three site suitability categories in descending order high (3.6cm), moderate (2.5cm), and low (1.6cm) suitability (Figure 5). No statistical interactions were found for annual diameter increment between grower socioeconomic category and site suitability.

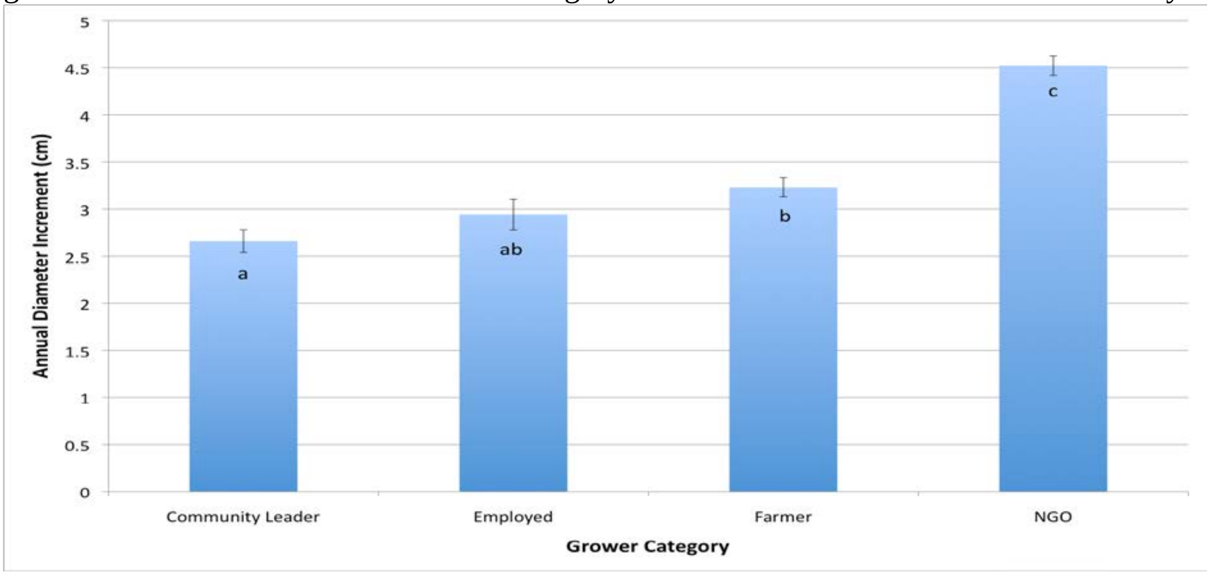

Figure 4: Annual diameter increment (cm) measured in 36 yield plots across four grower socioeconomic categories Community Leader, Employed, Farmer and Non-Government Organisation - NGO). Vertical error bars represent standard errors of the mean. Grower categories that share lower case letters are not significantly different (0.05 level).

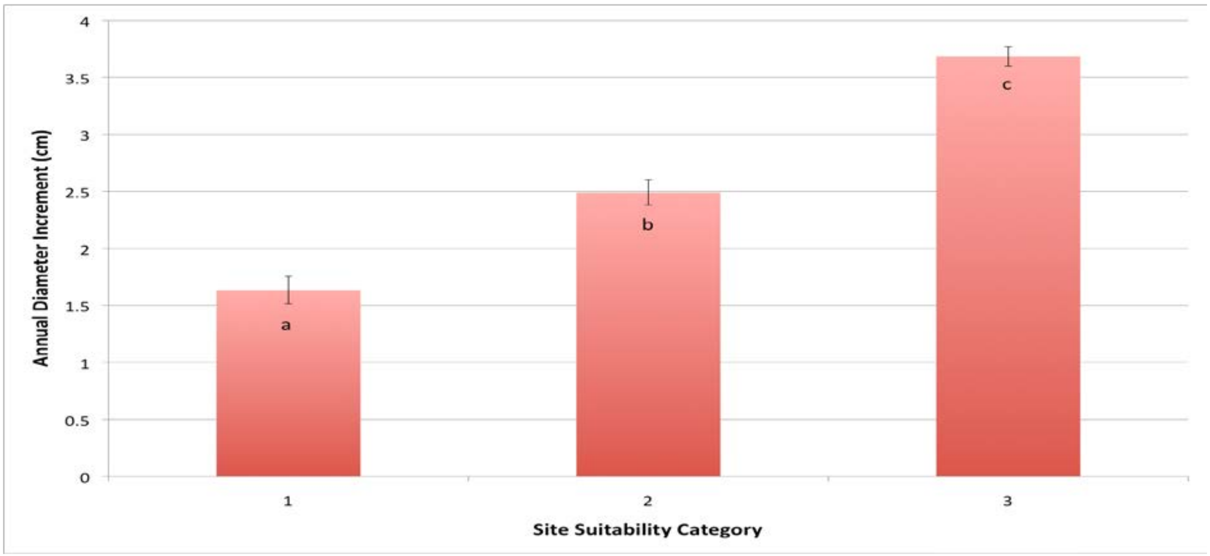

Figure 5: Annual diameter increment (cm) measured in 36 yield plots across three site suitability categories (1-Low, 2-Moderate, 3-High). Vertical error bars represent standard errors of the mean. Site suitability categories that share lower case letters are not significantly different (0.05 level).

Stem Form and Branch Size

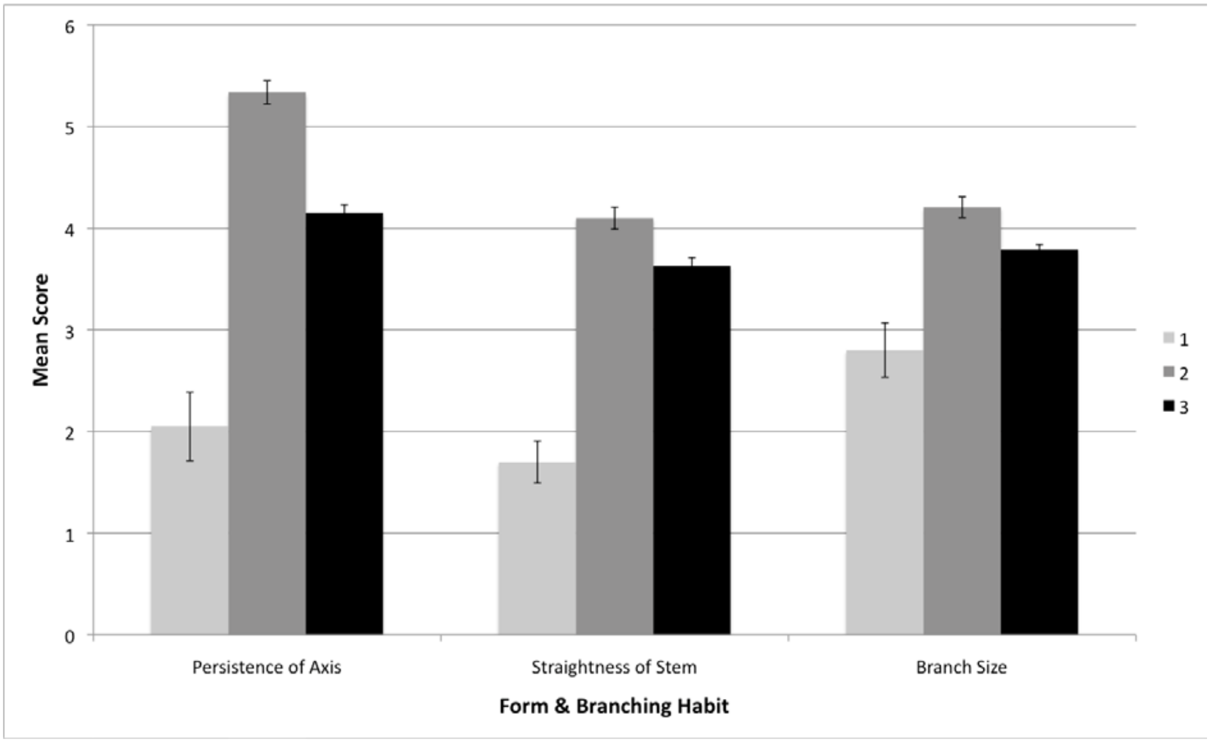

Figure 6: Persistence of axis (scale of 1 to 6), straightness of stem (scale of 1 to 5) and branch size (scale of 1 to 5) measured in 29 yield plots across three site suitability categories (1-Low, 2-Moderate, 3-High). Higher mean scores in all measures relate to a better tree form for each of these traits. Vertical error bars represent standard errors of the mean.

Stem form and branch size were found to be substantially lower in sites with low suitability compared with those from moderate or high suitability. Similar results between the latter site suitability categories were found for straightness of stem (slightly crooked, between few and many bends) and branch size (Light: branches around ¼ of stem). For trees growing in sites with moderate suitability trees were found to branch out in the final quarter of the tree (persistence of axis class 5), whereas those growing in sites of high suitability branched out lower on the trunk (i.e. in the 3rd quarter) (Figure 6).

Discussion

An aim of the study was to determine if involving progressive landowners in participatory research would have an effect on their capacity to monitor Teak woodlots. Our measure of success for this aim was that enumerators could independently implement the census and inventory following the training and practical activities. We found that enumerators independently and successfully carried out the census of growers and the numbers of trees planted in their woodlots. This data allowed the planning of the inventory work with the enumerators, however none of the enumerators successfully implemented the inventory independently. Discussions with the enumerators identified some minor practical reasons, but the study was not able to quantify the underlying issues preventing the implementation of the inventory. Anecdotal evidence from working with enumerators suggests that their confidence to implement independently is likely to have played a significant part. When the inventory was conducted in the presence of a scientist, it was evident that all enumerators had the capacity to measure the trees, assess the suitability of the site and accurately record the data. This is supported by the strong positive correlation between height and diameter, as well as the statistical differences in survival and diameter increments for the three site suitability categories. Therefore the study successfully demonstrated that progressive farmers have the capacity for participatory research and monitoring of Teak woodlots. Further work with enumerators is essential to build their capacity to implement such work independently.

The secondary and longer-term aim of this research was to determine if the capacity to monitor and understand the issues of the woodlots could potentially influence peer-mediated learning. Observations of peer interactions and transfer of knowledge from enumerators and landowners during the inventory provides some anecdotal evidence of this occurring, however these observations may have been influenced by the presence of the scientist. This study included only preliminary observations of peer learning and no systematic data were collected to confirm its utility in this study. Further research to facilitate and measure peer learning is therefore required to determine its efficacy in forestry extension in PNG.

The study demonstrated that differences in site suitability had an effect on the survival, growth and form of Teak grown under smallholder conditions. Lower measures of site suitability were largely determined by maintenance of the planting (weed competition and fire) and site selection (old gardens, under cash crops, under secondary regrowth and waterlogging). Growers categorised as Community Leaders and Employed had a higher proportion of sites with the lowest site suitability measure (37.5% and 25% respectively) compared with Farmers (0%). This was largely due to lower follow-up maintenance of the sites, which was a consequence of less available time for woodlot maintenance. This demonstrates the importance of matching the size of the woodlot with the time and resources available to maintain the site after planting. Interestingly all three smallholder categories (Community Leaders, Employed and Farmers) had sites categorised with the highest suitability score (37.5%, 75% and 58.3% of sites respectively). This finding is important as it shows that all types of smallholders can potentially manage woodlots.

The annual diameter increments of trees grown by the NGO were over 1cm greater than all smallholder farmer plots. The growth in the NGO plots provides a demonstration of the growth potential of Teak in this area of PNG and should be used to highlight the advantages of good silvicultural practice for smallholder growers. Given the resource constraints for smallholder forestry extension, exploring options such as peer-mediated extension is important so that future woodlots can attain their yield potential and maximise benefits to the growers.

Conclusion

Developing the planted forest sector in PNG will depend upon facilitating wider adoption of smallholder forestry. This study demonstrates the potential of smallholder Teak plantings in East New Britain. There is however a need for improved silvicultural management of these woodlots so that they can reach their yield potential. Many of the issues can be addressed through delivery of extension, but with current low-levels of government and private resources available for extension other avenues for engaging smallholders is required. The concept of peer-mediated extension has been demonstrated to be effective in other parts of the world and may also be applicable in the social context of PNG. Further consideration of peer-mediated forestry extension is therefore required with the view to developing more independent and sustainable delivery of forestry extension in PNG.

Acknowledgements

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Engaging Communities in Forest Landscape Restoration: Experiences from Biliran Province, Philippines

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Abstract

Engaging communities in forest landscape restoration is indeed a great challenge. The forest landscape in Barangay Kawayanon has been a recipient of several reforestation programs in the early 1980s, but illegal logging, fuelwood gathering, grazing, frequent forest fires and the lukewarm involvement of local people have kept the area as permanent grassland for more than three decades. Community people do not engage in forest restoration activities out of interest but rather due to the cash incentive they have from their involvement. After reforestation project implementation, their participation greatly declines. In support of the National Greening Program of the Philippine Government, a pilot reforestation project was implemented in May 2014 in Kawayanon by the ACIAR Watershed Rehabilitation Project Team. A series of meetings, consultations of the stakeholders, community mapping and an information campaign were undertaken by the team prior to the implementation of the project. Consequently, community members have been actively engaged in this project. They planted and are maintaining nearly 20ha of trees which are growing vigorously and have not been damaged by forest fires or grazing. This research has identified a number of keys to successful engagement of communities in forest landscape restoration. These include social preparation, deployment of community organizers, encouraging cooperation among stakeholders, an information and education campaign, and capacity building. Responsive leadership, weekly meetings with the community organizers and the people's organization, transparent financial accounting, and support for livelihoods (i.e. payments for seedling production, and plantation and agroforestry system establishment) likewise enhanced community engagement.

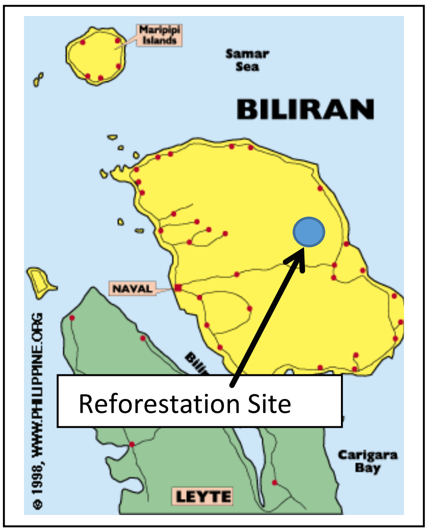
Keywords: Engaging communities, community-based forest management, forest landscape restoration, and watershed rehabilitation

Introduction

Engaging communities in forest landscape restoration is not a new concept in the Philippines. Since the 1970s, forest landscape restoration through reforestation programs in degraded forestlands involving upland communities have been practiced in the country. Harrison et al. (2004) found more than a dozen of these programs which were integrated under the Community-Based Forest Management (CBFM) Program implemented in 1995 through Executive Order 263 during the Ramos Administration as a national strategy to ensure the sustainable development of the Philippines' forest resources. The CBFM program unifies all current people-oriented forestry programs of the Philippine government which emphasizes the engagement of communities in and near public forests aimed to protect, rehabilitate, manage, conserve and utilize the resources (Harrison et al. 2004). Hull (2005) also stressed the engagement of forest peoples in the long-term conservation of tropical forests to minimize degradation, conserve biodiversity, maintain environmental services and strengthen people's livelihoods through effective forest governance. And the Philippine Government believes that such an approach will bring success to the forest landscape restoration work undertaken in the country.

The most recent program geared towards forest landscape restoration is the National Greening Program (NGP) through Executive Order 26. On the 24th day of February 2011, the NGP was signed by President Benigno Simeon C. Aquino III as a major strategy of the Philippine Government to alleviate poverty and food security, conserve biodiversity, and mitigate and adapt to climate change. The NGP aimed to plant some 1.5 billion trees covering about 1.5 million hectares for a period of six (6) years in the following lands of the public domain: forestlands, mangrove and protected areas, ancestral domains, civil and military reservations, urban areas under the greening plan of the Local Government Units (LGUs), inactive and abandoned mine sites, and other suitable lands. The philosophy behind the NGP is similar to CBFM where communities should be engaged in all phases of the program. However, despite the established system of engaging communities from the past until the present program, success in community engagement in forest landscape restoration in Biliran Province remains a great challenge.

The Pilot Reforestation Site



The site of the pilot reforestation program is Barangay Kawayanon, Caibiran, Biliran Province covering 26.6 hectares and located 11.59 north (latitude) and 124.52 east (longitude) which is about 17 kilometers from the municipality of Naval and 3.5 kilometers from the municipality of Caibiran. The prevailing climate condition is Type 2, characterized by having no dry season and with maximum rainfall between November and January. The site has been a recipient of several reforestation projects in the past but considerable grasslands remain due to forest fires, grazing, fuelwood gathering and illegal cutting. These prevailing conditions become a great challenge to the implementation of the pilot reforestation program within the site.

Methodology

In response to the need for rehabilitating the denuded uplands in Biliran, the Australian Center for International Agricultural Research (ACIAR) Research Team at the Visayas State University (VSU), in collaboration with the Department of Environment and Natural Resources (DENR), established a pilot reforestation program within the 26.6 hectares of grasslands in Barangay Kawayanon, Caibiran to support the NGP. The program aims to improve the rehabilitation of critical watersheds in the area by identifying the key technical, socio-economic and policy drivers for successful rehabilitation and then applying this knowledge to design and pilot-test initiatives to improve the outcomes from watershed rehabilitation. Such outcomes include improved watershed health, sustainable land use, and increased livelihood opportunities for rural upland poor leading to decreased poverty. Following the protocols of engaging communities in watershed rehabilitation, at the outset initial meetings and discussions on the various research and development activities, identification of stakeholders and deployment of two community organizers within the partner community were undertaken. Together with the research team members and DENR officials, initial activities were followed by several meetings, information and education campaigns, and capacity building activities involving not only the partner community but also the local barangay officials.

Results and Discussion

The results presented here are not yet conclusive as the program was assessed at its mid-term implementation stage but the initial findings are providing vital signs for program success. While working on the ground, the team identified a number of key factors that have direct influence in engaging communities within the partner community. Nonetheless, the team needs to push forward and work on these key factors (enumerated below) on a sustainable manner to achieve the desired outcome.

Keys to successful community engagement

There are several key issues to consider when implementing forest landscape restoration in a certain community depending on the prevailing social, economic and environmental factors. The ACIAR research team, based on field experience, would like to share how the team capitalized on these issues or factors and made significant milestones towards achieving the successful implementation of the pilot reforestation program in the partner barangay or village.

Social Preparation

Social preparation in landscape restoration or watershed rehabilitation is a great challenge to DENR and other line agencies and non-government organizations (NGOs) in Biliran Province. While this has been the usual method in upland development, particularly for reforestation, social preparation has not been intensively undertaken to prepare, stimulate the interest of and motivate community residents to participate in landscape restoration. Interviews and focus group discussions conducted by the ACIAR research team revealed that “cash incentive or payment” has become the main command and control mechanism of residents’ involvement rather than their interest or desire to restore landscapes or watersheds. With the support from the Australian Government, the research team decided to intensify social preparation (together with livelihood discussed in the succeeding paragraph) through several approaches including baseline community data and community mapping, delivery of vital information about the project to be implemented through meetings, open line communications and consultation with the concerned groups or stakeholders, involvement and collaboration of stakeholders in decision-making, and capacity building through training and educational tours (see also DSE 2013, JICA 2009 and UNICEF 2013 on the strategies the project adopted). Consequently, the members of the Kawayanon Farmers Association, Inc. (KFAI) have raised their awareness and inculcated the vital importance of the landscape restoration program in their barangay. Arousal of their interests through their involvement in various activities and group meetings became noticeable.

Deployment of community organizers

One of the crucial components in landscape restoration activity is the deployment of responsive community organizers. Estoria et al. (2005) revealed that community organizers are effective in forming people's organizations, motivating people to participate in voluntary activities, and encouraging cohesiveness among members of the people's organization. Hence, the project deployed two community organizers within the partner barangay. The two organizers keep the peoples' organization moving by joining and monitoring the day to day activities. They provide advice and suggest solutions on some issues that can be addressed at the local level. They call the attention of the officers and members of KFAI whenever problems arise and arrange meetings so that solutions can be formulated. They conduct weekly meetings to evaluate progress and determine whether some things have been missed. They see to it that every detail of the pilot reforestation program is implemented according to plan. They seek further advice from the project leader and other members of the research team as the need arises. In this way, the implementation is moving towards the targeted output.

As pointed out by Mangaoang and Cedamon, 2004, mere participation of local people in activities like forest research (in their case study) and other forest-related activities such as landscape restoration is not enough. These authors added that an ongoing or open interaction between the implementers and the local people is crucial in paving the way to partnership-building. The organizers deployed within the community adopted such findings thereby creating an open interaction system that strengthened partnership and engagement of all the stakeholders.

Cooperation of appropriate stakeholders

Gathering the right people to support the successful implementation of the pilot reforestation program within the partner barangay is another crucial component that the project considered. At the start, site selection for the pilot reforestation program was a great challenge for the research team. A solution was achieved through consultation meetings with DENR officials, LGU Officials, and several peoples' organizations. After site selection, meetings with the peoples' organization including the barangay officials of the selected site together with DENR officials were also undertaken to inform everyone about the pilot reforestation program implementation, the people involved, their respective role, and the benefit they will gain from the program. When all things were set and stakeholders informed, the program implementation began. Whenever problems arise, the stakeholders are consulted and solutions are formulated. Even those stakeholders with minimal involvement (as in the case of the Barangay officials) should be consulted from time to time in view of their contribution for the success of the program. They can make ordinance that could deter grazing and forest fires within the planting site and could impose penalties for all violators. Their role is indeed crucial, hence their involvement is crucial.

Information and education campaign

An information and education campaign (IEC) is also a vital component in engaging communities in forest landscape restoration. A study conducted by Gravoso et al. (2009) revealed that the flow of information (tree registration policies in this case) can be further improved through posters and presentation of seminars for farmers. Hence, in the course of the pilot reforestation program implementation, all barangay residents including the school children were informed about the project. Included here were meetings and workshops with the residents and officials in the barangay, an information campaign within the school, distribution of leaflets, and installation of information boards within the barangay including the plantation site. Through this strategy, all barangay residents including nearby communities became aware of the program being implemented. Related socio-economic and biophysical studies within the area involving interviews and surveys were also used as avenues for information dissemination. These activities further enhanced the information and education campaign of the project. In a barangay or village, residents can easily spread the information because everybody knows each other. The IEC thus enabled them to share any information about the project, and particularly to tell people to protect the established plantation.

Capacity building

Capacity building is another crucial factor to raise the level of awareness, interest and motivation of KFAI members to engage in the program. Thus, the research team together with the two deployed community organizers and DENR officials conducted a series of training activities for the KFAI members. These training activities covered tree nursery establishment, quality seedling production, seedling care and maintenance, mother tree selection, and plantation establishment, maintenance and protection. Consequently, a nursery with elevated hardening beds was established and the seedlings raised are high quality planting stock. Four months after planting in the harsh grassland, these seedlings showed vigorous growth performance reaching an average height of about one meter. At present, there are no grazing and forest fire incidents within the plantation sites. This is in part a result of the communities' awareness and cooperation, whereas adjacent grassland areas have suffered from several forest fires in recent weeks.

Another important activity conducted by the research team was the educational tour by KFAI members to a successful CBFM project of YISEDA (Young Innovators for Social and Environmental Development Association, Inc.) in Maasin, Southern Leyte. During this event, YISEDA officials gave lectures on the various aspects of their experiences including financial accounting, transparency and accountability, and provided useful insights on the successful implementation of their CBFM project. This activity also provided KFAI members very relevant and applicable information on how to undertake a successful pilot reforestation program in their barangay.

Responsive leadership

The leadership of the program at different levels has been responsive to the needs of the KFAI members for them to carry out various activities of the pilot reforestation program. The research team, the community organizers, DENR officials and KFAI officers conducted frequent meetings to ascertain that target activities are implemented according to plan. These meetings were also the avenues to resolve conflict among stakeholders, clarify issues and concerns, and address other important matters. The research team realized that a problem or conflict that started to emerge must be brought immediately to the leaders to avoid a perilous spread. Frequent meetings with the president of the people's organization are also conducted by the community organizers to discuss matters that will affect the entirety of the project implementation. In this way, the president also relays the essential information to the group as often as possible, thereby providing an open communication line for all group members.

Weekly meetings

Weekly meetings are also important particularly at the outset of the pilot reforestation program implementation to determine the aspiration of the partner people organization, past and present problems related to their involvement, and the benefits they will derive from the program. Weekly meetings were also the avenues to discuss concerns and issues related to the program implementation, and to resolve conflicts as mentioned above. As the group moves on the right track, meetings were changed to a monthly basis except when crucial issues arise that need immediate solutions.

Transparent financial accounting

Transparency in all transactions particularly on financial matters is a very important key to unity among the members of the peoples' organization. Thus, financial transparency was always emphasized during meetings and group activities. Interviews and focus group discussion conducted by the research team in a number of people's organization in Biliran showed that conflicts arise among members due to non-transparency of project financial transactions.

Financial accounting is also essential in providing members of the people's organization transparent disbursement of funds on where and how it is used. Confidence of the members of the people's organization to join and perform their specific tasks also hinges on the honest handling of funds. When members know there is clear and fair distribution of money for their specific outputs, they are united and move according to the targeted output.

Livelihoods

One of the crucial factors to consider for the successful engagement of communities in landscape restoration is the livelihood component. Engagement of the organization becomes shaky and superficial when the members will not obtain something to satisfy their daily needs. In fact, membership of KFAI at the start of the program implementation was attended by 170 people but sharply declined down to 23 when the majority found that the livelihood opportunities of the program are insufficient to support their daily subsistence. The shaky initial implementation of the program, however, became the barometer for the research team to identify who are the reliable members that can carry out the tasks ahead. As the program implementation progresses, all the remaining 23 members gladly received their monetary compensation on weekly basis as wages for their engagement in various activities.

Nevertheless, there are cases where some members have aired their aspiration for better opportunities and compensation. At this juncture, the research team decided to find augmentation funds specifically for the livelihood component. With the help from DENR officials in Biliran Province, additional funds were allotted for the livelihood component of the program providing KFAI members better opportunities than the previous situation. The livelihood component that will soon be implemented is focused on an agroforestry system which is beneficial to both the environment and the partner organization and the community as a whole.

Emtage (2004) found that households that intend to plant trees on land they owned or managed have higher levels of resources than those that who do not intend to plant. Jesusco et al. 2009 also found that providing financial assistance is the primary condition that would encourage tree planting among smallholders in Leyte Province. This means that the project needs to support the partner community in finding livelihood opportunities that could possibly increase their level of resources and encourage them to fully engage in the pilot reforestation program in their village. The research team is hopeful that with the proposed agroforestry establishment within the pilot site, the partner organization will be more enthusiastic in their engagement.

Challenges encountered

A number of challenges occurred during the course of the program's implementation. These include sustainable livelihood opportunities, fair distribution of wages, unnecessary cash advances and absences. The livelihood opportunities become a reference point for the members to sustain their involvement in the program implementation. A majority of the original KFAI members disengaged due to the absence of such a livelihood opportunity that is crucial for their survival. Fair distribution of wages on the other hand emerged when some members found that somebody received higher pay than others. Spreading the monetary benefits equally and justifiably is also a big challenge when engaging communities in the pilot reforestation program in this part of Biliran Province.

Members of KFAI would also like to make cash advances as often as possible particularly when they know that funding is available with the president and treasurer. This happened when special occasions demand celebrations like the annual fiesta. After receiving the cash advances, for some reason the members do not join the field activities the next day. When they find a better livelihood opportunity on certain days, they are also absent for obvious reasons thereby affecting the planned activity for the week.

Conclusion and Policy Implications

It is clear at this point that of all the factors influencing the engagement of the KFAI members in the pilot reforestation program in Barangay Kawayanon, livelihood is the most crucial component. Attendance of members in all program activities is largely driven by the available remuneration opportunities. This is a single driving force that would entice community members to engage in forest landscape restoration. It is vital that in all reforestation initiatives, a livelihood component should always be seriously considered. Nonetheless, other factors are also vital for the successful engagement of all the stakeholders and should therefore be seriously considered together with livelihood opportunities when conducting similar reforestation initiatives in other parts of the province or country.

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