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ARTICLE

Improving the smallholder balsa value chain in East New Britain Province, Papua New Guinea

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ABSTRACT

Ochroma pyramidale (balsa) is a fast-growing tree, grown as a plantation crop by both companies and smallholders in East New Britain Province (ENB) of Papua New Guinea (PNG). The ENB balsa industry is entirely export-oriented, producing 9% of the world's processed balsa. Balsa products have outstanding strength-for-weight qualities and an increasing market in high-technology composite materials, such as wind turbine blades and transportation applications. *Ochroma pyramidale* is attractive to smallholders because it is a relatively low labour-input crop with competitive returns and a relatively short (5–6 years) harvest cycle. There are *c.* 6200 ha of balsa plantations in ENB, including *c.* 1900 ha grown and managed by *c.* 1500 individual smallholder farmers. A workforce of some 2500–3000 is engaged in balsa harvest, transport, processing and export in ENB. These activities operate under the regulatory oversight of the PNG Forest Authority, which also plays an 'honest broker' role in transactions between processing companies and smallholders. The major challenges faced by the ENB balsa industry relate to balsa plantation productivity and sustainability, market access in the context of forest certification and legality verification, and product development and diversification. This paper reports outcomes of a research project supported by the Australian Centre for International Agricultural Research, in which Australian and PNG researchers worked with the ENB balsa industry to address these challenges. The project conducted balsa sector surveys and silvicultural experiments, introduced and tested genetic resources, and undertook both knowledge and product development for the industry. Key research outcomes included the development of a 'smallholder friendly' silvicultural regime that obviates the need for thinning or refilling, and should deliver greater merchantable volume and value recovery for growers; an updated *Balsa Manual* from which smallholder learning resources were developed and integrated into an established ENB agricultural training program; confirmation that harvesting recovery from smallholder plantations was consistent with log quality requirements, and that harvesting and transport activities were operating efficiently; and the development of new balsa panel products particularly suited to apartment interiors. Research also facilitated the adoption of certification in the ENB balsa sector, and identified targeted regulatory reform as desirable to support the continuing development of the ENB balsa industry.

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Introduction

The overwhelming majority, 88%, of Papua New Guinea's (PNG) population of *c.* 7.3 000 000 live in rural areas (2011 data: National Statistical Office 2015), and derive their livelihood from various forms of primary production on their land. These smallholder farming systems are very diverse, reflecting PNG's geographic, biological and cultural diversity; systems vary among and within geographic regions, presenting 'a bewildering variety of garden and tree crops' (Filer & Sekhran 1998; p. 38; see also Bourke & Harwood 2009). Trees are an important component of many of these traditional production systems. Plantation crops, notably cocoa (*Theobroma cacao* L.), coconut (*Cocos nucifera* L.) and coffee (*Coffea arabica* L.), were introduced with European colonisation in the 19th century, and have become important cash crops in some regions; oil palm (*Elaeis guineensis* Jacq.), introduced more recently, has expanded rapidly in some regions in the past 50 years, becoming PNG's most valuable agricultural export since the year 2000 (Bourke & Harwood 2009).

Although smallholders almost universally grow and manage trees as part of their farming systems, smallholder tree growing for commercial wood production in PNG is rare (Bourke & Harwood 2009; Mulung et al. 2011). A notable exception is the balsa industry in East New Britain (ENB) Province. Plantations of the fast-growing exotic tree, *Ochroma pyramidale* Cav. Ex Lam. (balsa), were first established in ENB following the Second World War. The ENB balsa industry is now globally significant, producing 9% of the world's processed balsa. Balsa products have outstanding strength-for-weight qualities, and an increasing market in high-technology composite materials, such as wind turbine blades and transportation applications (see Fig. 1).

Ochroma pyramidale is grown by both companies and smallholders in ENB; the total area of plantations is around 6200 ha. Smallholder adoption of balsa growing has accelerated over the past 15 years, largely in response to the contraction of the area of smallholder *T. cacao* plantations as a consequence of the severe impact of a pest, cocoa pod borer (*Conopomorpha cramerella* Snellen), on cocoa production and smallholder incomes (Curry et al. 2015).

This paper reports the principal outcomes of an Australian Centre for International Agricultural Research (ACIAR) research project, FST/2009/016 *Improving the Papua New Guinea balsa*

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(a) (b)

Figure 1. Contemporary products from East New Britain balsa (a) composite panels in railway rolling stock; (b) composite panels in wind turbine blades (Photographs: B. Jenkin)

value chain to enhance smallholder livelihoods, implemented between 2011 and 2016 (Kanowski & Jenkin 2016). The project was developed in response to an ACIAR Scoping Study (Midgely et al. 2010), which identified a suite of research and development activities in support of the ENB balsa industry, particularly smallholder balsa growers, in the context of their increasing interest in *O. pyramidale* as a plantation crop, and the significant expansion of smallholder plantations. Previous research on *O. pyramidale* in ENB was episodic: it had explored the commercial potential of ENB-grown balsa wood, including through a trial shipment to Australia in 1956 (Bourke & Harwood 2009), the silviculture of balsa plantations (White & Cameron 1965; Howcroft 2002), and their genetic improvement (Howcroft 2002).

Research context

East New Britain, livelihoods and industries

East New Britain is one of 22 PNG Provinces, and is located on the island of New Britain to the north-east of the PNG mainland. The Province covers 15 274 km^2 with a population of *c*. 328 000 people (in 2011: National Statistical Office 2015). The most densely settled, developed and agriculturally productive part of ENB is the Gazelle Peninsula, to the west and south of Rabaul town. The Peninsula includes parts of Gazelle and Rabaul Districts and all of Kokopo District (National Research Institute 2010), with an area of *c*. 1000 km^2. The Peninsula's rich volcanic soils reflect its proximity to the Rabaul caldera; annual rainfall ranges from 2000 to 5000 mm, and the topography is primarily undulating volcanic hills and plains. The landscape is among the most productive, and the region historically one of the most prosperous, in PNG (Midgley et al. 2010).

The labour force participation rate for ENB in 2011 was 57%; 75% of households grow food crops and 73% are engaged in growing betelnut (*Areca catechu L*: a palm fruit widely used as a stimulant; see Bourke & Harwood 2009). Sixty-two per cent of households sell fresh and cooked food, and 58% sell betel nut to generate income (National Statistical Office 2015). Bananas are an important staple tree crop (Bourke et al. 2002); the primary cash crops grown since European colonisation in the late 19th century are *T. cacao and C. nucifera* (Allen et al. 2009). Oil palm plantations have been recently established in parts of ENB, displacing these crops and traditional land uses (Midgley et al. 2010; Gabriel et al. 2017).

Prior to the cocoa pod borer infestation in 2006, cocoa was the primary cash income for 73% of ENB households, and represented half the value of ENB's exports (Curry et al. 2015). Estimates of the extent of *T. cacao* plantations per household vary among communities from 1.7 to 5 ha (Curry et al. 2007, table 4.2). Most smallholders managed their cocoa extensively, mixing other crops with *T. cacao* (Curry et al. 2007), and devoting most of their time to other livelihood activities—principally food crop production, and the sale of garden food and nut products at local markets. Cocoa-growing smallholders also engaged in copra production and village-scale enterprises, such as poultry production and trade stores (Curry et al. 2015). However, ENB cocoa production declined by 80% between 2008 and 2012, and individual growers sampled by Curry et al. (2007) lost 90% of their production, as a result of the cocoa pod borer. Although the impacts of the cocoa pod borer can be minimised through more intensive management of *T. cacao* plantations, such management is largely inconsistent with ENB smallholder farming systems, values and livelihoods (Curry et al. 2015). In this context, reducing the area of cocoa, and substituting a low-labour input crop such as *O. pyramidale*, was an attractive option for some ENB smallholders.

The East New Britain balsa industry

The balsa industry in ENB is also located in the Gazelle Peninsula, exporting product through the Port of Rabaul. When the project was initiated, in 2011, the area of *O. pyramidale* plantations had expanded more than ten-fold in the decade to 2010, from *c*. 300 ha in 2001 to *c*. 3500 ha. Around 40% of the 2010 area was company-owned and managed, established primarily in larger blocks; around 60% was in smallholder plantations of less than 5 ha each, with many less than 1 ha. Balsa exports were then 13 259 m^3, valued at around PGK 11 000 000 annually, originating from one major and ten smaller processors. The ENB sector is now estimated to generate 24 800 m^3 of exports with an estimated value of PGK 29.7 000 000 in 2014 (Midgely 2015). During the life of the project, *O. pyramidale* plantations continued to expand, to *c*. 6200 ha in 2016, of which some 4900 ha are owned or managed by two companies which also have large processing facilities (SGS Global 2015; Woodmark 2016); there are four other significant processors and a variable number of portable sawmills; some 1500 smallholder *O. pyramidale* growers; and a workforce of some 2500–3000 engaged in *O. pyramidale* plantation management, harvest, transport, processing and exporting. Activities in the balsa sector operate under the regulatory oversight of the PNG Forest Authority (PNGFA), which also plays an 'honest broker' role in financial transactions between companies and smallholders. The PNGFA and the ENB-based University of Natural Resources and Environment (UNRE) have played research and development roles since receiving project support from the International Tropical Timber Organization (ITTO) in the period 1996–2003 (Midgley et al. 2010).

In terms of harvesting and processing, *O. pyramidale* has more in common with some perishable food crops than with conventional plantation tree crops, although legally it is a tree crop regulated by the *Forestry Act 1991* (Independent State of Papua New Guinea 1991). *Ochroma pyramidale* trees need to be harvested between ages four and six to ensure the desired wood properties; older trees may develop heavier and darker wood (known locally as 'red heart'), which is not suitable for current balsa products. Once harvested, logs must be processed and kiln drying commenced within *c.* 48 hours to minimise degradation (Midgley et al. 2010). Growers cannot therefore leave trees 'on the stump'; they have only a relatively short and defined period, in comparison to most plantation tree crops, in which to harvest their trees, and only around a day to ensure the harvested logs reach a mill. As Midgley et al. (2010) discuss, these constraints determine the harvesting and transport logistics required for timely processing, and so shape the geographic distribution of plantations in relation to mills. In the ENB balsa industry, the processor that purchases smallholder logs generally assumes responsibilities for their harvest and transport.

The East New Britain smallholder value chain—key research results

This section presents key research results for each stage of the ENB smallholder value chain—smallholder growers, and the role of balsa in their livelihoods; genetic resources and management of *O. pyramidale* plantations; harvesting and transport; processing and products—and the enabling issues of state and market governance, and knowledge sharing and capacity development.

Smallholder Ochroma pyramidale *growers—livelihoods, motivations and plans*

The project conducted two surveys of smallholders between May 2014 and March 2015, in the three (of four) ENB Districts closest to balsa processing facilities (ACIAR Balsa Project 2016a). The first survey (140 respondents) focussed on farmers' extension needs and motivations for *O. pyramidale* growing; and the second (166 respondents) on their interest in market information. The results of the first survey confirmed both that smallholders grew *O. pyramidale* as part of a broader livelihood strategy, and that their motivation for adopting *O. pyramidale* was primarily financial. The majority (62%) grew both crops and trees, including *O. pyramidale*; 37% grew only crops. None of the respondents grew only trees. Almost all (90%) respondents indicated a high level of dependence on cash crops; and almost all (93%) of those who currently grow trees identified the generation of income for medium- and long-term needs as their motivation (see Fig. 2). Unsurprisingly, these results echo those reported by Curry et al. (2015) for ENB smallholders, as most respondents would also be *T. cacao* growers. The choice to grow tree species other than *O. pyramidale* (e.g. teak, *Tectona grandis* L.f.) was motivated by a broader range of factors than *O. pyramidale* growing (see Fig. 2), including future cash needs, house building materials or as a boundary markers.

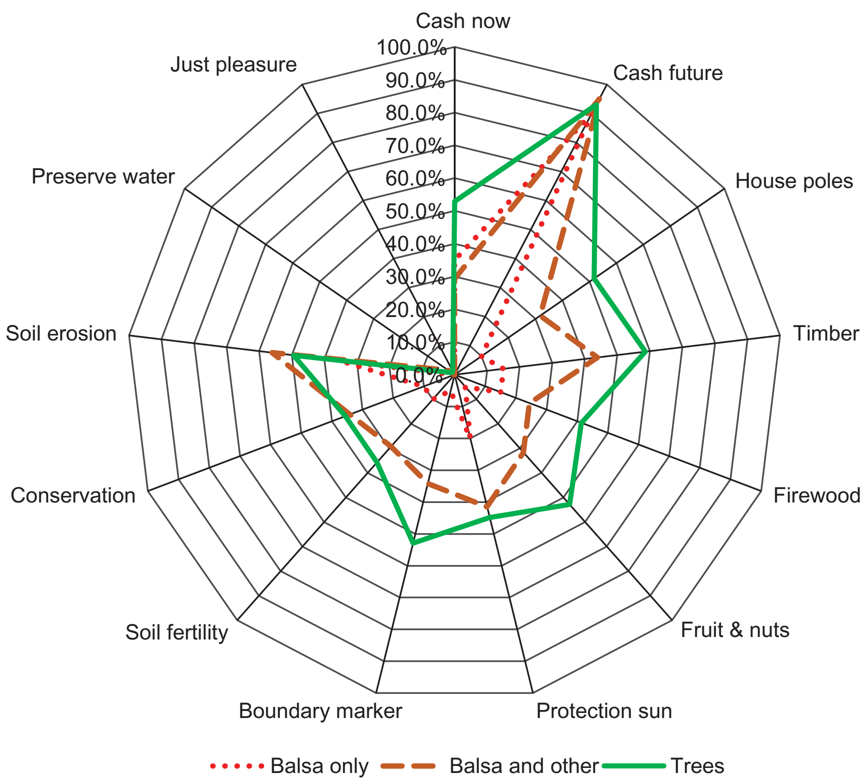

Figure 2. East New Britain farmer survey respondents' (n = 140) reasons for growing balsa and other trees

These results are consistent with those reported by Mulung et al. (2011) for regions of mainland PNG, where smallholders aligned their choice of tree growing with different financial planning horizons and with other personal or livelihood goals.

The second, market information, survey investigated respondents' future interest in growing *O. pyramidale*. Forty per cent of these survey respondents currently grew *O. pyramidale*; all of these indicated that they were interested in growing it in the future. Eighty-three per cent of those who were not current *O. pyramidale* growers (60% of respondents) indicated an interest in growing it in the future; only 10% of respondents advised that they were not interested in growing *O. pyramidale* in the future. These results suggest a favourable reputation for *O. pyramidale* as a cash crop, notwithstanding the downturn in world balsa markets and significant log price reductions experienced in ENB in 2013–2014.

The majority of respondents reported that they are not as well-informed as they would like to be about how best to integrate balsa growing with their farming systems and livelihoods, and that they would welcome more extension advice and support about farm planning, tree choice and tree growing, including how to manage *O. pyramidale* crops well. Respondents identified, as had the Scoping Study (Midgley et al. 2010), that farmers would also benefit from access to better germplasm, the value of which many recognise; and a clearer understanding of the drivers of product value and price, which would inform their management. The project sought to address a number of these issues, as discussed in the following sections.

Ochroma pyramidale *genetics and silviculture*

The genetic quality of ENB balsa germplasm has been recognised as an issue for some 20 years; a modest breeding program has operated sporadically since the 1980s, and genetic improvement was a major focus of the ITTO Balsa Industry Strengthening Project 1996–2003 (Midgley et al. 2010). The ACIAR Balsa Project invested in further development of the genetic base for ENB *O. pyramidale* plantations, establishing seedling seed orchards of *c.* 110 families on three sites. The majority of families comprised open-pollinated seedlings from phenotypically superior trees selected in ENB plantations, avoiding stands of known poor origin, and emphasising growth and stem quality.

The focus of project silvicultural research was on the impacts of stem quality and stand management on value recovery (see Fig. 3). Analysis of felled trees and the logs recovered from each tree in the sample plot demonstrated the importance to volume and value recovery of managing and minimising stem defects, and that most loss of merchantable volume was associated with the formation of stem forks, notably those resulting from multi-leader whorls at around 12 months of age, known locally as 'jorquettes' (*O. pyramidale* is categorised as having Koriba's model of tree architecture: Tomlinson 1983). Diameter at breast height over bark for sample trees was much more strongly correlated with stem merchantable volume (R^2 = 0.74) than with total tree height (R^2 = 0.10). These results suggest a silvicultural strategy for value improvement of *O. pyramidale* plantations that focuses on increasing the diameter of individual trees and reducing the impact of jorquettes.

For many ENB smallholders with available labour, purchasing seedlings may be the only cash expense associated with *O. pyramidale* plantation establishment. It has been established practice to plant at 3 × 3 m (1111 stems ha^{-1}), and to refill stands at ages up to three months if there is tree mortality, so full stocking is maintained. Smallholder growers are often reluctant to thin to waste, as they consider doing


(a) (b) (c) (d)

Figure 3. East New Britain balsa plantation and tree characteristics (a) balsa 'plus' tree (age ten years); (b) jorquette branch whorl in a 12-month-old balsa tree; (c) six-year-old stand ready for harvest (average DBHOB 38.3 cm (range 27.0–49.8 cm)); (d) six-year-old balsa tree in that stand (Photographs: B. Jenkin)

so is to waste a tree and associated expenditure. In short-rotation *O. pyramidale* stands, there is little prospect of commercial thinning. Hence, the project investigated the merits of refilling, by tracking the growth of original and refill trees in seedling seed orchard trials, which were managed as normal plantations to age three; and of silvicultural regimes that maximised individual tree volume without requiring thinning to waste. Other project research investigated the impacts of alternative weed control strategies in young balsa stands, and the nutrient status of balsa harvest residues and stands.

Investigation of the growth of refills found that, at age three, the refilled plants were less than 50% of the volume of those established originally, suggesting that refilling is unlikely to add value for the grower. Some second rotation *O. pyramidale* stands in some locations were found to be deficient in boron, and the practice of burning as a means of disposing of harvesting residue was found to reduce site nutrient status (Ghaffariyan et al. 2016). Therefore, the project developed recommendations for remedial boron treatment and for non-burning post-harvest management. These findings were incorporated, with the results of research on other nutrients as reported below, into a 'smallholder-friendly' silvicultural regime, which did not burn prior to planting, established plants at 4 × 4 m (625 stems ha^{-1}), did not refill, and pruned to manage jorquettes (ACIAR Balsa Project 2016b).

Harvesting, volume estimation and transport

Productivity estimates of ENB balsa plantations have generally been based on the volume of logs recovered at harvesting, with typical yields of 200 m^3 ha^{-1}, and a range from 180 m^3 ha^{-1} to in excess of 400 m^3 ha^{-1}, at year five (Midgley et al. 2010). Assessment of a sample plot established in six-year-old plantations found that the merchantable volume recovered (log volume of 418.9 m^3 ha^{-1} under-bark) was around half the total biological volume (838.9 m^3 ha^{-1} over-bark at age six) (Fig. 4). *Ochroma pyramidale* plantations are typically harvested at age 5–6, using chainsaws. Logs are cut to specifications (billet lengths of 1.2–2.0 m), and usually carried manually to transport bins or loaded directly onto trucks (Fig. 4). Logs must then be delivered to processing facilities to allow kiln drying of sawn boards to commence within 48 h, to avoid degradation through fungal infection. The project investigated three elements of harvesting that were of concern in the ENB industry: smallholder growers have expressed concern at the level of stemwood harvest residues (Fig. 4), and that they were disadvantaged by established methods of estimating log volume; and plantation managers have suspected a decline in site productivity with successive *O. pyramidale* crops attributable to harvest residue management.

The quantum and distribution of post-harvest stemwood residues from harvesting were reported by Ghaffariyan et al. (2016; Fig. 3). Stemwood of less than the required log small-end diameter and 'red heart'-impacted butt logs each represented *c*. 25% of the residue, and stem jorquette-related defects and bark each *c*. 20%. Red heart is most likely to be associated with tree age beyond the target rotation of 5–6 years (Record & Hess 1944) although, based on observations, there may also be genetic and environmental factors. Project research found that processors recovered all merchantable logs, that the stem wood residues were within current specifications, and hence current harvesting practices were not disadvantaging smallholders. Elemental analysis of the harvest residues revealed that, on a volume per hectare basis, bark contained the greatest proportion of the elements tested (nitrogen, phosphorous, potassium, calcium and magnesium) (Ghaffariyan et al. 2016; Fig. 4). While most harvesting operations removed the bark prior to log recovery, some logs are transported with the bark on. Management of the harvest residues following log recovery will also impact on site productivity, and smallholders' tendency to prepare for subsequent rotations, including integration with food garden systems, by piling and burning stem wood and bark residues, is likely to be detrimental to site productivity.

Processing and products

Under the PNG *Customs Tariff Act 1990* (Schedule 2, Export Item 44.03) (Independent State of Papua New Guinea 1990), balsa log exports are not permitted from PNG; hence, unlike many natural forest logs, *O. pyramidale* is only exported as processed products, ranging from kiln dry boards to manufactured end-grain sheets. Balsa wood is marketed by wood density classes (light, medium and heavy), focussed on


(a) (b)

Figure 4. Balsa harvesting and harvest residues (a) manual extraction and loading of a butt log; (b) harvest residue assessment (see Ghaffariyan et al. 2016) (Photographs: B. Jenkin)

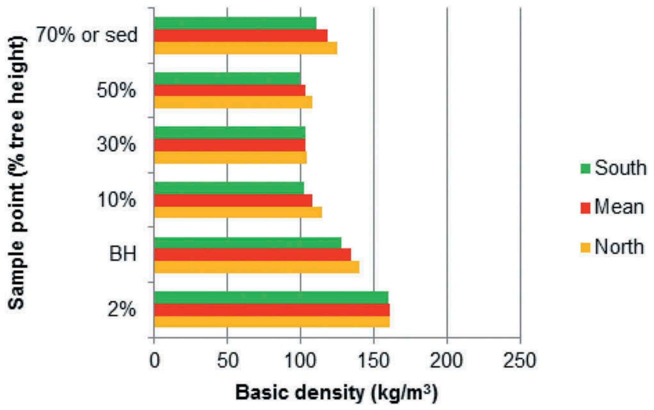

Figure 5. Balsa within-tree basic density variation as a percentage of total stem height (n = 10) (Note: BH—breast height, 1.3 m)

different markets and end uses. Project research found that wood density varied with height up the stem (Fig. 5), and thus that improved processing efficiency could be realised by batching logs of like density based on position in the tree. The high levels of expertise that already characterised the ENB balsa processing sector meant that other project research was focused on product development.

A container-load of ENB balsa was donated by processors and shipped by the project to laboratories at University of Melbourne, Swinburne University of Technology, and the Australian Defence Force Academy (ADFA), University of New South Wales. Various research projects were conducted with this material. Kotlarewski (2016) explored the systematic development of a novel and commercial balsa wood-based products. This work included determining the commercially important properties of PNG plantation-grown balsa wood, viz, static bending, hardness (Janka), compression parallel to the grain, compression perpendicular to the grain and shear parallel to the grain (Kotlarewski et al. 2016); and its thermal properties (Kotlarewski et al. 2014). Both sets of data underpinned the development of a novel balsa wall panel product, which itself was recognised with a design award (Swinburne University 2015; Kotlarewski 2016). One advantage of such novel products is that they could make use of balsa containing within-board defects (e.g. knots and red heart stain), which are not accepted for current products. Barnes et al. (2015) explored the use of balsa in wind turbine blades designed for low wind speed sites.

Policy and regulation

As with other forestry activities in PNG, the ENB balsa sector is governed by the PNG *Forestry Act 1991* (and Regulations) (Independent State of Papua New Guinea 2006). Given the history of forestry in PNG (Bird et al. 2007), the Act and Regulations are understandably framed around the regulation of native forest harvesting and management. Thus, the same levels of regulatory oversight apply to exports of balsa, sourced entirely from plantations, as to native forest wood: for example, each export shipment of balsa requires ministerial signature. Policy-related research conducted by the project (Crawford & Jenkin 2012a) suggests that the levels of regulation of balsa production systems could be relaxed, and that administrative processes governing exports streamlined, without adverse economic, environmental or social impacts. Future revisions of the Forestry Act and attendant Regulations could address this.

Some markets for balsa demand certification (Midgley et al. 2010; Midgley 2015), and thus ENB balsa value chains have become segregated into certified and non-certified product streams. Project research (Crawford & Jenkin 2012b) facilitated the adoption of Forest Stewardship Council (FSC) certification by the major ENB processors, and explored measures to facilitate the certification of balsa grown by smallholders. The characteristics of PNG land tenure, under which customary ownership applies to 97% of land (Bird et al. 2007), present challenges to certification systems; FSC certification has not yet been able to accommodate the certification of balsa wood produced by smallholder growers, except through use of FSC MIX (i.e. FSC Controlled Wood from smallholders combined with wood from FSC-certified company-managed plantation). While the FSC MIX 70% product stream offers a pathway for smallholder wood to enter value chains for certified wood, the extent of smallholder access is constrained by the 30% limit on its inclusion in controlled wood. Consequently, improving smallholder access to markets demanding certification will require development of certification systems and legal mechanisms, including amendment of the *Forestry Act 1991* and Regulations to better able to accommodate the particular characteristics of customary land ownership in PNG.

The local PNG Forest Authority office in ENB plays a fundamental role as intermediary and honest broker in payments from processors to smallholders, as required by the *Forestry Act 1991* and Regulations. While in principle this role could be played by other organisations, or become superfluous, project research found that it remained necessary, at least for the moment, as levels of trust between many smallholders and some processors were generally not sufficient for more direct relationships to become normalised. In the longer run, as smallholder knowledge of expected recovery and returns from *O. pyramidale* crops improves, other locally-based entities, such as a provincial government agency or grower organisation, might emerge to play this intermediary role if the regulatory environment allows.

Building collaborative relationships and capacity in the balsa sector

Enhanced collaborative relationships are fundamental to improving value chains (Collins et al. 2015). Smallholder *O. pyramidale* growers in ENB would benefit from stronger collaborative relationships in a number of dimensions: with each other; with processors; and among key balsa sector actors, including national and provincial government agencies. Organisations based on strong collaborative relationships—e.g. church groups, farmer and grower groups—are already well established in ENB, although not in the balsa sector. It was evident from project research that integration of balsa production into existing organisational arrangements, such as the PNG Growers Association, is likely to be a more effective approach than seeking to establish separate balsa-specific organisations. There are a number of reasons for this, including the established networks and resources that such organisations represent, and that *O. pyramidale* growers are typically already members of these organisations as a consequence of their other farming and/or community activities. These groups have evolved to focus on farmers and their livelihood portfolios, rather than on any individual crop, and so foster integration of *O. pyramidale* growing into those portfolios. By the conclusion of the project, there was also a renewed appreciation in the larger balsa processing companies of the benefits of strengthening and sustaining relationships with smallholder *O. pyramidale* growers. Continued development of each of these 'horizontal' (across the balsa sector) and 'vertical' (within particular companies' supply chains) relationships would be both complementary and beneficial for the ENB balsa sector.

An example of such integration on which the project was able to capitalise is the Integrated Agricultural Training Programme (IATP), based at ENB's UNRE. Integrated Agricultural Training Programme is well-established as an effective knowledge broker and training provider for agriculture in ENB and some other PNG provinces. The foundational *Balsa Manual* (Howcroft 2002), developed under the ITTO Balsa Industry Strengthening Project, was revised and updated with project resources and results (Jenkin 2014), and extended to a Tok-Pisin farmer training manual (Jenkin et al. 2014); these manuals provided the platform for development and incorporation of a suite of nine balsa learning modules into IATP's training resources and program. This approach ensured that ENB smallholders could access learning resources and training about key decisions and skills through an established and highly credible program well-adapted to their situation and needs. These learning modules were complemented by a series of brochures, in both English and Tok-Pisin (ACIAR Balsa Project 2016b), available through the website of an ENB-based project partner and consultancy services provider, Pacific Islands Projects (Pacific Islands Projects 2017).

Conclusions

The particular conjunction of climate, geography, history, infrastructure and land use in the Gazelle Peninsula region of ENB make *O. pyramidale* an attractive crop for smallholder growers, in the context of their broader portfolio of livelihood and farming activities. ACIAR Project FST/2009/016, *Improving the Papua New Guinea balsa value chain to enhance smallholder livelihoods*, built on previous research investment by ITTO and the Government of PNG in their *Balsa Industry Strengthening Project* (1996–2003), and on subsequent research, development and extension by ENB's UNRE and balsa processors. The principal conclusions from the project are summarised below:

(1) **Global demand for balsa** is likely to continue to remain strong, reflecting the growth in and diversification of high-technology applications for balsa products. Project research identified new balsa products that could further expand the market for *O. pyramidale*, in particular, for currently non-merchantable balsa wood such as that with red heart. The ENB balsa industry continues to be well placed to capitalise on this healthy market situation; this has been reflected in recent major investment in the ENB industry by both large international corporations and some smaller actors.

(2) **Expansion of balsa production in ENB** is dependent primarily on smallholder growers, as there is little prospect of major expansion in company estates. While *O. pyramidale* remains an attractive crop for both corporate and smallholder growers, it faces increasing competition for land from oil palm, and perhaps other crops new to ENB. Strengthening both horizontal and vertical relationships in the ENB balsa sector is necessary to facilitate smallholder participation in, and benefits from, the balsa value chain.

(3) **Smallholders** for whom balsa growing is most likely to be attractive and profitable in ENB are those who are close to road access and relatively close to processing facilities, who have sufficient land or income to allow them to establish a minimum area (*c*. 0.2 ha) of a crop that does not return income for 5–6 years, and who can undertake a threshold level of crop management to maximise value recovery. Many smallholders in ENB satisfy these criteria.

(4) **Smallholder balsa growers** would benefit from ongoing access to better germplasm and enhanced knowledge and skills in balsa management, and from a clear understanding of the drivers of balsa value and price at the farm gate. The ACIAR Balsa Project established new seed orchards, and knowledge and learning resources, in support of each of these needs. The majority of smallholders surveyed by the project would welcome more extension advice and support about these issues, part of which can be drawn from the established IATP.

(5) **Balsa processors** and the ENB balsa sector as a whole would benefit from more knowledgeable and capable smallholder growers who have access to improved balsa germplasm. A smallholder balsa resource that is of better genetic quality and of stands of trees that are better managed will deliver higher volume and value recovery to both growers and processors. Seed orchards established by the project will contribute to quality improvement, but timely management by smallholders to minimise defect and its impact on tree and log value is also critical. Project research identified smallholder-friendly silvicultural regimes for this purpose. Better and wider smallholder knowledge of log recovery and value will also diminish the lack of trust between some smallholders and processors about smallholders receiving fair returns from balsa. In contrast to current silviculture, established balsa harvesting and log delivery systems are relatively efficient, albeit with some areas for improvement.

(6) **Communication of knowledge** about balsa management and markets, and the development of growers' capacity to improve their management and value recovery, are best delivered as part of broader agricultural training programs already established in ENB. The IATP, based at ENB's UNRE, has a central role in knowledge communication to smallholders. The Programme can now draw on knowledge and learning resources developed by the project; these are complemented by a range of other project outputs accessible to smallholder growers and other ENB balsa sector stakeholders from a project legacy website.

(7) **The regulatory environment** for the ENB balsa industry remains one that is defined largely by PNG's focus on regulating the harvesting of native forests and the export of native forest logs. Project analysis of the policy

and regulatory environment identified how reform could address the consequent constraints along the balsa value chain without undermining the regulatory environment for native forestry operations. Targeted reform of the regulatory environment for balsa growing, processing and export, as identified by the project and discussed at two national policy workshops, would strengthen the comparative advantage of PNG balsa with little risk to environmental or social sustainability criteria. The introduction of certification to ENB's balsa sector has benefitted processors who have adopted it, and has collateral benefits to smallholders; but it has as yet delivered only limited direct benefits to smallholders, as forest certification systems have yet to accommodate PNG's land tenure arrangements.

In summary, the ENB balsa sector is the most successful example of smallholder commercial forest tree growing in PNG. Research conducted and knowledge communicated by the ACIAR Balsa Project have contributed to its continuing success, which will be facilitated by a range of measures identified by the Project but outside its scope. Effective extension provision, and regulatory reform by the Government of PNG and certification systems, are both important to the future of the ENB balsa industry.

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