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Australian Centre for International Agricultural Research

Final report

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prepared by	Prof Barbara Ozarska, The University of Melbourne
co-authors/ contributors/ collaborators	Dr Mex Peki, Benson Gusamo, Haron Jeremiah and Pendis Ono (UniTech), Dr Martin Golman, Frank Asok and Kilva Lancelot (FRI), Charles Tsiritsi, Vagi Lovo, Elaine Galore, Ravu Iru, Lus Pora, Moira Spairong and Morean Simeon (TFTC), Dr Ruth Turia, Dambis Kaip, Andrew Aopo and Alois Jenkihou (PNGFA), Bob Tate (PNGFIA), Dr Benoit Belleville (UoM) and Dr Bob Smith (LeafCarbon Pty Ltd)
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1 Acknowledgments

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In particular, I acknowledge the ACIAR Research Program Manager for Forestry, Dr Tony Bartlett, for his valuable advices and support provided to the project team.

Acronyms and initialisms used in the report:

Australian Centre for International Agriculture Research	- ACIAR
Bulolo University College	- BUC
Centralised Processing Unit	- CPU
Department of Agriculture and Fisheries	- DAF
Engineered Wood Products	- EWP
Forest Management Agreement	- FMA
Key Performance Indicators	- KPI
Monitoring and Evaluation	- M&E
Managing Director	- MD
Modulus of Elasticity	- MoE
Modulus of Rupture	- MoR
Memorandum of Understanding	- MoU
Mid-term Review	- MTR
Public-Private Partnership	- PPP
Papua New Guinea	- PNG
Pacific Islands Projects	- PIP
PNG Forest Authority	- PNGFA
PNG Forest Research Institute	- PNGFRI
PNG University of Technology	- PNG UniTech
PNG Forest Industry Association	- PNGFIA
Project Steering Committee	- PSC
Research Program Manager	- RPM
Small to Medium Enterprises	- SME
Small Research Activity	- SRA
Strength, Weakness, Opportunity and Threat	- SWOT
The University of Melbourne	- UoM
Timber and Forestry Training College	- TFTC
Timber Authority	- TA

2 Executive summary

The PNG Government formulated the National Strategies for Downstream Processing of Forest Products (2014 draft) with the view to encourage and promote domestic wood processing while phasing out log export over time, thereby building a sector that is sustainable and highly profitable. However, there are many research and structural challenges, constraints and opportunities (at Government, industry, community, and landowner levels) which need to be addressed to support the development of competitive value-added wood industries. To address these challenges, ACIAR project FST/2012/092 was developed with the aim to increase the contribution that utilisation of forest resources makes to national and local economies, including landowners and processors, through the development of domestic value-added wood processing methods. The project was built upon the achievements of a previous project, "Increasing downstream value adding in PNG's forest and wood products industry" (FST/2006/120), which focussed on building capacity of wood science and wood processing research and training.

The principal research findings in relation to the project objective are:

- The Wood Database and promotional materials were developed which combine the data on wood properties and processing characteristics (gluing, preservative treatment and machinability) of 26 PNG timber species. The database is a valuable resource of information for research education and training purposes in PNG and worldwide. It will also help the timber industry in promoting PNG timbers for a variety of products and applications according to their properties and characteristics. The utilization of timber species from secondary and plantation forests should reduce pressures on native old-growth forests.
- An important finding of this study was that the mechanical properties of species obtained from secondary and plantation forests were lower than those found in the literature from old-growth forests. Another interesting observation was that there was a significant improvement in the treatability of these younger timbers compared to same species of the old-growth forest with exception of few medium- and high- density species. These species were re-classified into new permeability classes. These findings have an important value to the research community as it makes them aware of the importance of assessing wood properties of younger timber resources, and to timber companies, as it prompts them to adjust the processing and manufacturing methods when utilising younger timbers.
- The development of a business plan for Central Processing Unit (CPU) and the preliminary production trials at PNG Timber and Forestry Training College (TFTC) in Lae revealed that an opportunity exists for CPU to become a viable system which would provide opportunities to landowners to increase their profit by selling their timber for further processing into value-added products and be involved in value-adding processes.
- The study on the potential contribution and distribution of economic impacts to national and local economies from enhanced value-added wood processing identified several factors which are considered to impede growth (adoption barriers) in transitioning of PNG forest industry to enhanced domestic downstream processing. Also, several actions were suggested which could assist in creating a conducive environment for potentially capturing additional value, including enhanced downstream processing of PNG's forest resources.
- The project made significant achievements in enhancing local capacity in wood science, wood processing, manufacturing and waste utilisation, mainly through collaborative research and the development of strong network linkages between partner organisations representing education, research, training and the industry.

3 Background

The Forestry Sector is an important economic contributor in PNG, in terms of foreign exchange, employment and contributions to the national and regional economies. Over 97 percent of forests are held in customary ownership, but the PNG Government is responsible for the allocation of 50-year forestry concessions via Timber Management Agreements. From 1979 until recently, the PNG Government's forest policy focussed on export logging and in very large areas of primary rainforest the most valuable commercial timbers have been harvested and the logs exported. Research under ACIAR's project FST/2004/061 found that these secondary forests are recovering in terms of merchantable timber and carbon stocks, but much of the potential timber resource is of lesser-known timber species.

The PNG Government has formulated and endorsed the PNG Development Strategic Plan 2010-2030 to foster and bring about economic and social advancement in PNG. Forestry has been given the target to increase the level of domestic processing of annual log harvest from 20 to 80 percent by 2030, thereby building a sector that is sustainable and highly profitable. To achieve this goal, the PNG Government has decided to formulate the National Strategies for Downstream Processing of Forest Products (2014 draft)[1] with the view to promote industrial development in the forestry sector, thus complementing the 1991 National Forest Policy. The strategy intends to re-enforce the policy directive of the government to encourage and promote domestic wood processing while phasing out log export over time. There is a growing demand for wood products in the domestic market due to the rapid development of PNG industries based on the extraction of natural resources (e.g. minerals, oil).

During this project development stage in 2013-2014, it was identified that there were many research and structural challenges, constraints and opportunities (at Government, industry, community, and landowner levels) which needed to be addressed to support the development of competitive value-added wood industries. Most local wood processing has been focused on primary conversion of logs to low-grade building materials. Technical knowledge and capacity about efficient processing of different native timber species and produce a broader range of wood products were very low. Therefore, it was identified that there was an urgent need to provide research and technology enhancement to develop and implement commercially sustainable log supply chains, knowledge and capacity in wood science and processing technologies, as well as the processing structures which support successful domestic value-adding wood processing enterprises.

This project was built upon a previous three-year ACIAR project "Increasing downstream value adding in PNG's forest and wood products industry" (FST/2006/120), which focussed on building capacity of wood science and wood processing research and training. The major output of the project was expanding the availability of basic wood science research equipment and upgrading research and technical skills in partner organisations. The project has also produced useful technical outputs by conducting preliminary studies on the properties and processing characteristics of selected PNG timber species. The project has significantly strengthened cooperation and collaboration between Australian and PNG partner organisations and between the collaborating institutions in PNG.

The review of project FST/2006/120[2] concluded that "*the present project has made the participants more research ready by providing and repairing equipment and generating closer collaboration between institutions*". The review recommended that ACIAR should consider developing a new value-adding wood processing project in PNG which would

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[1] *Papua New Guinea Forest Authority, National Service. 2014. National Strategies for Downstream Processing of Forest Products in PNG. Draft. 28p.*

[2] *Kile, G. 2012. Review Report of Project FST/2006/120 Increasing downstream value adding in PNG's forest and wood products industry. 26p.*

exploit the networks developed under the previous project and use its achievements to provide a significant scientific and capacity building support to PNG in the implementation of the National Strategies for Downstream Processing of Forest Products.

The overall research question which was formulated for the project was: How can the technical, policy and capacity impediments that are hindering the development of value-adding products and transitioning the PNG wood sector to a successful domestic wood processing industry, be overcome? This important question comprised many factors which needed to be considered as they could have a significant impact on the development of value-added processing industry. These factors have been used as the basis for developing the specific research questions that needed to be addressed in the project:

1. Will enhanced knowledge of wood properties and processing techniques for lesser-known and plantation timber species facilitate greater value adding?
2. Which mix of practices (for example supply chain structures from forest to market), organisational and ownership structures (private sector and landowner for example) and processing technologies would facilitate efficient returns to stakeholders and significant increases in value-added processing linked to markets for wood products?
3. What value-adding practices and production efficiencies can be commercially introduced to the existing and/or new timber processors?
4. Which value-added practices and market development activities would facilitate greater participation, employment and sustainable financial returns to customary landowners?
5. Will the increased proportion of native forest logs processed in PNG from 20 to 80 percent provide more benefits to the customary landowners, timber industry and the nation?
6. What are the factors which need to be in place to achieve significantly higher levels of viable domestic downstream processing to increase the contribution to economic growth, employment generation and greater participation in industry?
7. What benefits arise from enhanced wood science and wood processing capacity in terms of achieving enhanced value-added processing in PNG?

The above questions were included in the project four objectives and activities.

4 Objectives

The overall aim of the project was to increase the contribution that utilisation of forest resources makes to national and local economies, including landowners and processors, through the development of domestic value-added wood processing methods.

The underpinning objectives and associated activities were as follows:

Objective 1: To enhance the knowledge of wood properties and processing characteristics of PNG timbers.

Activities:

1.1 Extending the current database and creating a database for lesser-known species from secondary and plantation forests.

1.2 Testing of basic physical and mechanical properties of target species.

1.3 Development of kiln drying schedules and PNG appropriate technologies for the timbers.

1.4 Assessment of preservative treatment characteristics of timbers.

1.5 Testing gluing characteristics of the timbers for various wood product applications.

1.6 Assessment of other processing characteristics required to successfully produce value-added products for PNG and export markets.

1.7 Recommendations on best applications/types of product for the selected species based on their properties and processing characteristics.

Objective 2: To identify, pilot and evaluate interventions for enhanced value-added processing systems.

Activities:

2.1 Selection of companies and landowners groups willing to participate in the project.

2.2 Identifying what improvements in the current processing and manufacturing practices are required.

2.3 Conduct research to address identified practice and technology gaps.

2.4 Support trial implementation of improved value-adding processes.

2.5 Pilot innovative approaches to enable greater landowner involvement.

2.6 Work with PNGFA to operationalise the Central Processing Unit in Lae.

2.7 Developing public-private partnerships to support enhanced value-added wood processing in PNG.

Objective 3: To estimate the potential contribution and distribution of economic impacts to national and local economies from enhanced value-added wood processing.

Activities:

3.1 Establishment of benchmarks (employment, PNG participation rates and financial flows) of contribution of current forest resources processing sector (Private sector and other processing groups) to national and local economies including landowner groups.

3.2 Assessment of evidenced-based options for the development and/or enhancement of alternative wood processing and manufacturing facilities and structures which would increase returns to landowners and processors.

3.3 Assessment of potential changes in economic distributions with transition to viable organisational arrangements associated with PNG appropriate supply chain arrangements for increasing downstream processing.

3.4 Identification of appropriate pathways to assist decision makers deliver goal of significantly increased domestic processing of PNG's forest resources.

Objective 4: To enhance the capacity of Government, institutional support bodies, industry partners and landowners to implement value-added wood processing policies, strategies and practices.

Activities:

4.1 Training and technology transfer on value-added processing methods.

4.2 In collaboration with Government and industry association working towards implementation of the national policy on the development of downstream wood processing.

4.3 Monitoring and regulating the timber industry to meet required quality standards and also impart technical and appropriate advice for improvement.

4.4 Development of timber promotion materials such as wood sample and pamphlets.

5 Methodology

5.1 Project organisation and location

The project was led by the University of Melbourne. The leader of the project was Prof Barbara Ozarska and the Project Country Coordinator – Dr. Ruth Turia, PNG Forest Authority.

The principal partners in PNG were as follows: PNG Forest Authority, PNG Forest Research Institute, Timber and Forestry Training College, PNG University of Technology and PNG Forest Industry Association.

The focal points of the project were in Lae and Port Moresby. Local contact "offices" with the Project Communication Manager (PCM) were established: at FRI between February 2015 – April 2018 (with Benjamin Vali as the PCM), and at TFTC between May 2018 – March 2019 (with Charles Tsiritsi as the PCM). The role of the PCM was to assist the project partners with the operation of field research activities, implementation of research outcomes, and dissemination and communication with the project partners and stakeholders.

The project team included:

- Prof Barbara Ozarska, Dr. Benoit Belleville and Gerry Harris (retired in 2017) – UoM;
- Dr. Ruth Turia, Andrew Aopo, Dambis Kaip, Alois Jenkihau – PNGFA;
- Dr. Martin Golman, Kilva Lancelot, Frank Asok, Markson Naki, Benjamin Vali (until April 2017) and Dr. Simon Saulei (until July 2015) – FRI;
- Charles Tsiritsi, Vagi Lovo, Elaine Galore, Ravu Iru, Lus Pora, Moira Spairong, Daniel Marika, Morean Simeon – TFTC;
- Dr. Mex Peki, Haron Jeremiah, Pendis Ono, Dr. Larry Orsak (passed away in July 2017) – UniTech;
- Dr. Bob Smith - LeafCarbon P/L.

5.2 Research methods

Research and testing activities were conducted at FRI, TFTC, UniTech and UoM, while field-based activities (company visits, training and data collection) were held at the following Provinces: Morobe, Madang, Milne Bay, East New Britain, West New Britain and National Capital District.

The methodology applied in each of the project activities is summarised below.

Objective 1: To enhance the knowledge of wood properties and processing characteristics of PNG timbers

This Objective aimed to assess wood properties and processing characteristics of PNG timbers for plantation and secondary (regrowth) forests and provide recommendations for end uses of these timbers. The Objective included 7 Activities.

The Objective 1 leader was Dr. Benoit Belleville, UoM.

Activity 1.1. Extending the current database and creating a database for lesser-known species from secondary and plantation forests.

Online database software, the Wood Database on PNG Species, was developed by FRI within the previous ACIAR project FST/2006/120. The software collected data and information on properties, processing characteristics and potential uses of 292 PNG timber

species from natural forest. The data was obtained through an extensive review of publications on the properties of PNG timbers. According to the Project Proposal, this database was going to be expanded by filling in the properties data of the species tested within this project. However, a peer review of the database undertaken by IT experts and selected members of the project team in PNG and Australia revealed that the database was practically not usable. Examples of comments are provided below:

- *It took a very long time to open the database or it could not be open at all due to its massive size of 2.0 GB. The database was not suitable for placement on any website.*
- *The database was cumbersome to navigate and did not seem to have a logical layout.*
- *Macro errors. Multiple security concern messages were received when accessing mechanical properties information.*

In addition to the critical comments on the database, the principal researcher responsible for the database development (Activity 1.1-1.2) Mr. Benjamin Vali, left PNGFRI. The continuation of the activity was discussed during the PSC meeting on 24 April 2018 and it was agreed that the project leader should source an expert on database programming to re-program the software and develop a new database. Consequently, the database activity was assigned to Mr. Sipa Benny of Mathematics & Computer Science Department, PNG UniTech.

In order to capture the different wood properties for each species, the database was developed (entirely from scratch) using MySQL. MySQL is the most popular Open Source SQL database management system, that is developed, distributed, and supported by Oracle Corporation. MySQL stores data in a tabular manner. Therefore, to store all the information about the 26 selected wood species, appropriate tables were created. The database is user-friendly and new data can be added easily in the respective tables in the future. During the design of the database, links between each of the database tables were identified for storing the wood properties data. The design of the website is simple having three tabs:

- Wood Species Links tab to display wood properties of each species;
- Frequently Asked Questions (FAQ) tab to allow the viewers to ask questions;
- Optimized Search Tab to allow viewers to search for wood species based on different selection criteria.

The database has been uploaded with the data on 26 tested species and training on its usage has been provided to the project members.

Activity 1.2 – 1.6. Testing of wood properties and processing characteristics of target species.

The testing program included the following tests:

- Basic physical and mechanical wood properties (Activity 1.2)
- Development of kiln drying schedules (Activity 1.3)
- Assessment of preservative treatment characteristics (Activity 1.4)
- Testing gluing characteristics of the timbers for various wood product applications (Activity 1.5)
- Assessment of other processing characteristics required to successfully produce value-added products for PNG and export markets (Activity 1.6).

Twenty-six species were selected for testing: 9 species were from plantations and 17 from secondary (regrowth) forests located in the Morobe and West New Britain provinces, PNG. The group included 3 softwoods and 23 hardwoods (Table 1).

Table 1. PNG studied species Information

Species	Trade Name	Origin	Age (years)	DBH (cm)
Plantations (9 species)				
Araucaria cunninghamii	Pine, Hoop	Bulolo, Morobe	28	39 (4)
Araucaria hunsteinii	Pine, Klinki	Bulolo, Morobe	43	63 (5)
Castanospermum australe	Blackbean	Kimbe, West New Britain	17	42 (4)
Eucalyptus deglupta	Kamarere	Kimbe, West New Britain	29	60 (14)
Eucalyptus pellita	Pellita	Lae, Morobe	18	36 (5)
Magnolia tsiampacca	Beech, Wau	Lae, Morobe	17	34 (4)
Pinus caribaea	Pine, Caribbean	Lae, Morobe	31	55 (6)
Pometia pinnata	Taun	Lae, Morobe	18	48 (6)
Terminalia brassii	Terminalia, Brown	Lae, Morobe	31	54 (8)
Secondary Forests / Regrowth (17 species)				
Alstonia scholaris	Cheesewood, White	Lae, Morobe	17 to 20	46 (12)
Anisoptera thurifera	Mersawa, PNG	Lae, Morobe	+20♠	46 (8)
Anthocephalus chinensis	Labula	Lae, Morobe	+20♠	51 (8)
Canarium oleosum	Canarium, Grey	Lae, Morobe	17 to 20	40 (2)
Elaeocarpus sphaericus	Quandong, PNG	Lae, Morobe	17 to 20	54 (15)
Endospermum medullosum	Basswood, PNG	Lae, Morobe	+20♠	47 (14)
Falcataria moluccana	Albizia, White	Lae, Morobe	+20♠	64 (9)
Homalium foetidum	Malas	Lae, Morobe	17 to 20	52 (16)
Hopea iriana	Hopea, Heavy	Lae, Morobe	+20♠	44 (4)
Intsia bijuga	Kwila	Lae, Morobe	+20♠	40 (4)
Octomeles sumatrana	Erima	Lae, Morobe	+20♠	55 (11)
Palaquium warbargianum	Cedar, Pencil	Lae, Morobe	17 to 20	43 (2)
Pangium edule	Pangium	Lae, Morobe	17 to 20	38 (3)
Pterocarpus indicus	Rosewood, PNG	Lae, Morobe	+20♠	51 (8)
Syzygium spp.	Gum, Water	Lae, Morobe	17 to 20	40 (4)
Vitex cofassus	Vitex, PNG	Lae, Morobe	+20♠	41 (9)
Xanthophyllum papuanum	Boxwood, PNG	Lae, Morobe	+20♠	42 (9)

♠ No exact records of age are available in the harvested area. Species estimated age is +20 years old.

A total of 130 trees, i.e. 5 trees per species, were selected and harvested in accordance with an international standard. The trees were selected based on the following selection criteria: 1) the tree had to be more than 15 years old after regrowth or planting; 2) all trees for a specific species had to be from the same forest area; 3) the selected trees had to be representative of the population, with good form and merchantable height.

The timbers procurement process was difficult and there were many challenges encountered by the team. Discussions were held with landowners clarifying the purpose of the species procurement, abundance of each species in the area, negotiation and agreement on the log payments (logs were paid using TFTC's previous TA agreed on prices/volumes) and a group of species. This activity was done by the project researchers, TFTC harvesting team and landowners.

During the harvesting activity, standing trees were located and felled. Logs were then hauled (track/wheel skidder) to the log landing where the log labeling and scaling (diameter and length) was done and recorded using the PNGFA Log Scaling Sheet. Following harvesting, the total merchantable height of each tree has been further cut into 3 to 4 m-long logs, labeled as per height from ground (i.e., bottom, middle, and top section), and the logs were transported to TFTC timber yard for milling.

The milled sawn boards were then divided into groups for different tests:

- Boards for preservative treatment test were air-dried, dressed and pressure treated.
- Boards for wood properties, machining and gluing tests were kiln-dried to 12% moisture content. Eight species were dried at TFTC using a conventional kiln, while 18 species were dried at UniTech in a solar kiln. The TFTC kiln could not be used for drying all of the species because it was used for training and commercial drying purposes.

Dried timbers have then been machined into required dimensions according to relevant standards.

The process of samples preparation for testing, i.e., harvesting, milling, drying, machining and testing, is shown in Figure 1.

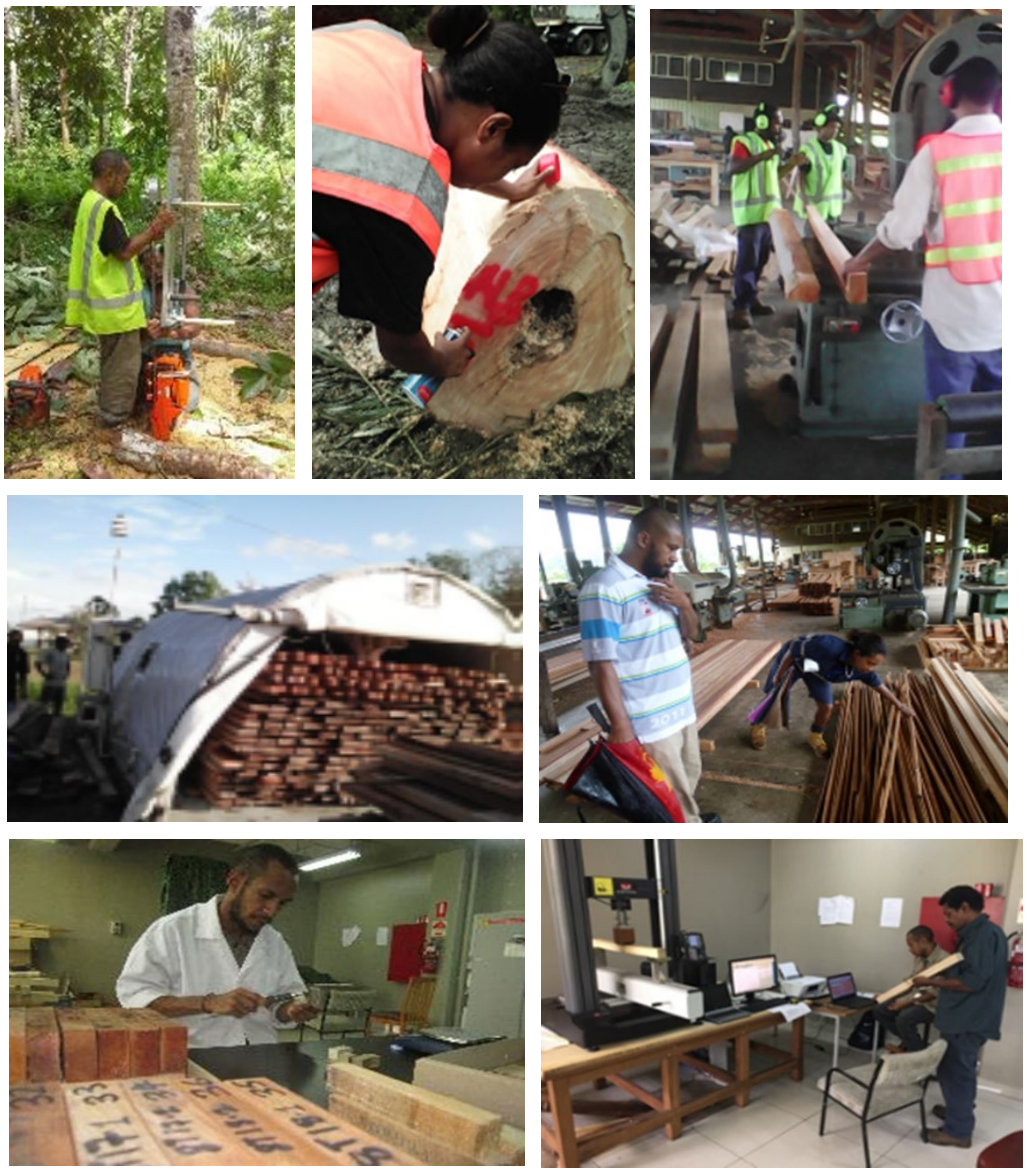

Figure 1. The process of samples preparation from harvesting to testing.

Activity 1.2 Testing basic physical and mechanical wood properties

The following wood properties were tested:

- Stiffness, also known as modulus of elasticity (MoE)
- Flexural bending strength, also known as modulus of rupture (MoR)
- Compression strength parallel to the grain
- Compression strength perpendicular to the grain
- Shear strength parallel to the grain
- Hardness (Janka)

Specimens were tested in accordance with ASTM D143 (2009) *Standard test methods for small clear specimens of timber,* using a universal testing machine (Instron model 5569, MA, USA), located at FRI.

A total of 2,641 specimens from 26 species and 130 trees were tested, i.e., shear: 528 specimens; compression parallel: 526 specimens; compression perpendicular: 532 specimens; static bending: 525 specimens; hardness: 530 specimens.

Activity 1.3 Development of kiln drying schedules

The development of drying schedules could not be conducted at the laboratory kiln at FRI, as initially planned, for two reasons:

- Not enough timber for each species has been secured for testing.
- Problems with electricity blackouts. Money for a battery backup system was provided, but the battery was not purchased. The matter was investigated by FRI Management but not solved.

Due to the above problems, the project team decided that schedules for drying the timbers in a solar kiln could be reported by providing data on drying time, drying rate and kiln parameters. Unfortunately, this option was also impossible to use due to technical problems in monitoring the drying data in the solar kiln. The kiln was also out of order for several months before it was repaired and used.

A report on this activity was written by the UniTech researcher responsible for this activity. Unfortunately, the report provides only data on the drying time for 18 species dried in the solar kiln and outdoor conditions for ambient temperatures and humidity obtained from the NASA database. The remaining 8 species were dried at TFTC conventional kiln at the time when the solar kiln was out of order.

Activity 1.4 Assessment of preservative treatment characteristics

The aim of the test was to assess the treatability/permeability of PNG timbers with alkaline copper quaternary (ACQ) wood preservative using conventional vacuum-pressure impregnation (VPI) process. Also, the data on permeability of the test species were compared with published information on the same species derived from primary (old-growth) forests. Further, the findings on their treatability could re-classify the species into their permeability classes and ultimately promote their end uses in structural engineering purposes. The treatability test using ACQ salt was conducted in line with international wood preservation standards, especially Australian (AS 1604.1:2012) and PNG (PNGS 1293:2012) standards. Thus, an intensive experimental design was developed in which physical characteristics (moisture content, density and porosity) were determined as elements that may have an influence on the permeability of test candidate species. The milling and sampling of wood specimens were done at TFTC, specimens were seasoned at PNGFRI, and actual treatment of the specimens was conducted at Sarco Timbers (Port Moresby) and PNG Forest Products PTY LTD (Bulolo) using their industrial VPI plants.

Replicates of 20 specimens per timber were prepared from the heartwood zones of the test timbers (Figure 2). After testing, absorption and retention were determined. Absorption, expressed in liters of preservative per cubic meter of wood, is the amount of preservative uptake during the wood treatment. Retention, expressed as kilograms of preservative per cubic meter of wood, is the amount of preservative retained in the wood after completion of the treating cycle and is one measure of the degree of protection provided.

Spot test using chrome azurol solution was conducted on treated specimens in order to assess the penetration and distribution of ACQ solution. In this experiment, 4-5 treated specimens were randomly selected as representatives of 20x replicates per test species for spot test. The specimens were cut across in their mid sections and sprayed with chrome azural solution on both ends. The dark blue coloured immediately appeared on the surfaces indicating the presence of copper (Cu) while untreated zones indicated reddish colour showing non penetration/distribution of Cu

The timbers were classified into 4 permeability classes and arranged in the order of easy treatable to difficult to treat.

In addition to the 26 species tested within the project, two species were tested by UniTech students within their final year research projects:

- Pine, Patula (*Pinus patula*) from Goroka, the Eastern Highlands, 35 years old;

- Teak (*Tectona grandis*) from Lae, Morobe, 20 years old.

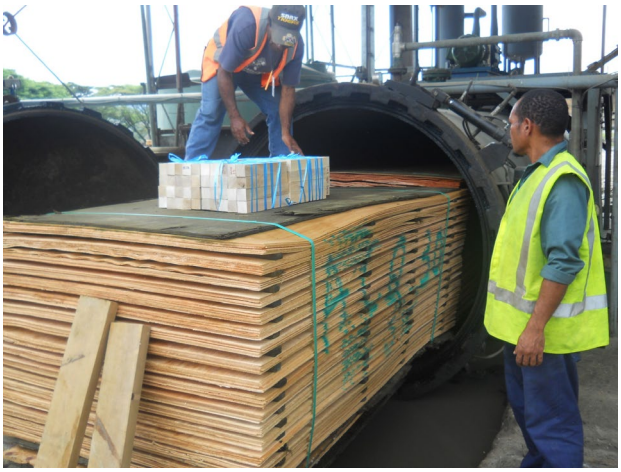

Figure 2. Bundles of wood specimens placed on top of plywood before pushing into a cylinder for treatment at PNG Forest Products PTY LTD (Photo credit: Benson Gusamo).

Activity 1.5 Testing gluing characteristics of the timbers for various wood product applications

The testing included the following studies:

- testing of glue-bond strength of different types of non-structural glues;
- testing of the performance of various types of adhesives in various climatic conditions which simulated service conditions in potential market destinations.

Two criteria, namely shear strength and wood failure, were used to determine if an adhesive meets the minimum requirements for either category. Testing was conducted in accordance with ASTM D905-08 *Test Method for Strength Properties of Adhesive* and ASTM D5266-99 *Standard practice for estimating the percentage of wood failure in adhesive bonded joints*.

Five exposure conditions were used in the testing as per ASTM D5751 (2012) S*tandard specification for adhesives used for laminate joints in non-structural lumber products:*

- Cured (No Treatment)
- Elevated Temperature
- 3-Cycle Soak
- Boil
- Vacuum-Pressure

A one-component cross-linking polyvinyl acetate (PVAc) emulsion adhesive (Jowacoll® 107.20, Jowat 2018a) was used for testing. Additional experiments were conducted using a two-component emulsion polymer isocyanate (EPI) adhesive (Jowacoll® 102.49). The EPI used is a non-structural polyurethane adhesive and unlike PVAc adhesive, the process involves mixing with a crosslinking agent (hardener) before application.

Based on the testing results, each of the PNG selected species has been classified into bondability classes (bond very well, bond well, bond with difficulty, very difficult to bond).

Twenty-four species were tested: ellita and Wau beech could not be assessed because of a lack of enough timber harvested for all tests involved in the project.

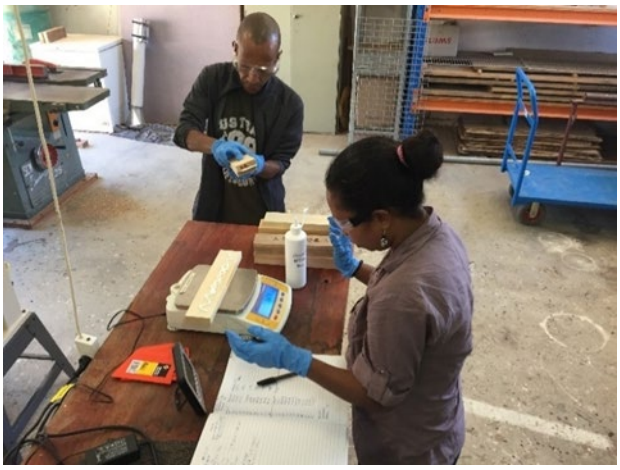

Figure 3. PNG researchers Elaine Galore of TFTC and Kilva Lancelot of PNGFRI are preparing samples for testing glue bond strength of PNG timbers (Photo credit: Benoit Belleville).

Activity 1.6 Assessment of other processing characteristics required to successfully produce value-added products for PNG and export markets

The project team decided that the assessment of machining characteristics would provide essential data for efficient processing and manufacturing of PNG timber species. Therefore, the planing behaviour under cutting tools was selected for testing of the species.

Twenty-five species were tested. One species, Pellita, could not be assessed because of lack of enough timber harvested for all tests involved in the project.

A total of 1,337 timber specimens 50 mm x 50 mm x 900 mm and more than 3,600 linear meters of timber have been planed with a standard moulder machine. The specimens were fed through the moulder and machined with the grain (Figure 4). A high-speed steel cutter material and a 30° grinding angle were used. A visual assessment of the surface quality was conducted after each run using machining grading rules developed for the project. The grading system developed is based on the worst affected area of a machined surface. One or two people using the sight and touch method have graded the planed surface. The defects were checked for were torn grain, fuzzy grain, raised grain, chipped knife mark and knife mark. A score was then assigned to the worst defect of each type. If no defects were present, then the sample was graded as A-Grade. Samples graded as A-Grade or B-Grade would be considered acceptable in furniture manufacturing and only requiring very light or light sanding.

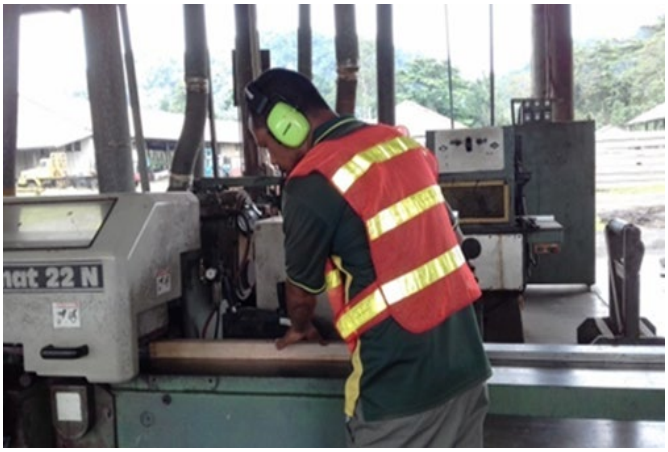

Figure 4. Planing trials at TFTC (Photo: Ravu Iru).

Activity 1.7 Recommendations on best applications/types of products for the selected species based on their properties and processing characteristics

The data on wood properties and characteristics of 26 PNG species from plantation and secondary forests were combined and presented in summary tables (Appendices 1 & 2). Recommendations were provided on the type of products and service conditions in which each species could be used.

The classification of wood products was made by dividing products into non-structural and structural products for dry and wet uses.

- Structural product or component in relation to a building means any internal or external load-bearing component of the building that is essential to the stability of the building or any component that forms part of the external walls or roof of the building;
- Non-structural components (e.g., cladding, roofing, interior walls and ceilings) are permanently attached to and supported by the structure.

According to ASTM D5751 dry-use refers to service conditions in which Equilibrium Moisture Content (EMC) of wood does not exceed 16%, while wet-use refers to the conditions in which the EMC of the wood may be 16% or greater.

It is important to highlight that the suggestions for wood products and service conditions have been given merely as guidelines and other products could be considered if the species meets the required criteria.

Objective 2: To identify, pilot and evaluate interventions for enhanced value-added processing systems.

The Objective 2 leader was Dr. Mex Peki, UniTech (until July 2017) and Haron Jeremiah (August 2017 - until the project end).

Activity 2.1 Selection of companies and landowners groups willing to participate in the Project.

A list of landowners and processing companies was prepared by PNGFA in conjunction with the project team and invitation letters were sent by PNGFA in December 2015. However, no responses were received. During 2016, visits to wood processing and manufacturing companies were undertaken with the aim to identify what improvements in the current production practices are required (Activity 2.2). Sixteen companies were visited and reports written on each company. Seven companies were selected which met the main selection criteria for being involved in the project: timber used for processing must be sourced from legal resources and the company should be of small or medium size. The list of the selected companies was sent to PNGFA for approval. The approval was obtained on 21 Feb 2017. However, of the seven companies, only one agreed to sign the MoU. It is presumed that the reason for withdrawal from the project was the companies' concerns that their performance would be formally assessed by PNGFA which could have negative implications on their businesses.

The project team decided that technical support and training could be still provided to the companies which were not willing to sign MoU. Further visits were made to these and other companies to provide training and technical advices.

The involvement of landowners in the project was challenging because most landowners do not have TA and it would be difficult to work with them as their operations were not legal. Therefore, the involvement of landowners in the project was postponed until a decision on CPU establishment could be made. Finally, the list of landowners was developed after the trials on CPU Commercial Unit were conducted in 2018.

Activity 2.2 Identifying what improvements in the current processing and manufacturing practices are required.

Visits to small and medium size wood processing and manufacturing companies were made (Figure 5). Reports on 16 companies were written and sent to each company.

Current production capacity, technology methods, efficiency and types/quality of products of the companies were evaluated via a benchmarking survey and analysis was undertaken to identify practice and technology gaps and key areas for improvement. The analysis involved the evaluation of primary processing operations and manufacturing processes.

The assessment was performed by 2 teams consisting of experts in primary processing and manufacturing from TFTC, Unitech, FRI and UoM:

- Team 1 (Wood processing) was led by Mr. Frank Asok, FRI;
- Team 2 (Wood manufacturing) was led by Mr. Ravu Iru, TFTC.

Summary reports on the assessment of the current practices in PNG primary processing and manufacturing were completed. A report “Gaps in wood processing and manufacturing practices in PNG” was completed which identified gaps in downstream wood processing supply chain, policy and administration.

Workshops were organised in Port Moresby and Lae to present and discuss the generalised assessment results involving the members of the timber industry, participants of the project, relevant government representatives and stakeholders.

Figure 5. The project team visits to SME companies.

Activity 2.3 Conduct research to address identified practice and technology gaps.

It should be pointed out that this activity has been amended to avoid duplication of activities undertaken by FST/2014/065 project (EWP project). Both projects have activities which involve working with wood processing companies on improving their production methods and developing new products. During the Project Steering Committee (PSC) meeting held in September 2016, it was agreed that EWP project should work with the large wood processing companies while this Value-Adding project should focus on small wood processing companies and furniture companies. Consequently, parts of the Milestones 2.3.5 - 2.3.8 involved collaborative work between the two projects. For example, wood drying recommendations and wood preservation manual were developed by DAF staff (EWP project) while the Value-Adding team developed twelve simple “checklists” (Fact Sheets) on various aspects of wood processing and manufacturing: wood waste utilisation and control, wood gluing, finishing, machining and OHS machining. The checklists were placed on the project website.

A Market Research Analysis was conducted by IndustryEdge company in Australia to identify target wood products and engineered wood products, linked to identified target market opportunities, and develop recommendations for improving the market conditions

for the take--up of identified opportunities. The report was funded jointly by both ACIAR projects.

Activity 2.4 Support trial implementation of improved value-adding processes.

Value-added processes investigated in Activity 2.3 were implemented at relevant companies. The selection of processes for the production of various value-added products for the participating companies was done according to the companies' current capabilities (e.g., equipment available, labour's skills), market information and the management commitment for improvements, innovation and investment in updating existing machinery or purchasing new equipment (if required).

Detailed implementation program was developed for each assessed company which was included in the company's assessment report.

A training program was developed on the relevant value-added processes (e.g., wood grading, sawing, treatment, drying) to train the companies' workers.

Activity 2.5 Pilot innovative approaches to enable greater landowner involvement.

The aim of Activity 2.5 was to investigate innovative pilot approaches to enable greater landowner involvement. Three case studies were undertaken within the project which aimed to provide value-added opportunities for local communities.

1) Establishment of the Central Processing Unit (CPU (see Activity 2.6)
2) Designing low-cost and light-weight furniture for children and women in local communities
3) A study on the involvement of carvers in the wood downstream processing industry.

A collaboration has been developed with ACIAR project ASEM/2010/052 "Examining women's business acumen in Papua New Guinea: Working with women smallholders in horticulture" led by Prof. Barbara Pamphilon from The University of Canberra. The project has been working with remote villages in New Ireland (and other locations) and found that often the women groups don't have any tables or stools which would be used during their planning activities or for children to use for homework activities. The Value-Adding project team recognised the collaboration with the above project as an exciting opportunity for developing value-adding activities for local communities. It was agreed that our project would design and develop low-cost light-weight tables, stools or benches that could be quickly moved around by women undertaking various activities or used by children to do their homework. A Design Competition was initiated with the aim of encouraging TFTC students and teachers to design portable folded furniture which could be used by people in the villages. Prototypes were made according to the awarded designs.

A survey of carvers was conducted to give a general perspective of the carving making not only as an art but more importantly as a small-scale industry supporting local people's livelihood.

Activity 2.6 Work with PNGFA to operationalise the Central Processing Unit in Lae

The idea of the Central Processing Unit (CPU) was an initiative of the PNGFA which was in line with the Strategy to encourage downstream processing. The aim of the establishment of CPU was to ensure that PNG small sawmillers and landowners are able to sell their sawn timber which can be further processed. However, PNGFA did not have the capacity to undertake the CPU activity and hence, it was proposed that CPU be based at TFTC, Lae, which would allow the building of capacity in training of landowners and small wood processors to effectively and sustainably use natural resources and generate sustainable income streams for their local community.

Four concept models for CPU were developed and discussed at workshops held at UniTech and PNGFRI in April 2016. Finally, a business plan for the proposed CPU structure and operational procedures was developed by Mr. Don Yakuma, a PNG consultant.

Small-scale trials were undertaken at TFTC by the Commercial Manager, Mr. Morean Simeon, and Deputy Principal, Mr. Charles Tsiritsi, to see if the idea of working with landowners and small wood processors is feasible for the benefit of the resource owners, CPU and the buyers. Landowners and small wood processors in Lae and across the Huon and Nawaeb electorate were involved in the trials. A loan of PGK10,000 was provided by the ACIAR Project to conduct the study. The study showed a significant interest from landowners and small wood processors in participating in CPU activities. Two reports on the trials have been written by Mr. Simeon.

Activity 2.7 Developing public-private partnerships to support enhanced value-added wood processing in PNG.

This activity was assigned to PNGFA but its team did not have the resources to undertake this study. However, a comprehensive report on private-public partnership was written by Mr. Jon Marlow, a consultant to the EWP project. Therefore, it was suggested by PSC members that this report is reviewed by PNGFA and the PSC would decide if Activity 2.7 is still required within this project. However, it is understood that Mr. Marlow did not continue working on this report due to the lack of data available and lack of support in obtaining the information essential to this work.

Objective 3: To estimate the potential contribution and distribution of economic impacts to national and local economies from enhanced value-added wood processing.

The leader of Objective 3 was Dr. Bob Smith, LeafCarbon P/L.

In the Project Proposal 4 activities were included in this objective:

3.1 Establishment of benchmarks (employment, PNG participation rates and financial flows) of contribution of current forest resources processing sector (Private sector and other processing groups) to national and local economies including landowner groups.

3.2 Assessment of evidenced based options for the development and/or enhancement of alternative wood processing and manufacturing facilities and structures which would increase returns to landowners and processors.

3.3 Assessment of potential changes in economic distributions with transition to viable organisational arrangements associated with PNG appropriate supply chain arrangements for increasing downstream processing.

3.4 Identification of appropriate pathways to assist decision makers deliver goal of significantly increased domestic processing of PNG's forest resources.

A substantial effort was made by the team members of this objective during the first two years of the project term to conduct the above studies. However, significant difficulties and challenges were encountered in collecting data and information critical to addressing the above activities. The difficulties were associated with extended leave of a key PNGFA staff, withdrawal by major timber companies from the participation in the Project, difficulties in obtaining timely data from Databases being developed by PNGFA and lack of reliable integration of various data bases to generate data sets useful for Project.

During this challenging time, the focus of work for progressing Objective 3 was on the collection of data sets to document log production and use (covering log export and domestic processing). The data gathering was divided into two streams. The first stream focused on the establishment of baseline for log production sites. The second stream

focused on obtaining baseline data (log inputs/products, employment, markets and financial inputs) for large scale domestic processing activities in PNG.

A Workshop was held in PNGFA Offices on Tuesday 6th September 2016 to integrate SGS log export data (recorded by Sites) and log volumes supplied to domestic processing sites by approved PNGFA Project areas. An outcome of Workshop was a consolidated Worksheet of export sites as used by SGS and domestic processing facilities matched to PNGFA Project areas and Provence.

The progress on the Objective 3 was documented in a Progress Report and presented during the Project Mid-term Review.

Following the Mid-term Review, RPM agreed that activities for Objective 3 (relevant to the formal sector) would be revised to address the above problems.

The activities listed below are the revised activities which were used for research work within this remaining 2.5 years of the project.

Activity 3.1 To document the evolution over the last 25 years of PNG's policies for implementing enhanced domestic downstream processing of logs harvested from PNG forests; and commentary on the current legal status of policies currently in place.

Activity 3.2 To analyse at National level the historical performance of PNG in enhancing downstream processing of logs harvested from PNG FIA Project areas (Formal sector).

Activity 3.3 Working at National level estimate the current markets for categories of wood products consumed in PNG by sector (industrial, commercial and residential); and the source of supply (domestic production and/or imports) for these markets.

Activity 3.4 Assess implications for Government revenue and employment outcomes from the proposed implementation of Government Policy on domestic downstream processing.

Activity 3.5 Building on the results of work from the two ACIAR Projects and identify the key factors/structures, in the context of PNG forest industries, considered to be necessary to increase the probability of successfully achieving implementation of Government Policy on enhanced domestic processing for PNG.

Activity 3.6 Identification of potential pathways to assist decision makers deliver the goal of significantly increased domestic processing of PNG's forest resources.

The data collection for this study was still challenging due to issues associated with limited/reduced participation of the major operators of the PNG forest industry in financial component of the project and completion of databases being developed by PNGFA for the monitoring of PNG forest activities.

Results of the studies on the 6 activities were combined in the final report "Estimates of the potential contribution and distribution of economic impacts to national and local economies from enhanced value-added wood processing".

To deliver these Activities the Report was organised under the following structure:

- presentation of snapshot of current structure of forest industry operating in PNG, the regulatory and administrative systems used to manage resource allocations and Statutory revenue streams generated from harvesting activities (Chapter 1);
- track the evolution of PNG Government's policies/strategies in the utilization of PNG forest resources for enhancing downstream processing of PNG forest resources (Chapter 2);
- evaluate the implementation performance of the policies through criteria such as industry structure, employment and markets (Chapter 3);
- identify the key drivers shaping the current structure of industry (Chapter 4);

- identify the key challenges/issues impacting on PNG enhanced value adding of PNG forest resources (Chapter 5); and
- outline some of the potential pathways to generate enhanced value adding (Chapter 5).

The methodology employed to deliver the activities consisted of following.

- The snapshot of current outcomes from forest industry (formal sector) operating in PNG, (covering acquisition, allocation and use of resources) were generated primarily from review of PNG Forestry Act, 1991 (as amended); Workshop and discussions with PNGFA staff; and review of PNGFIA reports. The Statutory revenue streams generated, and beneficiaries, were documented primarily from information provided by PNGFA and PNGFIA.
- The evolution of PNG Government policies/strategies was tracked by reviewing historical records of relevant documentation for specific policy/strategy announced by Government and other agencies including PNGFA; reviews of literature related to implementation of specific policies; Workshop and discussions with PNGFA and PNGFIA; and feedback from individuals with knowledge of history of development of forest industries in PNG.
- PNG has limited publicly available data on wood products production and consumption. In order to evaluate the historical performance in meeting the targets specified in the various policies and strategies for enhanced domestic processing of harvested logs a model was developed to estimate the total volumes of logs harvested (Formal Sector) and the markets (log export or domestic processing) and the volumes of wood products produced (sawnwood, plywood and veneer). The model estimates the markets for various wood products (export and domestic) and considering imports estimates apparent domestic consumption of wood products between 2007 and 2017. A wide variety of data sources were used to populate the model, including SGS Log Export records, PNGFIA records and reports, PNGFA Export of Forest Products reports, FAO and ITTO reports, UN Comtrade reports and interviews with current industry participants. Similar approach was used to develop employment performance and changes in wood processing facilities.
- Key drivers and challenges facing PNG forest industry in transitioning to enhanced downstream processing were identified for the results of analyses undertaken and knowledge of the structure and organisation of forest industries in PNG.

Contributors to this report were: Mr. Haron Jeremiah (UniTech), Mr. Andrew Aopo, Mr. Alois Jenkihau, Dr. Ruth Turia, Mr. Dambis Kaip, Ms. Susan Kulukulu and Mr. Ivo Kusip (PNGFA), Mr. Bob Smith (LeafCarbon), Mr. Bob Tate (PNGFIA).

Objective 4: To enhance the capacity of Government, institutional support bodies, industry partners and landowners to implement value-added wood processing policies, strategies and practices.

Activity 4.1 Training and technology transfer on value-added processing methods.

This Activity was led by Mr. Charles Tsiritsi, TFTC.

The review of current training and teaching courses at TFTC available to timber industry was undertaken in Year 1. The gaps in the current training and equipment were identified.

The curriculum for a National Diploma in Timber Processing and Wood Products developed under the previous ACIAR project (FST/2006/120) was revised. Approval of the Diploma course is pending vetting process through PNG UniTech Courses Committee & Academic Board. Short-term & long-term training for various segments of the TFTC course program was undertaken on an on-going basis.

Training and technology transfer courses included:

- short-term and long-term training for various segments of value-added wood processing. The training was undertaken “in-house” at individual companies and at TFTC (Figure 6);
- training in Australia for some PNG researchers on value-added wood processing methods and production systems: furniture design and manufacturing and cabinet making, use of timber in building construction, automated hardwood manufacturing, production of veneered panels, and training in wood processing and machining. The participants of the training included 2 females and 6 males.
- workshops and seminars for the industry and stakeholders to disseminate the research findings; and
- technical specifications, fact sheets, standards and manuals were collated and distributed to the industry through the PIP website and during the company visits.

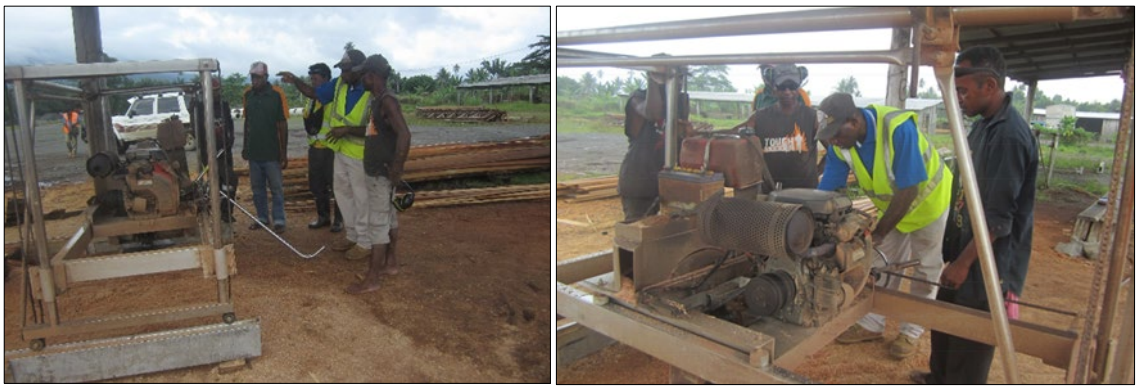

Figure 6. Mr. Steven and Mr. Asok doing onsite training on basic cutting techniques and portable mill maintenance at SPTE (Photo credit: Haron Jeremiah)

Activity 4.2 In collaboration with Government and industry association working towards implementation of the national policy on the development of downstream wood processing.

This activity was led by Mr. Alois Jenkihau, PNGFA, with the support of Dr. Ruth Turia and Mr. Dambis Kaip, PNGFA.

Due to limited funding, information gathering for this activity was through circulation of written questionnaires to FIA members in PNG, particularly those who are involved in timber processing, to gauge their views on opportunities and challenges of timber processing in the provinces of PNG. Since most timber processors are out in provinces, it was impossible to reach them individually. Thus, the alternative was to interview in person the FIA executives who are available in Port Moresby.

In PNG, there are also many non-FIA members who are engaged in timber processing but located in provinces. These members were also unable to provide their views regarding timber processing due to funding constraint. Some former and current PNGFA forestry officials with good experiences were interviewed to gauge their views on the outlook to domestic wood processing in PNG. Despite all these challenges, a report of the activity 4.2 was put together.

Activity 4.3 Monitoring and regulating the timber industry to meet required quality standards and also impart technical and appropriate advice for improvement.

A Monitoring & Evaluation Workshop was held on 6 February 2015, which provided an opportunity for the partners to participate in group activities intended to network building and to determine the essential foundation elements of the project Monitoring and Evaluation Plan. The participants could also review the 'impact pathway' for the project through defining expected longer term, intermediate and immediate outcomes, activities, inputs and foundational activities.

A workshop was held in Canberra in June 2017 for the Australian researchers when the Monitoring and Evaluation (M&E) plan and Key Performance Indicators (KPIs) were developed for the project. The M&E assessments were conducted by Mr Simon Dorries, an expert in an impact pathway analysis. The M&E process consisted of 2 parts:

- Part A – Monitoring of project delivery: a review of project outcomes against the milestones defined in the proposal and plan. This has been achieved by reviewing all technical deliverables i.e. requirements, databases, Standards, functions, key learnings and communications against the project plan. This has included a physical review of each written report in addition to interviews with project personnel and participants. Where specific issues have been identified, they have been reported with the intent of providing improvements in the management of project delivery.
- Part B – Evaluation of project impact: a review of the impact on this project on the PNG wood processing Sector and capacity building of PNG partners (technical, educational, research and training organisations). The review was undertaken by a questionnaire survey and by interviews with the PNG project partners which took place in Melbourne and Lae.

Activity 4.4 Development of timber promotion materials such as wood sample and pamphlets.

Sets of promotion materials have been developed to promote PNG commercially available timbers from plantation and secondary forests. The promotion materials include:

- sets of wood samples packaged in separate boxes which represent 26 species tested within the project. Each wood sample has a label describing wood properties and processing characteristics, potential uses and location;
- database on the 26 species; and
- pamphlets which will describe properties and processing characteristics of PNG timbers.

This activity was led by Ms. Elaine Galore, TFTC.

6 Achievements against activities and outputs/milestones

The project started at the Inception meeting on 5 February 2015. The completion dates for the project activities proposed in the Project Proposal have been adjusted accordingly.

Objective 1: To enhance the knowledge of wood properties and processing characteristics of PNG timbers.

No.	Activity	Outputs/milestones	Completion date	Comments
1.1	Extending the current database and creating a database for lesser-known species from secondary and plantation forests.	1. Review of the current database and publications on PNG timbers completed. 2. List of lesser-known timbers species to be tested completed. 3. Extensive database for PNG lesser-known species published online.	31-03-2015 31-07-2015 30-01-2019	The database was developed and populated with existing data for 292 PNG commercial species. However, the database was too large and too complex to use. A new database was developed. The list of 26 species from secondary and plantation forests for testing was completed. The database was developed and populated with the test results.
1.2	Testing of basic physical and mechanical properties of target species.	1. Testing program developed. 2. Progress report of wood properties for 13 species from secondary forests, plantation and lesser-known species. 3. Report on physical and mechanical properties of the PNG lesser-known timbers completed.	31-07-2015 30-01-2017 31-12-2018	Reports: 1.2.1, 1.2.2 & 1.2.3 Reports: 1.2.4 and 1.2.5 Testing of 26 species was completed. Report 1.2.6
1.3	Development of kiln drying schedules and PNG appropriate technologies for the timbers.	1. Testing program developed. 2. Progress report on drying schedules for 13 species. 3. Report on drying schedules for the timbers completed.	31-07-2015 30-08-2017 31-10-2018	Delayed due to problems with laboratory kiln at FRI (electrical blackouts). Battery backup system was purchased but not delivered/ installed. It should also be pointed out that not enough timber for each species has been secured for testing. Drying of 8 species was done at TFTC conventional kiln, and 18 species were dried at Unitech using a solar kiln. The final report completed. Report 1.3.1
1.4	Assessment of preservative treatment characteristics of timbers.	1. Testing program developed. 2. Progress report on treatment characteristics for 13 species. 3. Report on preservative treatment characteristics of the timbers.	31-07-2015 30-06-2017 31-10-2018	Report 1.4.1 Reports 1.4.2, 1.4.3 and 1.4.4 Testing completed. Report 1.4.5

1.5	Testing gluing characteristics of the timbers for various wood product applications.	1. Testing program developed. 2. Progress report on gluing characteristics for 13 species. 3. Report on gluing characteristics of the timbers for various applications.	31-07-2015 30-10-2017 31-12-2018	Report 1.5.1 The testing could not be done at FRI because the Instron machine was fully dedicated to wood properties testing (Act. 1.2). The testing was conducted at UoM in Melbourne after all specimens for gluing were transported to Melbourne. Testing completed. Report 1.5.2
1.6	Assessment of other processing characteristics required to successfully produce value-added products for PNG and export markets.	1. Discussion paper completed with suggestions on other processing characteristics required for value-added products with the testing program to be undertaken according to the resources available. 2. Report on other characteristics completed.	31-07-2016 31-12-2018	In the Annual Review 1 it was suggested that no additional testing should be undertaken to ensure that the current tests meet their deadlines. However, the team members agreed that machinability tests could be conducted at TFTC using timber which was available for testing and preparation of promotional samples. The methodology for timber machining tests and grading system for the assessment of the quality of planed surfaces were developed and tests were conducted at TFTC. Reports 1.6.1, 1.6.2 and 1.6.3
1.7	Recommendations on best applications/types of products for the selected species based on their properties and processing characteristics.	1. Workshop to present to date results on the testing & discuss value-added opportunities for PNG timbers. 2. Discussion paper completed with recommendations on best applications/types of products for the selected species based on their properties and processing characteristics. 3. Workshop with industry, government and stakeholders to brainstorm the results.	30-04-2017 15-11-2018 30-11-2018	One Workshops was conducted: first in Port Moresby on 21 April 2017 and then in Lae on 4 August 2017. Report 1.7.1 The Workshop will be conducted in Port Moresby in the last week of March 2019.

Objective 2: To identify, pilot and evaluate interventions for enhanced value-added processing systems.

No.	Activity	Outputs/ milestones	Completion date	Comments
2.1	Selection of companies and landowners groups willing to participate in the Project.	1. A group of processing companies which will be involved in the project established. 2. A group of landowners which will be involved in the project established.	31-03-2015 30-08-2016	Report 2.1.1 The involvement of landowners in the project was postponed until a decision on CPU establishment could be made. Finally, the list of landowners was developed after the trials on CPU Commercial Unit were conducted in October 2018 – February 2019. Report 2.5.5
2.2	Identifying what improvements in the current processing and manufacturing practices are required.	1. Benchmarking survey and SWOT analysis of the current primary processing practices completed. 2. Benchmarking survey and SWOT analysis of the current manufacturing practices completed. 3. Workshop held to discuss the assessment results with government, industry, and stakeholders. 4. Research program developed which will identify gaps and areas for improvements.	31-01-2016 5-07-2016 30-04-2017 30-10- 2016	Visits to wood processing companies, small processors and landowners were completed. Reports on the companies visited have been written and summary reports on primary processing and manufacturing completed. Reports: 2.2.1 – 2.2.19; 2.2.21 and 2.2.22 A workshop with PNGFIA, PNGFA and project partners was conducted on 21 April 2017 in Port Moresby. A 2nd workshop was held on 4 August 2017 in Lae. Report 2.2.20

2.3	Conduct research to address identified practice and technology gaps.	1. Proposal for log grading rules/standards at the log yards/mills for comments by the industry.	30-10-2015	According to PNGFIA, the current log grading rules are broadly used by the industry and there was no need for any changes or modifications.
		2. Proposal for grading rules for sawn timbers for comments by the industry.	*31-09-2016*	The proposed grading rules were sent to PNGFIA for comments.
		3. Waste grading rules for primary and secondary processing operations completed for comments by the industry.	*31-07-2106*	Report 2.3.2
		4. Report on the revised grading rules submitted to industry and government for endorsement and implementation.	30-08-2017	The grading rules were submitted to the National Institute of Standard Industrial Technology (NISIT) by PNGFA for adoption as PNG standard. Reports 2.3.3 – 2.3.5
		5. Report on recommendations for improving sawing operations and wood recovery completed.	31-01-2017	During the PSC meeting held in September 2016, it was decided that the EWP project and this project should develop a close collaboration in their work with the industry. It was agreed that the Milestones 2.3.5- 2.3.8 would involve collaborative work between the two projects by developing Manuals and user-friendly Fact Sheets on wood processing and manufacturing topics and published on the PIP website. Reports 2.3.1 and 2.3.2 were written by EWP project team and Fact Sheets 2.4.1 – 2.4.16 by this project team.
		6. Best practices guidelines for air and kiln drying operations for the PNG timbers.	31-01-2018	
		7. Report on recommendations for preservative treatment methods suitable PNG conditions completed.	30-11-2017	
		8. Report completed which will suggest a range of wood products and relevant value-added processes based on market demands (domestic and international).	31-07-2017	The report was completed by LeadingEdge (for this and EWP projects). Report 2.3.7
		9. Workshop to discuss support required from the government policy to enhance value-added processes identified within to date studies.	31-07-2017	This topic was discussed during the Workshop in Port Moresby on 21 April 2017. It was agreed that PNGFA would continue the dialogue with the government about the downstream wood processing policy.
		10. Report on any policy responses that can usefully be implemented to enhance prospects for PNG value-added products on international markets.	31-07-2018	This topic was addressed in Report 2.3.7.
		11. Set of specifications on quality and performance requirements for various wood products for different market segments.	30-05-2017	Report 2.3.6

2.4	Support trial implementation of improved value-adding processes.	1. Implementation program for each company completed and agreed by all parties. 2. Training for company workers completed. 3. Report on implementation work completed.	30-07-2017 31-10-2018 31-10-2018	Recommendations for improvement have been proposed for each of the assessed companies in Reports 2.2.3 – 2.2.18. The in-house training has been undertaken on a continuous basis until the project completion date. Training materials and Fact Sheets for companies were developed: Training materials: 2.4.1 – 2.4.17 and 2.4.19. The final training will be conducted at the beginning of March 2019 and a report then completed. Interim Report 2.4.18.
2.5	Pilot innovative approaches to enable greater landowner involvement.	1. Program for collaboration with Project FST/2011/057 completed. 2. Workshop held to brainstorm options for value-added opportunities for local communities. 3. Report on case studies with recommendations on value-added opportunities for communities completed.	30-08-2017 31-03-2016 31-07-2018	The project FST/2011/057 has been completed and a new ACIAR Agroforestry project FST/2016/153 started in September 2017. The Project leader attended the Inception Workshops in Lae and a collaborative program has been discussed. Completed. A workshop with about 20 landowners/resource owners was held on 27 April 2016 in Lae. Involvement of carvers in value-adding has been identified as an important activity. Landowners showed interest to be involved in CPU, but many of them did not have TA. Reports: 2.5.1 – 2.5.5
2.6	Work with PNGFA to operationalise the Central Processing Unit in Lae.	1. Analysis of PNGFIA scoping study on the establishment of CPU in Lae completed. 2. Proposal on the structure and operational procedures of the CPU (jointly with PNGFA).	30-06-2015 15-04-2017	PNGFA did not have the capacity to undertake the CPU activity and hence passed it on to TFTC. Four concept models for CPU have been developed and discussed at workshops held at UniTech and FRI in April 2016. Reports: 2.6.1 – 2.6.3
2.7	Developing public-private partnerships to support enhanced value-added wood processing in PNG.	1. Report on the analysis of the current partnership between PNGFA and timber industry completed, and 2. Recommendations for a partnership strategy developed. 3. Report on evaluation of the pilot trials completed.	30-09-2017 30-11-2018	A short interim report was written by PNGFA in April 2016 (Report 2.7.1). During PSC meeting in February 2017, the Committee members suggested that this work could be combined with PPP activity in EWP project. Mr. Jon Marlow agreed to include this project component of the study in the EWP project report. However, due to the lack of data from PNGFA, this work has not been completed.

Objective 3: To estimate the potential contribution and distribution of economic impacts to national and local economies from enhanced value-added wood processing.

Detailed below are revised activities and outputs/milestones for Objective 3. Following the Project Mid-term Review, RPM agreed that activities for Objective 3 (relevant to the formal sector) would be revised to address issues associated with participation of major organisation in PNG forest industry, difficulties in obtaining timely data from Databases being developed by PNG FIA and to strengthen alignment with economic activities incorporated into ACIAR Project "Development of Durable EWP in PNG and Australia".

No.	Activity	Outputs/ milestones	Completion date	Comments
3.1	Document the evolution over the last 25 years of PNG's policies for implementing enhanced domestic downstream processing of logs harvested from PNG forests; and commentary on the current legal status of policies currently in place.	A report detailing the history- over the last 25 years- of major policies from PNG Government relevant to enhancing levels of domestic processing of logs harvested from PNGFIA Project areas in PNG.	31-12- 2017	Activities 3.1 to 3.6 have been completed and integrated into a single Final Report. The delay in submitting drafts was in part to changes in levy policies implemented by PNG Government which impact on Government revenue collections and financial benefits to landowners. Reports 3.1.1 and 3.1.2
3.2	Analyse at National level the historical performance of PNG in enhancing downstream processing of logs harvested from PNGFIA Project areas (Formal sector).	A report detailing an assessment of the historical performance of PNG in meeting policy goals for enhanced downstream processing. The report, based on feedback from industry interviews and workshops, of factors driving historical performance in enhancing downstream processing of PNG forest resources.	31-01-2018	Report 3.1.2
3.3	Working at National level to estimate the current markets for categories of wood products consumed in PNG by sector (industrial, commercial and residential); and the source of supply (domestic production and/or imports) for these markets.	Report on the estimated size of wood product markets currently operating in PNG and the source of supply (domestic production and/or import) for these markets.	28-02-2018	Report 3.1.2
3.4	Assess implications for Government revenue and employment outcomes from the proposed	Report: - On the assessed current structure and estimated Government revenues and employment outcomes for forest industries in PNG;	31-03-2018	Report 3.1.2

	implementation of Government Policy on domestic downstream processing.	- On assessed implications for Government revenue and employment flowing from successful implementation of Government Policy on enhanced downstream processing.		
3.5	Building on the results of work from the two ACIAR Projects to identify the key factors/structures, in the context of PNG forest industries, considered to be necessary to increase the probability of successfully achieving implementation of Government Policy on enhanced domestic processing for PNG.	Report identifying the key drivers considered necessary in PNG to commercially support increasing domestic downstream processing of logs. This Report will incorporate the outcomes of Objectives 1 and 2 for this Project (FST/2012/092) and ACIAR Project Development of Durable EWP in PNG and Australia (FST/2014/065). Report on the potential business model(s) which offer most commercial promise in enhancing domestic downstream processing in PNG.	30-09-2018	Report 3.1.2
3.6	Identification of potential pathways to assist decision makers deliver the goal of significantly increased domestic processing of PNG's forest resources.	Report which integrates the research results of all components of research results to suggest most promising pathway(s) and actions policymakers may consider in developing and successfully implementing increasing domestic downstream processing.	31-10-2018	Report 3.1.2

Objective 4: To enhance the capacity of Government, institutional support bodies, industry partners and landowners to implement value-added wood processing policies, strategies and practices.

No.	Activity	Outputs/ milestones	Completion date	Comments
4.1	Training and technology transfer on value-added processing methods.	1. Communication strategy developed & approved.	30-03-2015	Completed.
		2. Program for enhancement of research capabilities developed.	31-07-2015	List of equipment and research facilities at each partner organisation has been prepared. Training in "Research design and methods" was conducted at TFTC (2017)
		3. Report completed on the review of current training and teaching courses available to timber industry and recommendations for future programs.	30-11-2015	Completed. Presented at the Annual Review. Report 4.1.5
		4. Training in Australia for PNG researchers on value-added technologies.	31-12-2017	The project leader successfully applied for additional funds to Crawford Fund. Eight PNG researchers were trained in Australia on advanced wood value-added technologies. Two PNG researchers were trained on glue bond assessment testing procedures at UoM. Reports 4.1.1 and 4.1.2
		5. Training courses and curricula on various aspects of value-added wood processing according to the training and teaching program completed.	31-07-2018	Training courses have been conducted continuously. Diploma courses on Timber processing and wood products were revised and submitted to Unitech Board. Report 4.1.4
		6. Annual workshops and seminars for the industry and stakeholders to disseminate the research findings completed.	Each year in Feb.	Two workshops were conducted in 2017. The final Workshop will be conducted in March 2019, after the Final review.
		7. Reports on the review of training need to be undertaken annually.	Jan 2017 & 2018	The training review was presented at the MTR, and PSC meetings each year.

4.2	In collaboration with Government and industry association working towards implementation of the national policy on the development of downstream wood processing.	1. Interim report of an assessment of the effectiveness/constraints of current policies, regulation and other arrangements related to value-added businesses. 2. Report on recommendations for the key stakeholders on major requirements for developing successful downstream wood processing industry (e.g., investment in equipment and new technologies, training and skills development) completed.	*30-09-2017* 31-07-2018	As suggested at PSC this milestone was to be done in collaboration with the EWP project. Report 4.2.1 - A brief report was completed by PNGFA in September 2017. Final report completed by PNGFA. Report 4.2.2
4.3	Monitoring and regulating the timber industry to meet required quality standards and also impart technical and appropriate advice for improvement.	1. A detailed Monitoring and Evaluation plan and key performance indicators for monitoring developed. 2. Half-yearly monitoring completed and reports completed.	31-07-2015 Jan 2017 and then every 6 months	Mr. Simon Dorries was approved to lead M&E work for the project. A workshop was held in Canberra when the M&E plan and KPIs were developed. Report 4.3.1 One M&E report was completed. Report 4.3.2
4.4	Development of timber promotion materials such as wood sample and pamphlets.	1. Sets of wood samples completed. 2. Pamphlets on wood properties and processing characteristics of PNG timbers completed. 3. Technical data sheets completed. 4. Consolidated technical report covering the outcomes of all the technical research.	As the project progresses with the final completion in Jan 2019.	Sets of samples for promotional purposes have been completed for 26 species. Pamphlets and technical data sheets on properties and characteristics were completed. Example provided in Report 4.4.1. This report is combined with the Activity 1.7 and Report 1.7.1 completed.

7 Key results and discussion

An overview and a discussion of the key results of the project are provided below.

Objective 1: To enhance the knowledge of wood properties and processing characteristics of PNG timbers

Activity 1.1 Extending the current database and creating a database for lesser-known species from secondary forest and plantations forests.

The Wood Database on PNG species has been developed to collect data and information on properties, processing characteristics and potential uses of 26 PNG timber species from secondary and plantation forests. It has been developed as a user-friendly application which will be of great value to scientists and stakeholders involved in developing downstream wood processing in PNG. The database will be published on the PNGFA server for public use.

Activity 1.2 Testing basic physical and mechanical wood properties

Six mechanical properties, namely flexural bending strength (MoR), stiffness (MoE), compression strength parallel and perpendicular to the grain, shear parallel to the grain, and hardness were evaluated for 26 PNG species using 2,641 small clear specimens from 130 trees. The results of the testing are provided in Table 2.

Heavy Hopea (*Hopea iriana*) always offered the best mechanical properties of all selected species, providing significantly higher properties in all categories. Pellita (*Eucalyptus pellita*), Malas (*Homalium foetidum*), and Kwila (*Intsia bijuga*) are other species that usually performed significantly better than the average. PNG Boxwood (*Xanthophyllum papuanum*), PNG Mersawa (*Anisoptera thurifera*), and Blackbean (*Castanospermum australe*) usually performed above average. Erima (*Octomeles sumatrana*), White Albizia (*Falcataria moluccana*), PNG Basswood (*Endospermum medullosum*), White Cheesewood (*Alstonia scholaris*), Pencil Cedar (*Palaquium warbargianum*), PNG Quandong (*Elaeocarpus sphaericus*), and Wau Beech (*Magnolia tsiampacca*) offered mechanical testing results below the average of the selected species.

The impact of the position in the tree on the selected mechanical properties has also been assessed. Stiffness and bending strength tend to decrease or remain unchanged along the stem across all studied species. While shear and hardness testing results showed a similar trend to a lesser extent, the position in the tree had a much more limited impact on the compression strength properties. Further experiments where sampling would consider the radial position within the tree might accentuate observed trends. Therefore, segregating logs based on the position in the tree could be of interest where desired timber mechanical properties and costs associated with segregating is justifying optimum mechanical properties for the intended end use.

The mechanical properties of species obtained from plantations and regrowth forests were lower than those found in the literature from old-growth forests. Different factors including the size of specimens tested, the amount and provenance of tested material, and some adaptive traits for tropical tree species might explain some differences. However, comparisons of mechanical testing results with other recent studies tend to confirm a reduction of physical and mechanical properties when comparing with timbers from old-growth forests. Of the 26 species selected for the ACIAR study, 18 have also been assessed by Eddowes (1977) i.e., stiffness, compression parallel to the grain, and shear parallel to the grain.

Table 2. Summary of mechanical and physical properties per species (Belleville *et al.* 2018)

	Air Dry Density @ 12% Moisture Content	MoE	MoR	Compression		Shear	Hardness
				Parallel to grain	Perpendicular to grain	Parallel to grain	Janka
Trade name	**kg/m^3**	**GPa**	**MPa**	**MPa**	**MPa**	**MPa**	**N**
Albizia, White	321	6.7	42.7	25.5	4.1	5.6	1,192
Basswood, PNG	356	7.8	44.9	29.5	4.2	5.4	1,311
Beech, Wau	339	6.1	48.5	25.4	5.6	5.5	1,273
Blackbean	792	11.5	85.2	48.2	12.7	10.9	4,490
Boxwood, PNG	718	13.1	94.2	47.7	13.6	10.6	4,899
Canarium, Grey	464	9.3	62.3	33.5	7.2	8.5	2,177
Cedar, Pencil	381	7.5	50.8	25.4	4.5	5.5	1,374
Cheesewood, White	296	5.1	33.4	18.7	3.5	4.6	896
Erima	276	4.8	31.5	18.5	2.7	3.6	735
Gum, Water	495	9.6	68.1	38.3	8.2	8.7	2,410
Hopea, Heavy	932	20.0	136.9	69.0	20.6	16.5	8,753
Kamarere	562	8.6	62.1	31.3	9.5	8.6	3,132
Kwila	758	14.2	116.6	64.1	17.3	13.5	6,361
Labula	418	7.7	56.5	31.4	6.8	7.5	2,179
Malas	800	15.4	128.4	58.6	15.5	14.1	6,893
Mersawa, PNG	685	14.6	86.0	51.2	9.3	10.4	3,797
Pangium	618	12.1	70.1	36.7	7.5	8.0	3,091
Pellita	779	15.6	120.6	52.7	16.0	12.3	6,215
Pine, Caribbean	525	8.0	67.2	29.1	8.3	9.0	2,311
Pine, Hoop	496	8.1	60.1	24.4	7.5	7.7	2,229
Pine, Klinki	473	10.6	68.9	31.0	7.5	8.6	2,121
Quandong, PNG	385	7.7	50.5	28.6	4.9	6.6	1,554
Rosewood, PNG	557	10.0	76.1	45.7	11.4	9.3	3,239
Taun	664	11.1	91.1	36.9	12.7	11.2	4,904
Terminalia, Brown	433	6.9	54.4	29.9	6.0	8.5	2,518
Vitex, PNG	591	11.5	80.8	45.9	10.0	9.3	3,327

ADD: Air dry density; MoE: Modulus of elasticity or stiffness; MoR: Modulus of rupture or bending strength.

Overall, the mechanical properties of the species tested under ACIAR study are usually lower than those listed in Eddowes. The compression parallel to the grain testing results are on average 30% lower than the values listed in Eddowes. The biggest difference can be observed for Kamarere where the crushing strength drops from 69.7 MPa to 31.3 MPa (-55%). Only one species, namely PNG mersawa, sees its crushing strength increasing, going from 44.3 MPa to 51.2 MPa (+16%). In the case of shear parallel to grain, the average reduction represents 24%. The biggest difference can be observed for Wau beech

where the shear strength drops from 11.2 MPa to 5.5 MPa (-51%). Two species, namely PNG basswood and Brown terminalia, see a slight (although probably not significant) increase in shear strength, going from 5.2 MPa to 5.4 MPa (+4%) and 8.2 MPa to 8.5 MPa (+4%), respectively. Finally, the average reduction in stiffness represents 24%. The highest difference can be observed for White cheesewood where stiffness drops from 9.1 GPa to 5.1 GPa (-44%). Interestingly, the only species seeing an increase in stiffness is again PNG mersawa, going from 13.3 GPa to 14.6 GPa (+10%). However, it is important to stress that the timber used by Eddowes was taken from mature trees in native forests. Most of the timber material used under the ACIAR study is from relatively young trees i.e. 20 years old and harvested from regrowth forests and plantations. Therefore, such a gap between the different mechanical properties will probably reduce as trees get older.

Activity 1.3 Development of kiln drying schedules

As explained in the Methodology (Chapter 5), kiln drying schedules using a laboratory kiln were not developed due to technical problems with the kiln. Therefore, a report on this activity provides only data on the drying time for 18 species and outdoor conditions (ambient temperatures and humidity) during drying in the UniTech solar kiln. The remaining 8 species were dried in a conventional kiln at TFTC and no data on their drying schedules could be collected.

Activity 1.4 Assessment of preservative treatment characteristics

The species tested for their treatability/permeability with ACQ preservative solution using VPI process were classified accordingly into various permeability classes under newly developed permeability range. The solution absorption (L/m^3) of the species was the main treatment characteristic used for classification of the species (as per used in Malaysian standard). The physical characteristics (MC, density, void volume/porosity) played major role in determining the species treatability characteristics (solution/fluid uptake, absorption and retentions). Greater absorption of ACQ preservatives was noted in low-density species whose void volumes (porosities) were higher. In contrast, high-density species with low void volumes (porosities) absorbed less ACQ solutions. Other treatment characteristics (solution/fluid uptake and retentions) followed similar pattern in low and high-density species respectively.

Further, the findings on their treatability were used to re-classify the species into their permeability classes and ultimately promote their end uses in structural engineering purposes. Also, the data on permeability of the test species were compared with published information on the same species derived from primary (old-growth) forests. Although few medium- to high-density species showed no improvements in their treatability and remained in same permeability classes, most species indicated a significant improvement in their permeability to ACQ solution for species sourced from secondary forest or plantations compared to same species of the old-growth forest.

The species were arranged according to their treatment characteristics i.e., from the highest solution/fluid uptake and absorption to the lowest (Table 3). It was observed that low-density species with high porosity have greater preservative uptake and absorption than the high-density species that have low porosity. Thus, low-density species with greater solution uptake/absorption were ranked at the top followed by medium and high densities at the bottom. Additionally, retention (kg/m^3) followed a similar pattern as solution uptake/absorption where high retentions were observed in low-density species and decreased with increasing wood density. As far as newly developed permeability class is a concern, species with high solution uptakes/absorptions and retentions were categorised in classes 1 and 2 followed by classes 3 and 4. This means species categorised in class 1 were permeable while species of class 4 were refractory (difficult to treat) under pressure impregnation.

Table 3. Classification of test species into permeability classes (Gusamo *et al.*, 2019)

Species	**Basic Density (kg/m^3)**	**Absorption (L/m^3)**	**Retention (kg/m^3)**	**Permeability Class (TS)***	**Permeability Class (PE)****
Basswood, PNG	358.6	680.8	10.2	1	1
Cheesewood, White	285.2	645.1	9.7	1	1
Erima	277.2	641.2	9.6	1	2
Pine, Klinki	463.6	623.8	9.4	1	2*
Pine, Hoop	507.3	619.8	9.3	1	2*
Pine, Caribbean	545.9	580.3	8.7	1	Not given
Labula	420.3	579.3	8.7	1	1
Canarium, Grey	467.1	529.8	7.9	1	4
Pine, Patula	556.8	504.0	7.6	1	Not given
Pangium	614.0	451.8	6.8	2	4
Quandong, PNG	388.9	439.7	6.6	2	2
Beech, Wau†	307.3	403.5	12.1	2	4
Terminalia, Brown	454.9	350.6	5.3	2	4*
Cedar, Pencil	380.6	332.2	5.0	2	3 or 4
Malas	786.4	325.8	4.9	2	2
Gum, Water	502.0	307.6	4.6	2	4
Albizia, White†	335.3	297.8	8.9	2	2
Boxwood, PNG†	746.9	265.3	8.0	2	4
Kamarere	555.9	212.6	3.2	2 or 3	4*
Mersawa, PNG	718.2	190.7	2.9	3	4
Taun†	556.2	169.7	5.1	3	4
Hopea, Heavy	921.8	123.4	1.9	3	4
Rosewood, PNG	565.9	122.8	1.8	3	4
Blackbean	701.3	111.0	1.7	3	Not given
Kwila	707.6	55.4	0.8	4	4
Vitex, PNG	594.7	51.3	0.8	4	4

Pellita†	709.5	45.0	1.4	4	Not given
Teak	648.2	30.6	0.5	4	4

*TS: this study; **PE: Eddowes (1977); † Five species were pressure- treated with 0.03 kg/L (3.0 %) ACQ solution concentration whilst the other 21 species were impregnated 0.015 kg/L (1.5 %) solution concentration.

Activity 1.5 Testing gluing characteristics of the timbers for various wood product applications

Laboratory testing of glue-bond strength and performance of 24 PNG timber species has been conducted in various climatic conditions to simulate a broad range of service conditions. Two species: Pellita and Wau beech could not be assessed because of lack of enough timber was harvested for all tests involved in the project.

Based on the testing results, each of the 24 selected species has been classified based on their bondability (Table 4).

Species considered to "*bond very well,*" *i.e.,* being able to meet or exceed shear strength and wood failure requirements for both dry use and wet use exposure conditions included:

- PNG Basswood
- White Cheesewood
- Erima
- Labula
- Klinki Pine.

*S*pecies considered to "*bond well,*" *i.e.,* being able to meet or exceed the requirements for dry use applications included:

- Grey Canarium
- Pencil Cedar
- Pangium
- Caribbean Pine
- Hoop Pine
- PNG Quandong
- Taun
- Brown Terminalia

Species identified under "*bond with difficulty,*" *i.e.,* exhibiting a certain level of wood failure and shear strength but not high enough to meet the requirements for dry use applications included or not being compatible with a PVA-based adhesive but potentially compatible for other types of adhesive included:

- PNG Boxwood
- Kwila
- PNG Mersawa
- PNG Rosewood
- PNG Vitex

It is recommended that additional testing should be done for such species using different types of adhesive.

Species considered to be "*very difficult to bond*" *i.e.,* not managing to meet the shear strength requirements for dry use applications while providing very low wood failure across all exposure conditions included:

- Blackbean
- Heavy Hopea
- Kamarere
- Malas

Such species would require careful selection of adhesives and very close control of bonding conditions. The special surface treatment may be required to achieve satisfactory results.

Table 4. Bondability groupings for selected PNG species (Belleville et al., 2019)

Species	**ADD**	**Dry Use**	**Wet Use**	**Remark**
Basswood, PNG	356	Yes	Yes	Bond Very Well
Cheesewood, White	296	Yes	Yes	Bond Very Well
Erima	276	Yes	Yes	Bond Very Well
Labula	418	Yes	Yes	Bond Very Well
Pine, Klinki	473	Yes	Yes	Bond Very Well
Canarium, Grey	464	Yes	No	Bond Well
Cedar, Pencil	381	Yes	No	Bond Well
Pangium	618	Yes	No	Bond Well
Pine, Caribbean	525	Yes	No	Bond Well
Pine, Hoop	496	Yes	No	Bond Well
Quandong, PNG	385	Yes	No	Bond Well
Taun	664	Yes	No	Bond Well
Terminalia, Brown	433	Yes	No	Bond Well
Albizia, White	321	Special care needed†	No	Bond with Difficulty
Boxwood, PNG	718	No ♠	No	Bond with Difficulty
Gum, Water	495	Special care needed†	No	Bond with Difficulty
Kwila	758	No ♠	No	Bond with Difficulty
Mersawa, PNG	685	No ♠	No	Bond with Difficulty
Rosewood, PNG	557	No ♠	No	Bond with Difficulty
Vitex, PNG	591	No ♠	No ♠	Bond with Difficulty
Blackbean	792	No	No	Very Difficult to Bond
Hopea, Heavy	932	No	No	Very Difficult to Bond
Kamarere	562	No	No	Very Difficult to Bond
Malas	800	No	No	Very Difficult to Bond
Beech, Wau	339	Not available	Not available	Not enough timber
Pellita	779	Not available	Not available	Not enough timber

♠ Preliminary results using a non-structural PUR adhesive suggest that some dense PNG species could satisfy the requirements for dry use applications and wet use applications. † Satisfactory results with White Albizia and Water Gum would surely be achieved with optimisation of gluing parameters.

Activity 1.6 Assessment of other processing characteristics required to successfully produce value-added products for PNG and export markets

The machinability behaviour of 25 species was assessed; one species, namely Pelita, was not tested due to lack of enough timber for this test.

A total of 18 wood species proved to machine very well with more than 90% of boards being graded either “excellent and requiring very light sanding” or “good and requiring light sanding.” Eight species from this group obtained a perfect score (*i.e.,* 100%) across all three runs:

- Hoop Pine (*Araucaria cunninghamii*) **100%**
- Kwila (*Intsia bijuga*) **100%**
- Labula (*Anthocephalus chinensis*) **100%**
- Malas (*Homalium foetidum*) **100%**
- Pangium (*Pangium edule*) **100%**

- PNG Rosewood (*Pterocarpus indicus*) **100%**
- PNG Mersawa (*Anisoptera thurifera*) **100%**
- White Cheesewood (*Alstonia scholaris*) **100%**
- Erima (*Octomeles sumatrana*) **99%**
- Pencil Cedar (*Palaquium warbargianum*) **99%**
- PNG Basswood (*Endospermum medullosum*) **99%**
- Water Gum (*Syzygium spp.*) **99%**
- Kamarere (*Eucalyptus deglupta*) **98%**
- Blackbean (*Castanospermum australe*) **97%**
- Brown Terminalia (*Terminalia brassii*) **97%**
- PNG Quandong (*Elaeocarpus sphaericus*) **97%**
- Wau Beech (*Magnolia tsiampacca*) **94%**
- Caribbean Pine (*Pinus caribaea*) **91%**

A second group consisting of PNG Vitex (*Vitex cofassus*), Grey Canarium (*Canarium oleosum*), Heavy Hopea (*Hopea iriana*), Klinki Pine (*Araucaria hunsteinii*), and PNG Boxwood (*Xanthophyllum papuanum*) machined moderately well with averages across all three machining runs ranging between 70% and 90%.

Two species, namely White albizia (*Falcataria moluccana*) and Taun (*Pometia pinnata*), proved to machine with difficulty with average scores of 64% and 57%, respectively.

Most common machining defects observed consisted of fuzzy grain, torn grain or raised grain, but some higher density species also incurred chipped knife marks. Overall, most machining defects encountered in the study can be minimised with the introduction of regular sharpening schedules and training to woodworkers on how to identify machining defects as part of a quality control program.

Activity 1.7 Recommendations on best applications/types of products for the selected species based on their properties and processing characteristics

Combining the results of testing wood properties and processing characteristics of 26 tested species enabled to develop recommendations on potential uses of these species; for non-structural and structural components/products, for dry and wet applications (Appendix 2).

The guideline has been provided for specifiers and users of various timbers for specific wood products and service conditions.

The following factors must be considered when selecting timber species for specific wood products:

- The selection of products for external applications must be made according to the species treatability results; the timber must be treated before being used in a specific application.
- Special care should be taken with species which are classified as “difficult to glue.” Adhesives for difficult to bond timbers should be selected according to the service conditions and type of products. Gluing procedures specified by the adhesive supplier should be strictly followed.
- Strength group of timber must be taken into account when selecting timber species for structural components.

Objective 2: To identify, pilot and evaluate interventions for enhanced value-added processing systems.

Activity 2.1 Selection of companies and landowners groups willing to participate in the Project, and

Activity 2.2 Identifying what improvements in the current processing and manufacturing practices are required.

A detailed assessment of current processing and manufacturing methods, production efficiency and production infrastructure of sixteen SME companies was completed. The study identified impediments in downstream wood processing that affect the development of efficient wood processing in the country and provided recommendations to improve current standards and profitability based on the weaknesses and gaps identified during the assessment. The study emphasised the importance of addressing these gaps to progress value-adding in the wood processing industry in PNG.

Major gaps were identified in static and portable sawmills, wood machining and manufacturing, wood treatment and preservation, wood packing, storing and transportation. Gaps were also identified in marketing and policy and forest resource administration impediments that affect wood processing in the country.

The results of the survey showed that most wood processing companies involved in the survey were involved in producing solid timber (56.3%) complimented with the manufacture of basic furniture (18.8%). About 25% of the visited companies were engaged solely in furniture making and joinery. Many companies indicated that further wood processing into secondary processed wood products in the country is too costly.

From the 16 surveyed wood processing companies, only 7 companies formally sourced its wood resource from approved forest areas while 3 companies sourced wood informally. Six companies had formal permits but were also engaged in sourcing timber informally.

Some major weaknesses were:

- most employees in the companies had a lack of standard education and may require consistent supervision in data collection and proper research undertakings during collaborative work;
- most of the companies were engaged in producing basic wood products with basic processing practices and machinery. Collaborations using cutting edge practices and technologies to produce new product might take time;
- most companies expressed financial constraints.

A key opportunity identified was that although most of these companies were SMEs, there was a desire to grow and improve on current production practices, technologies and investment in product diversification.

Recommendations for potential collaboration in research and capacity building were provided in the report (Jeremiah, 2017). Most recommendations confirmed the list of potential processing gaps that are outlined in the project document (ACIAR FST 2012/092). Development of grading systems for logs, sawn timber and wastes from primary and secondary wood processing.

- Research into how recovery rates of break down saws can be improved to cater for decreasing diameter sizes of PNG's natural forest trees due to multiple rotational harvests.
- Investigation of preservative treatment methods for PNG timbers, using environmentally friendly preservatives and treatment methods to increase the durability of wood products.

- Study and design cost-effective drying techniques to dry mix hardwood (MHW) species. This study should include energy efficient technologies and development of cumulative drying schedules for various MHW species for various processing and utilization needs.
- There is a need to identify value-added technologies and manufacturing methods which are required to produce the selected wood products (e.g., finger jointing, glue laminating, veneering). These technologies must be matched with the properties and processing characteristics of various timber species to ensure efficient production of high quality and durable products.
- Assess and recommend policy developments and amendments especially in areas of participation in wood resource acquisition, supply and use of portable mills and an increase in fair trade in both domestic and export markets. Other areas of focus should be on policies that may assist wood processing companies on their cost of production and competitions from imported cheap wood product alternatives.
- Skills and training upgrade in practices and use of high-tech machines must be undertaken between wood processing training institutions and the selected companies.
- Study into reasons why many companies do not employ females and develop strategies on how equal employment can be achieved by wood processing industries in PNG.
- Asses how wood processing companies can have easy access to purchase cheaper processing accessories such as treatment chemicals, saw blades and other processing machinery spare parts.
- Study and develop proper methods to pack and store finished wood products to reduce packing, storing and handling defects like the development of fungi, mushrooms, decay and induced wear and tear of the processed woods.
- Study market demand for the wood products that are not currently processed in PNG but could be produced in PNG using available resource and production capacity especially those products that can utilize current processing wood waste and species from secondary and plantation forests. This study should also consider the potential increase of degradation and deforestation by harvesting secondary/lesser known species which are left from the previous harvest of commercial species.

Activity 2.3 Conduct research to address identified practice and technology gaps, and

Activity 2.4 Support trial implementation of improved value-adding processes.

The following activities were undertaken to address the gaps identified in Activity 2.2:

A standard on grading rules for sawn timber was developed and distributed to the industry members for comments. The grading rules were submitted to the National Institute of Standard Industrial Technology (NISIT) for adoption as PNG standard.

Manuals, specifications, reports and fact sheets were developed for the industry use. As explained in Chapter 5, close collaboration has been developed with the EWP project which allowed to share research resources developed within each project. Research and training materials have been placed on a joint website hosted by the Pacific Islands Project, under “Wood Processors Tool Kit.” Twelve simple checklists were developed by this project team on wood waste utilisation, gluing, finishing, machining, OH&S procedures. Training guides

for chainsaw & sawmill operations and on wood value-adding operations were developed on Campus training for the timber industry.

A Market Research Analysis was conducted by the IndustryEdge company in Australia. The report addressed the requirements of both ACIAR projects. A range of wood products was identified that could be produced in PNG using timbers available from secondary and plantation forests, along with relevant value-adding processes based on market demands (domestic and international). The products include both structural applications (e.g., prefabricated houses, windows, doors) and appearance products (e.g., flooring, commercial and domestic furniture, panelling). Value-adding technologies and manufacturing methods required to produce the selected wood products were identified. Options for utilisation of small dimension timbers, the wood of current low market demand, wood waste and off-cuts were provided to maximise wood recovery and increase overall benefits to PNG timber companies. The report has also outlined optimum engineered wood product (EWP) and market options for timber resources in PNG and timber resources in Australia. Options for target markets were assessed and recommendations made for 'best bet' EWPs from each country for domestic and export destinations. To assist in evaluating the commercial viability of EWP production for current and potential emerging markets, commentary on current applications and evolving trends for EWPs in various segments of global markets was provided.

Activity 2.5 Pilot innovative approaches to enable greater landowner involvement, and

Activity 2.6 Work with PNGFA to operationalise the Central Processing Unit in Lae

As explained in the Methodology (Chapter 5), three case studies were undertaken within the project which aimed to provide value-added opportunities for local communities.

1) Establishment of the Central Processing Unit.
2) Designing low-cost light-weight furniture for children and women in local communities.
3) A study on the involvement of carvers in the wood downstream processing industry.

The three case studies show examples of how landowners could be connected with small wood processors to add value to timber and increase income to local communities.

The trials conducted at TFTC to assess the validity of CPU concept provided promising results. There has been a very positive response from local communities, families and landowner groups which showed interest in establishing a partnership with TFTC Commercial Unit in utilising their forest resources. The record of interested people and groups showed that they have confidence and trust to work with the Institution in developing their resources as well as providing training to the communities. A report on the CPU trials undertaken by TFTC Commercial Unit is provided in Appendix 4.

As a National Training Institution, the focus of training at TFTC is not only for the currently registered students but also for those who are unfortunate and marginalised citizens who have the resources to develop and sustain their livelihood and communities at large. There are 37 local timber suppliers recorded from July 2018 – January 2019, who showed interest to partner with TFTC for developing their forest resources. Although they are rich in resources, it is difficult for them to transform those resources into end use.

Currently, there are no markets nor large demand for useable short length timbers (waste timber as it is commonly referred to) in Lae and PNG as a whole. Timber companies producing various wood products seem to have not much choice but to sell good quality timber under 1.2m-long as fuelwood or discard as waste timber. The Furniture Design Development of prototypes of portable furniture is an example of possible arrangements with timber companies to bring short length timbers (rejects) to TFTC for further processing

into affordable, foldable, portable and do-it-yourself (DIY) products such as student desks small tables and stools (Figure 7 and 8). The portable folded furniture using small dimension rejected timber, wood off-cuts and wood waste could be initially produced at CPU facility. The skills could then be transferred to rural communities through training to allow them to make the products by themselves for their own use and for selling. Carvers could be involved in CPU in making carvings and carved furniture components using rejected parts of logs and sawn timber.

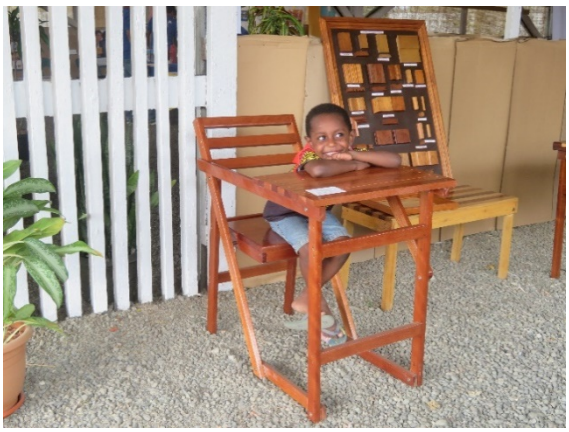

Figure 7. A school desk for children and students (Photo credit: Elaine Galore)

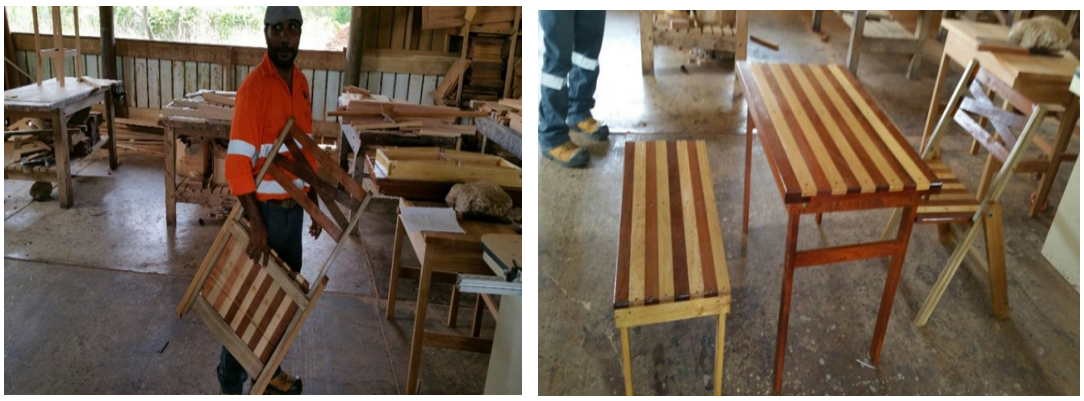

Figure 8. Examples of portable folded furniture (Photo credit: Barbara Ozarska)

Objective 3: To estimate the potential contribution and distribution of economic impacts to national and local economies from enhanced value-added wood processing.

The focus of the Objective study was the wood products resulting from harvesting in natural forest and plantation forest estate managed within sustainability criteria. The study did not cover harvesting associated with conversion to non-forestry uses or harvesting by informal sector.

One of the most important outputs of the study is the identification of factors influencing current structure of PNG forest industry. Several factors are listed in the final report which are considered to generate inertia and impede growth (adoption barriers) in transitioning of PNG forest industry to enhanced domestic downstream processing, covering;

1. RESOURCE ENDOWMENT NOT SUFFICIENT: PNG's large forest resource endowment does not in itself provide PNG with a competitive advantage Resource endowment is only one, but important, component of competitiveness. PNG's competitiveness, particularly in globally supplied export markets, will be underpinned,

not only in resource endowment factors but also the total productivity of using all factors including wood costs, labour, infrastructure, capital and operating costs and sovereign risk issues. As noted in the recent PNG Government policies, PNG faces many challenges in delivering a total productivity package for domestically produced wood products which provides a competitive position and comparative advantage in global markets. PNG's competitiveness, particularly in globally supplied export markets, will be underpinned, not only in resource endowment factors but also the total productivity of using all factors including wood costs, labour, infrastructure, capital and operating costs and sovereign risk issues. While PNG has large endowment of forest resources the commercial resources are in geographically diverse locations containing a wide variety of species adding to the commercial challenges of aggregating enough volume of market preferred species for downstream processing.

2. MARKETS: PNG has small, cyclical and poorly structured domestic markets for wood products, limited by dispersed but growing population (8m people in 2017, growing by 3.1% per annum), and low incomes (estimated wage GDP per capita US$2,600 in 2017, or US$4,130 per capita on Purchasing Power Parity basis, increasing by 65% and 31% respectively since 2010). Majority of population have limited involvement in cash economy. Domestic wood product markets are primarily located in major cities. In summary, the small underlying domestic markets for wood products in PNG and challenges in meeting commercially viable (internationally competitive) processing facilities in PNG servicing export markets, does not provide an incentive to shift away from current business model for companies operating in PNG or make attractive to new entrants. Growing the domestic market to support enhanced domestic downstream processing is also being impacted by competition from non-wood products, e.g. steel and concrete, in residential, commercial and industrial sectors.
3. BUSINESS STRUCTURE: With the downsizing of PNG's domestic processing industries using natural forest resources over the last 20 years the current legacy industry is dominated by small number of companies. These companies operate, or have business relationships, involving log export, sawmilling, veneer and plywood manufacturing, and marketing flexibility for domestically produced wood products to domestic and/or overseas based on demand factors. The structure of the major companies facilitates flexibility to capture commercial opportunities by shifting production between log export and domestic processing but also shifting sales for wood products between export and domestic market depending on demand conditions in these markets.
4. The business models currently employed by PNG forest industries are to retain capacity and relationships to service both export (log and wood products) markets and domestic wood products markets. During periods of higher domestic demand processors place more of their products in domestic markets; often servicing the domestic markets with wide variety of locally accepted wood products and species. Higher quality wood products (species such as Kwila and PNG Rosewood with well-known wood properties) are traditionally sold to export markets where higher standards (durability, appearance and strength) and certifications are required.
5. CAPTURING VALUE IN PRODUCTION/PRODUCT CHAINS: In PNG processing plants (with notable exception of Panakawa Complex in Western Provence) tend to be single product focused (for example sawn wood, veneer/plywood) with limited markets for wood material not suitable for primary product. In PNG this waste material often only used as wood fuel. One of the challenges for generating enhanced at scale commercially viable value adding in PNG is structure of manufacturing product chains to utilize more of logs for commercial use. This conclusion is further expanded in Industry Edge Market Analysis Report supporting ACIAR Projects.
6. REVENUE STRUCTURES: The structure of Statutory charges (primarily application of export levy for logs exported/exemption of logs domestically processed) and the volume of log exports compared to volumes domestically processed generates larger and more

reliable revenue flows to all beneficiaries. This outcome adds to inertia in implementing enhanced domestic processing.

7. AVAILABILITY OF UNCOMMITTED FOREST RESOURCES: Currently there is no readily available and commercially attractive basket of timber resources on which to support new domestic processing.
8. CONTRACTUAL FOOTPRINT OF CURRENT INDUSTRY: The majority (67%) of commercially attractive forest production areas (classified as Production Forest areas) has been allocated to current industry with the remaining forest areas available for commercial use generally considered to face several hurdles in meeting commercial criteria including significantly lower merchantable volume by area and higher costs of production.
9. BUSINESS RISK MANAGEMENT: The current use conditions, facilitating log export, are more commercially attractive to operators. The reduced exposure in terms of investment for enabling infrastructure, working capital and overall enterprise risk (including relative flexibility to mothball operations) with log only export business model, compared to establishment and operation of domestic processing activities, favours continuation of log export. Value-added wood processing requires significantly higher investment for more complex enabling infrastructure (plant and equipment), higher skilled workforce and enhanced community support structures.
10. RELATIVE ATTRACTIVENESS OF COMMERCIAL AGRICULTURE: Anecdotal evidence that more financially attractive for land (forest) owners in forest areas previously harvested to switch to other land uses, such as commercial agriculture with consequential clearing of native forests. For example, palm oil plantations.

Some pathways to increased domestic processing have been suggested.

While no magic bullet can be identified to deliver substantial increases in domestic processing of logs in short term, there are several actions which could assist in creating an environment for potentially capturing additional value, including enhanced downstream processing of PNG's forest resources.

At overarching level, it is suggested that PNG could benefit from a committed process which generates commercially realistic and innovative assessments of the "better" opportunities (natural and plantation forests) and trade-offs for PNG to capture additional value (economic and social) from management and harvesting forest resources.

More specific suggestions include identifying fit for purpose and market test commercial potential for basket of resources based on "cut over forest" ; work with current industry to robustly test their appetite, requirements and specific proposals they may have for enhanced domestic processing; accelerate effective and efficient structures to support commercial activities for forest sector in informal sector (including capture of CPU's potential); develop and implement investment strategy to deliver globally competitive plantation resources; and delivery of commercially effective structures (covering supply, production and marketing chains) to support expanding exports opportunities for primary wood products such as flitch/baulks wood products.

Exploring these suggestions would be informed by outcomes from other activities of ACIAR Projects including wood properties for lesser-known species, business plan for CPU, Marketing Analysis supporting ACIAR Projects, PPP frameworks and contribution of informal forest sector to PNG's economy.

Objective 4: To enhance the capacity of Government, institutional support bodies, industry partners and landowners to implement value-added wood processing policies, strategies and practices.

Activity 4.1 Training and technology transfer on value-added processing methods.

A detailed description of the training provided to PNG project team members and the industry has been provided in Chapter 8.2 Capacity Building.

Activity 4.2 In collaboration with Government and industry association working towards implementation of the national policy on the development of downstream wood processing.

In collaboration with Government, industry association and stakeholders, the activity team through PNGFA has been working towards developing and implementation of a national policy on the development of downstream wood processing. Key areas have been identified to be addressed, and the formulation of the PNG Downstream Processing Strategies has been developed to address the key identified constraints. The finalised version of the PNG Downstream Processing Strategies has been endorsed by the National Forest Board. The PNGFA team has on some occasions tried to submit to the Government through the National Executive Council through the Forests Minister but has been derailed due to unknown reasons. Until the Strategies are approved, we would see progress in addressing key constraints by the government to develop a successful timber processing industry in PNG thus having a significant impact on the value-added processing industry.

Perhaps to look at the real causes of slow growth in domestic processing, there are this current Downstream Processing Strategies which has been developed with inputs from the Forest Industry and other key stakeholders. The strategies have highlighted key constraints which require government interventions to address to provide a conducive environment for processing of wood industry to flourish. These key constraints include:

- The high cost of fuel;
- Availability of skilled labour;
- The high cost of transport, due to poor road infrastructure;
- The high cost of export formalities;
- Inability to access plantation timber;
- Unsustainable demands for landowner payments;
- Complicated export permitting and port clearance procedures;
- Highly diversified species composition inhibits the ability to produce shipments consisting of single species;
- High risk of loading delays drive additional costs (demurrage);
- Unavailability of government incentives.

Until the highlighted constraints are addressed, timber processing in PNG will continue to remain a small part of the overall forestry sector with log exports continuing to dominate the industry's activity unless the government provides the necessary infrastructure to facilitate increased processing of forest products.

Activity 4.3 Monitoring and regulating the timber industry to meet required quality standards and also impart technical and appropriate advice for improvement.

The purpose of monitoring and evaluation was to track implementation and outputs systematically and measure the effectiveness of the project activities.

The project was evaluated and refined on a regular (three monthly) basis by the project Leader and yearly by ACIAR RPM (Annual Reports and Annual Workshops). The evaluation was used to:

- determine the extent to which the project was on track and to make any needed corrections;
- make decisions regarding various operations, management and communication;

- ensure the most effective and efficient use of resources;
- evaluate the extent to which the project was having or has had the desired impact.

Activity 4.4 Development of timber promotion materials such as wood sample and pamphlets.

Sets of promotion materials have been developed to promote PNG commercially available timbers from secondary and plantation forests. Customers will be able to look at and touch the 26 species and gain knowledge on their properties, processing characteristics and potential products for various service conditions. In particular, visual surface characteristics (colour, grain pattern, luster) of wood samples will provide advantages directing production and marketing efforts more towards consumers' preferences and thus increasing satisfaction and value-added.

8 Impacts

8.1 Scientific impacts – now and in 5 years

The major scientific impacts realised by the project are summarised below.

The outcomes from this project add a significant amount of knowledge to wood technology science as it provides valuable data on the properties and processing characteristics of PNG lesser-known species from secondary (regrowth) and plantation forests. Although many data have been published on the properties and processing methods for PNG timber from primary (old-growth) forests, there is limited information available on properties, characteristics and technologies applicable to the utilization of lesser-known timbers of a younger age for various products. Lack of this information creates a barrier for using these timbers for various value-added wood products. Therefore, it is envisaged that the availability of such technical data will facilitate the process of technological advancement in processing and manufacturing of hardwood and softwood timbers.

The study found that the mechanical properties of the species obtained from plantations and regrowth forests were lower than those found in the literature from old-growth forests. Different factors including the size of specimens tested, the amount and provenance of tested material, and some adaptive traits for tropical tree species might explain some differences. However, comparisons of mechanical testing results with other studies confirmed a reduction of physical and mechanical properties when comparing with timbers from old-growth forests (Bendtsen,1978; Moya *et al,* 2009, Negi *et al,* 2004).

This study's finding has important scientific value because it adds new knowledge to wood technology science and makes scientists aware of the importance of assessing wood properties of younger timber resources. The results have been presented in a research report and a manuscript has been submitted to an international journal for publication.

The findings of the study on treatment characteristics of 26 PNG species using vacuum-pressure impregnation ultimately provide baseline data on treatability of hardwoods sourced from secondary forest concessions and plantations, and thus, will contribute to efficient utilization of the resources. The results have been presented in a research report, and a draft manuscript has been written for submission to an international journal.

PNG Wood Preservation Standard (PNGS 1293:1989; PNGS 1293:2012) and Australian Standard (AS 1604.1:2012) do not have clear prescriptions on any treatment characteristics (fluid uptake, absorption or retention range) that could be used to classify new species into permeability class upon treatment test. Thus, it was a difficult task to classify treated species in this study into their respective permeability classes 1-4 as provided by Eddowes (1977) in his classification of PNG old-growth timbers. Elsewhere in other countries/regions, standards for wood preservation have been developed and used where new species treated are classified accordingly. For instance, in Malaysia, a standard was developed and applied for classifying timber species upon pressure impregnation trials. Malaysian Standard (MS 544: Part 10: 2003) has 5 permeability classes with their preservative absorption (L/m^3) range and descriptions. In this case, the Malaysian standard was adopted as a guide/reference to develop or modify permeability classes 1 to 4. This new classification can be used for assessing the permeability of PNG timbers in future studies.

The data on gluing characteristics of PNG timbers will be of great value to both the scientific community and timber industry. The assessment of bonding strength and wood failure for non-structural applications in dry and wet service conditions is the first research study of this type ever conducted for PNG timbers. The results will be particularly relevant to the companies which are involved in manufacturing value-added solid wood products and EWPs where gluing of timber components (solid and veneer) is a pivotal part of the manufacturing process.

Wood machining (planing) grading rules were developed and used in the study. The grading rules developed provide a systematic basis for comparing the planing behaviour of different species where surface quality is of prime importance. Testing of machinability of PNG species will be in high demand as there is a lack of scientific references on the methods used for assessing machining characteristics of timbers.

Based on the data on wood properties and processing characteristics of 26 species, suggestions were made on potential wood products and service conditions suitable for each species. This extensive data has been used for developing a database on the PNG timbers which will be published online and in data sheets. Therefore, the findings of research studies will be widely available to the research community and the industry. A possibility of publishing a book on the properties, characteristics and potential uses of PNG timbers from secondary and plantation forests should be considered.

The results of the research studies allow researchers to develop joint publications - both as detailed ACIAR technical reports and refereed publications in high-quality scientific journals and conference proceedings. One paper on the assessment of wood properties of PNG timbers has been submitted to the international journal Maderas Ciencia y Tecnologia, and more papers are in preparation.

Capacity impacts – now and in 5 years

Capacity building

Capacity enhancement has been an important component of the project FST/2012/092. A foundation, built within the previous ACIAR project FST/2006/120 for research, teaching and training in wood processing for the PNG timber sector, has been further developed by empowering the collaboration between the project partners.

A wide range of research studies undertaken within the four objectives of the project has significantly strengthened the skills and expertise of the PNG and Australian team members. These studies enable researchers and students to learn and undertake experiments on wood properties testing, drying, timber treatment, gluing, machining and the industry capability assessment.

Improved networking between the partner organisations has been an integral part of this project and has been achieved through the active involvement of team members from all partner organisations in the project activities. A cohesive team has been formed based on trust and support to each other. Consequently, it can be observed that the team members have always been cooperative and effective in achieving the project goals.

The experience gained by the project participants has prepared them for future collaborative work and established strong linkages and friendships, which are likely to continue after the project's completion. This collaboration has been demonstrated through various collaborative activities undertaken by the team members. For example:

- Preparation of samples for testing of wood properties and characteristics was made as a collaborative effort of the project partners with clearly defined tasks and budget allocation for harvesting, milling, drying, machining and conducting various tests by various team members;
- Training provided to timber companies and landowners was done jointly by team members from all partner organisations;
- Extensive training of young researchers was done continuously by senior team members.

A significant achievement has been a close collaboration with a parallel ACIAR project FST/2014/065 "Development of durable engineered wood products in PNG and Australia" managed by Queensland Department of Agriculture and Fisheries (DAF). The two projects

have been working side by side on various aspects of downstream wood processing through information sharing, collaborative research and training activities. Some examples of collaborative activities of the two projects are:

- Four joint Project Steering Committee meetings were held on 29 August 2017 and 24 April 2018. The meetings helped both projects' teams to learn about their achievements and ensure that the activities were not duplicated but complemented each other.
- Market Analysis study was conducted by LeadingEdge company to inform the two ACIAR projects on market opportunities for PNG value-added wood products and EWPs.
- Data on wood properties and processing characteristics of PNG timbers will be useful to EWP project in the development of various new EWPs.
- Manuals and Fact sheets on various aspects of wood processing and manufacturing were developed jointly by the two project teams using each other resources.
- Outputs of the Objective 3 on the economic analysis of the PNG timber industry provides valuable data to the EWP project.

It is also evident that by having two wood processing projects working side by side, various implementation efficiencies could be achieved through the close project to project collaboration and dialogue at the joint PSC meetings.

The project leader and selected team members participated in the Inception Meetings of a new community forestry project in PNG (FST/2016/153), which were held on 18-20 October 2017 in Lae. Opportunities for a collaborative work was discussed, in particular in sharing the Market Research Analysis report developed by the LeadingEdge and the Business Plan for CPU. A researcher of the community forest project, Mr. Micah Scudder, developed recommendations for an additional research study which would address some gaps in the CPU concept. He suggested that the identification of a series of wood products that serve a customer need and are differentiated from the competition is a critical step that needs to be addressed for the proposed CPU. Specific items that need to be researched are:

- The location of potential customers (Construction contractors, wood product retailers, and wood product manufacturers) that exist within the geographic market should be identified.
- The housing construction styles being built within the geographic market and the wood product types that they use should be identified.
- Identifying exactly which type of wood products the competitor businesses produce.
- Identifying any other competitors that serve the customers discussed above and specific wood products that they produce.
- Identification of any specific portions of the geographic market that are currently not being served by the competition.

A collaboration has been developed with ACIAR project ASEM/2010/052 "Examining women's business acumen in Papua New Guinea: Working with women smallholders in horticulture" led by Prof. Barbara Pamphilon from The University of Canberra. The project identified that often women in villages don't have any tables or stools which would be used during their planning activities or for children to use for homework activities. A series of low-cost light-weight tables, stools or benches were designed within our project and prototypes made using short-length timber and off-cuts. A program for transferring the skills on how to produce the furniture by rural village people has been proposed as part of the activities within TFTC CPU/Commercial Unit.

A collaboration with The Pacific Horticultural and Agricultural Market Access Program (PHAMA) and The Solomon Islands Timber Processors and Exporters Association

(SITPEA) was developed by Mr. Charles Tsiritsi, Deputy Principal of TFTC. His visit to the Solomon Islands initiated a collaboration between PNG and the Solomon Islands and opened opportunities for training courses incorporating timber handling, machinery use and maintenance, options for refurbishment or procurement of alternate equipment and related areas.

Research equipment

The capacity of PNG wood processing research has been significantly increased by purchasing major items of equipment for testing wood properties:

- Instron Universal Testing Machine, 50 kN capacity, for testing wood mechanical properties, which was provided under SRA project FST/2014/030 “Pilot testing of wood properties for PNG timber species”.
- Thermoline chamber for conditioning wood samples to different moisture content values required for various tests.
- Autoclave for testing of glue-bond strength of various types of glues used for PNG selected timber species in different service conditions.

The above "state of the art" testing equipment, not available anywhere else in PNG, will enable researchers and the University students to learn and undertake experiments on wood properties and processing characteristic of wood. The Instron machine has been already used by undergraduate and postgraduate students from the University of Technology.

Training activities and their impacts on the capacity building

Training in Australia for PNG project team members

- The Crawford Fund supported an intensive one-week training course “Advanced technologies in wood processing and manufacturing of high-quality timber products” for eight delegates from PNG institutions involved in the project. The trainees represented the following sectors: education (PNG UniTech), research (PNGFRI), training (TFTC) and government (PNGFA). Two females were involved in the training. The training was organised by the University of Melbourne and was held on 22 – 28 March 2018. The training was structured to provide the participants with both theoretical and practical knowledge of advanced wood processing and manufacturing technologies (Figure 9). Feedback from the participants indicates that the training course has exceeded their expectation:

  “The training has been an eye opener after seeing the operations of timber industries and as well as veneer companies. With the assistance of ACIAR, the PNG government should collaborate with timber industries and stakeholders to work out a way to adopt the practices used in Australia to develop downstream wood processing in PNG”.

  The training in advanced wood production methods will substantially enhance the participants’ capabilities and expertise on wood value-adding processing and product development.

Figure 9. Discussion on the production of veneered panels at Timberwood Panels Pty Ltd, Melbourne (Photo credit: Barbara Ozarska).

- Two PNG researchers, Ms. Elaine Galore of TFTC and Mr. Kilva Lancelot of PNGFRI, spent 4 weeks at the University of Melbourne undertaking training on testing gluing characteristics of PNG timbers. They were trained on how to prepare samples for testing, conduct the tests and analyse results. As the production of laminated wood and veneer products is increasing in PNG, their skills will be of great value as they will be confident to assess gluing characteristics of different species and define which glues are suitable for various service conditions.

Training for PNG researchers and students

Several training courses have been conducted for researchers involved in the project and students at UniTech and TFTC on testing wood properties, wood processing characteristics (gluing, machining, wood drying and preservative treatment), “Research Design and Methods” and statistical data analysis. Each course involved 8-15 participants.

Several students from UniTech were working on their research projects in collaboration with PNGFRI and TFTC. Research equipment and facilities, as well as technical and scientific support, were provided to the students by experienced staff members of these institutions.

TFTC apprentices and secondary school students were involved in the project Activity 1.6 on testing machining properties of PNG timbers. The knowledge they gained on the assessment of timbers machinability will be useful in their future study and work.

A lecturer/researcher at UniTech, Peter Edwin, was awarded a prestigious John Allwright Scholarship to undertake PhD study at the University of Melbourne.

Training provided to timber companies

Visits to timber processing companies in PNG were undertaken within Objective 2 to provide technical advice and onsite training. The project team provided onsite training on the following topics:

- The use of a portable mill (Lucas;
- Portable sawmill maintenance and care, and the importance of increased efficiency and productivity;
- The importance of proper log positioning and cutting patterns for specific end uses and to increase recovery;
- Basic safety rules during the process of cutting for both operators and assistants;
- Proper felling and crosscutting techniques to reduce offcuts;
- Timber drying and machining.

There was a lot of interest and enthusiasm by the mill operators and assistants during the field coaching.

One-week training on timber grading for Open Bay Timber's employees, in East New Britain Province, was conducted by Mrs. Moira Spairong, TFTC. The training on the grading rules provided new knowledge to the employees and they requested that a follow-up course is conducted.

The final one-week training for timber company workers was conducted on 25 February – 1 March 2019 on chainsaw and sawmill operations, and wood value-adding technologies.

In summary, it is believed that the collaboration established during the project term will substantially enhance the participants' capabilities and expertise on wood properties and characteristics assessment and value-adding processing technologies. This knowledge and experience will be essential in ensuring the long-term sustainability of the project outcomes and will enable the participating organisations to take key leadership roles in downstream wood processing after the project completion.

8.2 Community impacts – now and in 5 years

8.2.1 Economic impacts

1. Background[3]

PNG has identified around 25M ha of natural forest as potentially available for production of timber and associated products.

The PNG Government has advanced strong policy positions over the last 25+ years aimed at transitioning from forest industry currently dominated by export of harvested logs to enhanced domestic downstream processing activities and products.

The attraction of these policies, if successfully implemented, are that they provide opportunities for increased regional development, participation of PNG nationals in the formal economy (cash economy) through increased employment; infrastructure provision (health, transport, energy and education); increased depth and diversity of social and economic structures; foreign exchange generation; and potentially increased revenue generation for PNG Government to support economy-wide socio-economic programs.

2. Forest industry (Current economic outcomes)

Formal Sector

While PNG Government has expressed strong policy position to transition the forest industry harvesting natural forests (current target is 80% of log harvest to be processed domestically by 2030; and supported by other initiatives) the export of harvested logs has been and continues to be the dominant market for logs harvested from Natural Production Forest areas.

Over the decade 2007-2017 it is estimated an average of 2.7M m^3/year of natural logs were harvested with average of 85% exported and 15% used in domestic processing for sawn wood, plywood and veneer. While there have been year-on-year variations in volumes harvested and small percentage changes, percentage of harvest processed domestically (varied between 14 – 19% over the period 2007-2017), the variations can be traced to changes in export and domestic demand. For example, the increased domestic demand for timber associated with construction activities during oil and gas boom in PNG in 2011/2012.

[3] *The Economic Impacts chapter has been written by Dr Bob Smith, Objective 3 leader.*

In addition, PNG has a small, but regionally significant plantation industry (recorded at 60,000 ha.). In 2017 plantations produced 194,000 m^3 of logs of which 138,999 m^3 was exported and 56,000 m^3 used in domestic processing.

It is estimated the forest industry (Formal Sector) generated approximately 9,300 direct jobs in 2017; comprising 7,200 jobs in harvesting and log export, and 2,100 in processing. Processing jobs are located in 11 manufacturing facilities.

The above harvesting levels are estimated to have generated payments (via various Statutory structures) to PNG Government of PNG Kina 340M; payments to Provincial governments of PGK 32M; landowners PKG 36m; and forest management PGK 10.1M.

Informal Sector

PNG also operates significant, but of unknown size, wood processing by informal sector producing wood products from rough sawn through to furniture. Feedback from marketing personnel for large timber processing plants in PNG estimate that on aggregate the PNG forest industry supplying the domestic market is currently supplied 25-30% by formal sector and 70-75% by informal sector. The increasing role of informal sector in PNF forest industry is addressed in the Objective 3 report (Smith, 2019).

3. Some key economic challenges in transitioning to enhanced domestic processing

The lack of success of PNG forest industry in transitioning to enhanced domestic processing is not new. Several PNGFA documents articulate the technical constraints and complexities facing PNG in moving to enhanced downstream processing.

The continued dominance of logs export for harvested logs from PNG natural forests is supported by several inter-related factors maintaining the current structure of PNG forest industry including:

- PNG, while having a large forest resource endowment (sustained yield estimated 3.5M m3/year) faces significant challenges (wood costs, labour, infrastructure capital, operating costs and sovereign risks) in delivering a total productivity package for domestically produced wood products which provide a competitive position and comparative advantage in global markets.
- PNG currently has small, cyclical and poorly structured domestic markets for wood products, limited by dispersed population and low incomes. These factors are a significant brake on increasing domestic demand for wood products, more so in residential market than commercial/industrial markets.
- The business model currently employed by major firms in PNG forest industry retain capacity and relationship to service both changes in export (log and wood products) markets and domestic wood markets.
- Under current Statutory revenue structures, the PNG Government, agencies and landowners receive PGK127/m^3 for harvested logs exported, compared to PGK27/m^3 if log domestically processed. At aggregate level it is estimated in 2017 log export generated around PGK313M in revenue, compared to PKG 27M from logs processed domestically. The revenue differential is incentive in maintaining dominance of log export.
- The current industry (where dominant requirement is log export) has contracts over the most commercially attractive Production Forest areas. No readily identifiable resource to attract new industry.
- Related to above the correct use conditions in Timber Permits, facilitating log export, are more commercially attractive to operators given the higher financial risk required for investment, infrastructure, working capital and markets associated with domestic processing.

- Relative attractiveness of commercial agriculture (for example palm oil) for landowners in forest areas previously harvested to switch.

4. Potential Next Steps

Given that limited appetite for current forest industry to transition to enhanced domestic processing- albeit for rationale reasons documented in the project report (Smith, 2019), there are significant potential economic benefits to PNG in testing and implementing processes to capture additional value from current and potential forest resources.

At policy level, taking into account the characteristics of resources (species, locations), the commercial parameters required to be met to profitably supply markets, the higher level of security for revenue flows to PNG Government and other beneficiaries, and overall sovereign risk issues, it is very difficult to see a pathway for shifting the current business structure for forest industries in PNG to enhanced domestic processing.

Given the barriers (financial Government revenue streams, profitable markets) impeding current PNG forest industry moving to enhanced downstream processing, one pathway to increase the economic return (employment, investment, etc) to PNG above current levels is:

- Specific project to examine options for generating economic values from cut-over forests. Work of current ACIAR Project would provide technical base for this work;
- Place priority on supporting current and expanding opportunities in informal sector;
- Examine the economic case for large-scale plantations in PNG. Future resource attractive on global markets.

8.2.2 Social impacts

It is envisaged that there will be significant social benefits arising from the project activities.

The study of the properties of PNG timbers will assist local producers to engage in small-scale wood processing. The technical data will be widely disseminated through education and training institutions and will be available for the PNGFA to facilitate formulation of policy in the areas of resource management, allocation and development, and wood products marketing. Thus, the outcome of this study will have a significant impact on the people of PNG.

The research study on environmentally-friendly preservative treatment of PNG species has the potential to increase the durability of wood products and houses. This will benefit local communities in both rural and urban settlements.

During the assessments of wood processing and manufacturing companies, the research teams noted a lack of workplace health and safety culture. Recommendations for increasing awareness of risk in the workplace have been incorporated within all company reports to foster a safety culture. Training to the companies' management and workers were conducted to ensure a significantly safer environment for logging operations and factory workers.

There have been several females actively participating in the project and their research and management capabilities have been outstanding. This indicates that a stronger focus should be placed on encouraging women to increase their roles in the PNG wood industry in the future.

A program for the production of simple folded chairs and tables for rural communities will provide benefits to women and children. The furniture will be strong and durable, low in cost, will require little maintenance, and can be made by local industries from locally available timbers. The main elements of this concept have been poverty, lack of available

material and lack of financial resources at rural communities. The design and making of the simple, affordable furniture using wood off-cuts and wood waste could increase the efficacy of living space utilization, while likely giving the people a sense of self-worth to encourage them to build the furniture themselves with the limited resources available. As a result, poverty-stricken areas could hopefully prosper in a better living environment.

Links with local communities have been developed through the acquisition of trees for the testing program and their involvement in harvesting and in preliminary trials of CPU at TFTC.

The CPU is in its early stages of development, but it could play a fundamental role in providing an opportunity for employment, including skilled positions in administration, sourcing, and processing. The CPU concept aligns with the government strategy to encourage downstream processing, ensure that PNG small sawmillers and landowners are able to sell their sawn timber which can be further processed and to build capacity in training of landowners to effectively and sustainably use natural resources to sustain income flows in the future in their community. A business plan is very ambitious but should be seen as a good start if necessary funding can be identified and secured. Possible funding for the CPU full development should be investigated by PNG government and PNG Business Development units.

The enhanced capacity in research, training and education developed within the project, is likely to provide both social and economic benefits.

8.2.3 Environmental impacts

It is expected that the project outcomes will have significant environmental impacts on the PNG forest and communities. However, at this stage these impacts are not yet quantifiable.

The project has provided an opportunity to realise greater value and potential for utilization of timber species from secondary and plantation forests, which should reduce pressures on native old-growth forests.

A PhD study undertaken at the University of Melbourne by Peter Edwin, a lecturer at UniTech, aims to develop a multi-criterion optimisation framework for reducing the greenhouse gas (GHG) emissions associated with hardwood processing in PNG. The study will have a positive impact on global carbon mitigation efforts as well as improving the environmental profile of the timber industry in PNG.

8.3 Communication and dissemination activities

Project coordination and management

The project has been managed by the University of Melbourne in a close partnership with all participating organisations working together towards achieving its objectives.

The focal points of the project were in Port Moresby, where the major government partner (PNGFA) and industry association (PNGFIA) are located, and in Lae district where R&D and training were conducted and where the majority of timber companies and landowners are located.

A project communication plan was developed to enable frequent, efficient and open discussions between the project team members.

The Project Steering Committee (PSC) was nominated, consisting of representatives from each partner organisation, to overview and coordinate project activities. Four meetings were held during the project term. As explained above, the PSC was shared with the project FST/2014/065 “Development of durable engineered wood products in PNG and Australia.”

Every effort was made by the Project Management Team to involve all project participants in each step of the project and to give them a sense of membership and ownership of the project that will be carried on past the final review of the project.

The project sought to communicate information about activities through publications, newsletters, technical reports, coordination meetings, workshops, competitions, and through media outlets such as TV and internet. The information tools used during the project are summarised below.

Publications

In total 89 publications were produced during the project period ranging from technical reports, research reports, manuals, journal papers and training materials. The list of publications is provided in Section 10.2 of this report.

Coordination meetings

Various coordination meetings were conducted throughout the project. They are listed in detail in the project annual reports but in summary include frequent communication by email, telephone, skype and face-to-face meetings:

- between the Project Leader and the Communication Manager, the Country Coordinator, objective team leaders and team members to discuss the project progress, planning and reporting;
- between team leaders and team members of each objective and activity, regarding the work program for activities for each team (action plan, timetable, research progress, budget, publications);
- PNG team meetings in Lae to review the progress of various project activities and tasks;
- between researchers and landowners and timber companies.

Management workshops

The project inception meeting was held on 5 February 2015 in Port Moresby, attended by the project members, government and industry representatives, landowners, stakeholders and interest groups to discuss the project objectives and implementation pathways.

Annual workshops were held throughout the project, aimed at providing industry, management and policymakers with key project outcomes and/or hands-on demonstrations.

The project MTR was held in Lae on 21 April 2017. The event provided an opportunity for project members and stakeholders to gather and discuss the challenges and opportunities for the project and review its progress.

Workshops and training courses

As stated in the previous sections, training courses and workshops were conducted for smallholders, the timber industry and PNG researchers. Extensive training materials were developed and given to the course participants. The training materials are being used for teaching and training at UniTech and TFTC.

A successful Crawford Fund application allowed PNG researchers to be trained in value-added wood technologies in Victoria, Australia.

The project logo

The project logo (Figure 10) was developed to enable easy identification of the project publications, activities and announcements and to enable a group identity to be established.

Figure 10. Logo of the project FST/2012/092

Website

The project webpage contains project specific information, including a photo gallery and files for viewing and downloading (e.g. newsletters, presentations, technical pamphlets and research reports). The webpage is hosted on the Pacific Island Projects (PIP) website at: http://www.pip.com.pg/projects/current-projects/31-enhancing-value-added-wood-processing-in-papua-new-guinea.html. The project webpage will be transferred to the completed projects section of the PIP website at project closure.

The PIP website also hosts the Wood Processes Tool Kit (WPTK) which has been set-up under the sister wood processing project: FST/2014/065. The WPTK contains a growing set of multimedia resources which are freely available online via Google Drive and the PIP website at: http://pip.com.pg/resources/wood-processors/welcome.html. The project has contributed the following resources to the WPTK:

- **Wood species and properties:** 6 technical reports
- **Wood processing techniques:** 6 technical reports and 5 pamphlets (Figure 11)
- **Wood processing partnerships:** 1 video (with project FST/2014/065)
- **Wood products and markets:** I technical report (with project FST/2014/065)

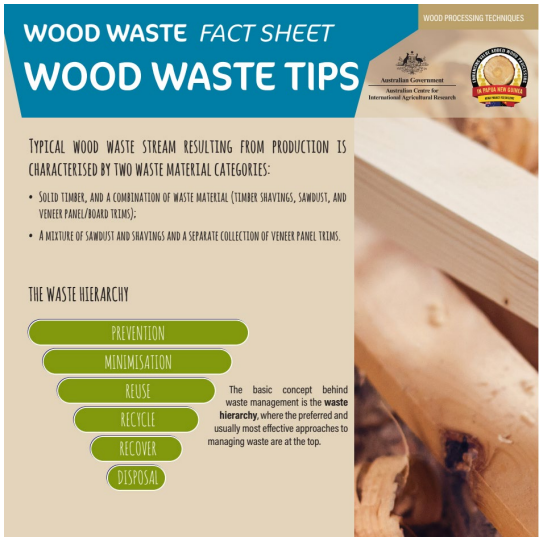

Figure 11. Wood waste pamphlet

PIP will continue to promote and share these wood processing resources amongst the sustainable forestry sector after project closure via the most appropriate communication hubs (currently website, shared folders, news updates & alerts, and social media).

Newsletters

A total of seven newsletters were produced during the project and were submitted to the project members, stakeholders and industry as well as uploaded onto the project website. The last newsletter will be produced after the completion of the Final Review Workshop.

Media

During the project development stage, an article was published in “The Age” (18 October 2014) entitled “Making Papua New Guinea's community-managed tree plantations sustainable”. An interview with the Project Leader, Prof. Barbara Ozarska was published which covered the aims of the project and its potential social and environmental benefits to PNG community.

Following the inception meeting and project workshops, short articles about the project activities were published in the local Lao newspapers “The National” and interviews with team members were shown on TV.

Tony Bartlett was interviewed in May 2018 by “Business Advantage PNG” about the CPU which was investigated in the project.

9 Conclusions and recommendations

The following section presents the main project conclusions followed by recommendations for further research and development.

Conclusions

The project team encountered many technical and administrative problems during the project term but due to the team members dedication and commitment all project activities have been completed on time and within budget.

The key learnings from the project are as follows:

The data on wood properties and processing characteristics of PNG timbers from secondary and plantation forests provide a valuable contribution to research communities, government and the wood processing industry in PNG, and scientific communities around the world. It is envisaged that the availability of this technical data will enable the utilisation of the PNG timbers for the production of value-added wood products for domestic and export markets.

An important finding of this study was that the mechanical properties of species obtained from secondary and plantation forests were lower than those found in the literature from old-growth forests. Another interesting observation was that there was a significant improvement in the treatability of these younger timbers compared to same species of the old-growth forest with exception of few medium- and high- density species. These species were re-classified into new permeability classes. These findings have an important value to the research community as it makes them aware of the importance of assessing wood properties of younger timber resources, and to timber companies as it prompts them to adjust the processing and manufacturing methods when utilising younger timbers.

The Wood Database and promotional materials were developed which combine the data on wood properties and characteristics of 26 PNG timber species. These resources will be a valuable resource of information for research education and training purposes in PNG and worldwide. It will also help the timber industry in promoting PNG timbers for a variety of products and applications according to their properties and characteristics.

In this project, the team, with support funding from the project, have tried the best possible way to visit and listen to forestry/wood processing companies in an effort to assist them. Feedback suggested there was a willingness by smallholders and, small processors to collaborate, however, the formal approach via a “Memorandum of Understanding” appears to have caused anxiety to some potential project collaborators. This formal approach using what at face value is a “legal document” appeared to be misunderstood and may have resulted in a less than ideal engagement with the project. However, some implementation visits and training were provided to small- and medium-sized timber companies which can be seen as a good start in developing a training program to disseminate the project findings.

The development of a business plan for CPU and the preliminary production trials revealed that an opportunity exists for CPU to become a viable system which would provide opportunities to landowners to increase their profit by selling their timber for further processing into value-added products and be involved in value-adding processes. It has been estimated that funding of 1.4 million PNG Kina for infrastructure and equipment is needed from government or donor organisations to ensure the CPU could operate as a successful commercial unit.

The study on the potential contribution and distribution of economic impacts to national and local economies from enhanced value-added wood processing identified several factors which are considered to impede growth (adoption barriers) in transitioning of PNG forest industry to enhanced domestic downstream processing. Also, several actions were suggested which could assist in creating a conducive environment for potentially capturing additional value, including enhanced downstream processing of PNG’s forest resources.

At overarching level, it has been suggested that PNG would benefit from a committed process which generates realistic and innovative assessments of the opportunities and trade-offs for PNG to capture additional value (economic and social) from management and harvesting of forest resources. More specific suggestions include:

- identifying 'fit for purpose' and 'market test commercial potential' for a basket of resources based on “cut over forest”;
- work with current industry to robustly test their appetite, requirements and specific proposals they may have for enhanced domestic processing;
- accelerate effective and efficient structures to support commercial activities for forest sector in informal sector (including capture of CPU’s potential); develop and implement investment strategy to deliver globally competitive plantation resources; and delivery of commercially effective structures (covering supply, production and marketing chains) to support expanding exports opportunities for primary wood products such as flitch/ bulk wood products.

Recommendations

Based on the outcomes of this project and experience gained while working on the project activities, the following recommendations were developed for future research activities, which would cover gaps and address prospects in the development of downstream wood processing industry in PNG.

Through the collaboration with a parallel ACIAR project FST/2014/065 “Development of durable engineered wood products in PNG and Australia” the project team has recognised that opportunity exists to introduce new value-adding technologies to PNG industry based on veneer for developing novel appearance and structural wood products, for which there is a strong demand in domestic and international markets.

Some suggested activities include[4]:

Testing gluing characteristics of PNG timber for structural products and applications (the current project focused on non-structural products).

Testing structural properties of timbers and EWPs according to relevant standards.

Developing research and training facilities for veneer, plywood and other EWPs production which would enable the development of novel appearance and structural wood products based on veneer, sawn wood and composite products that would provide new markets for the existing plantation resources.

Further development of CPU concept at TFTC to provide value-added opportunities for local communities.

Establishing a “One-stop” Advisory Service Centre to provide technical support to landowners, small wood processors and medium-sized companies. This would eliminate the problem of signing formal MoU which was experienced within the current project. The services would provide technical and research advice and training according to companies’ needs.

Given the barriers (financial Government revenue streams, profitable markets) impeding current PNG forest industry moving to enhanced downstream processing, some pathways to increase the economic return (employment, investment, etc) to PNG above current levels are:

[4] As the report is in the draft form and has not been yet reviewed by PNG team members, the suggestions for future activities have been provided only by the Australian team members. The final version of Final Report will provide the recommendations made by all project members during discussions and meetings at the final stage of the project.

- Specific project to examine options for generating economic values from cut-over forests. Work of current ACIAR project would provide technical base for this work.
- Place priority on supporting current and expanding opportunities in informal sector.
- Examine the economic case for large-scale plantations in PNG.

It is envisaged that the experience gained by the participants within this and previous ACIAR project has established strong linkages, which should continue after the project is completed and has prepared them for future collaborative work.

10 References

10.1 References cited in report

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10.2 List of publications produced by project

List of project reports for each Objective and Activity is presented in Table 5.

Note: The following abbreviations have been used: DB – Database, TM – Training material, RR – Research report, JP – Journal paper, TR – Technical report/note.

Table 5. List of reports and training materials for each Objective and Activity

Objective 1: To enhance the knowledge of wood properties and processing characteristics of PNG timbers.				
Activity		Title of publications		Category (see Note above)
1.1	Extending the current database and creating database for lesser-known species from secondary forest and plantations forests.	1.1.1	Vali, B. 2015. Database on 120 PNG timber species (withdrawn)	DB
		1.1.2	Benny, S and Nerit, L. 2019. Database on 26 PNG timbers from planation and secondary forests.	TR
1.2	Testing of basic physical and mechanical properties of target species.	1.2.1	Belleville, B. 2015. Methodology for testing wood properties of PNG timbers. Training materials, 21 pp.	TM
		1.2.2	Belleville, B. 2015. Checklists for mechanical properties tests. Training materials. 5pp.	TM
		1.2.3	Vali, B. 2016. Protocol for wood sample procurement for research into wood properties. 8 pp.	TM
		1.2.4	Galore, E., Asok, F., Naki, M. 2018. Kimbe Trip, Activity Report - Milling and Harvesting Batch 2 species: *Eucalyptus deglupta* (Kamarere) and *Castanospermum australe* (Blackbean) 27th May to 2nd June 2018. 7 pp.	RR
		1.2.5	Belleville, B., Lancelot, K., Galore, E. and Ozarska, B. 2018. Testing of Basic Physical & Mechanical Properties of PNG timbers. Research Report. 50 pp.	RR
		1.2.6	Belleville B, Lancelot K, Galore E, Ozarska, B. 2019. Assessment of physical and mechanical properties of Papua New Guinea timber species. Maderas Ciencia y Tecnologia. (under Review).	JP
		1.2.7	Belleville, B., Iru, R., Tsiritsi, C. and Ozarska, B. 2019. Machining characteristics of Papua New Guinea timber species from plantation and regrowth forests (manuscript submitted, under review).	JP
		1.2.8	Galore, E. 2019. Process of procurement of timbers for testing. 2pp.	TR

1.3	Development of kiln drying schedules and PNG appropriate technologies for the timbers.	1.3.1	Ono, P. 2019. Timber drying using PNG Unitech Solar Kiln. Technical report. 23 pp	RP
1.4	Assessment of preservative treatment characteristics of timbers.	1.4.1	Gusamo, B. 2016. Methodology for assessment of preservative treatment characteristics of timbers. Training materials. 7pp.	TM
		1.4.2	Gusamo, B. 2017. Treatment characteristics of 10 secondary timber species using vacuum-pressure impregnation process. 9 pp.	RR
		1.4.3	Midi, E. 2018. Investigating natural durability of 10 hardwoods of Oomsis Secondary Forest, Morobe Province, Papua New Guinea. Report by the final year UniTech student. 16 pp.	RR
		1.4.4	Sow, D. 2018. Pressure impregnation of five timber species from Oomsis Secondary Forest using ACQ preservative, Papua New Guinea. Report by the final year UniTech student. 25 pp.	RR
		1.4.5	Gusamo, B., Lancelot, K., Naki, M., Asok, F and Sow, D. 2019. Testing of treatability properties of PNG timbers. Research Report. 15pp.	RR
		1.4.6	Gusamo, B. 2019. Evaluating Preservative Treatment Characteristics of Selected Plantation and Secondary Forest Hardwoods of Papua New Guinea using Vacuum-Pressure Impregnation Process. (Manuscript in preparation).	JP
1.5	Testing gluing characteristics of the timbers for various wood product applications.	1.5.1	Belleville, B. 2016. Methodology for testing gluing characteristics of the timbers for various wood product applications. Training Materials.	TM
		1.5.2	Belleville, B., Galore, E., Lancelot, K, and Ozarska, B. 2019. Gluing characteristics of PNG timber species for various wood product applications. Research Report. 41 pp.	RR
		1.5.3	Belleville, B., Galore, E., Lancelot, K, and Ozarska, B. 2019. Gluing characteristics of PNG timber species for various wood product applications (Manuscript in preparation).	JP
1.6	Assessment of other processing characteristics required to successfully produce value-added products for PNG and export markets.	1.6.1	Iru, R. 2017. Assessment of machining characteristic for Taun (*Pometia pinnata*): Planning characteristics. 15 pp.	TR
		1.6.2	Iru, R. and Belleville, B. 2019. Planing grading rules. Report. 8pp.	RR
		1.6.3	Iru, R., Belleville, B., Tsiritsi, C. and Ozarska, B. 2019. Machining characteristics of PNG timber species. Research Report. 35pp	RR
		1.6.4	Belleville, B., Iru, R., Tsiritsi, C. and Ozarska, B. 2019. Machining characteristics of plantation and regrowth timber species from Papua New	JP

			Guinea. Journal of Materials Processing Technology. (Under Review)	
1.7	Recommendations on best applications/types of products for the selected species based on their properties and processing characteristics.	1.7.1	Ozarska, B., Belleville, B., Iru, R. and Gusamo, R. 2019. Recommendations on best applications/types of products for the PNG species based on their properties and processing characteristics. Research Report. 33 pp.	RR
Objective 2: To identify, pilot and evaluate interventions for enhanced value-added processing systems.				
2.1	Selection of companies and landowners' groups willing to participate in the Project.	2.1.1	Peki, M (2016). List of companies visited. 9pp.	TR
2.2	Identifying what improvements in the current processing and manufacturing practices are required.	2.2.1	Ozarska, B. 2015. Questionnaire for the assessment of current manufacturing capabilities of furniture companies.19pp.	TM
		2.2.2	Asok, F. 2015. Questionnaire for the assessment of sawmilling operations. 4pp.	TM
		2.2.3	Ozarska, B., Asok, F., Jeremiah, H and A. Jenkihau. 2016. Assessment of wood manufacturing capabilities in PNG: Pryde Furniture Pty Ltd. 10pp.	TR
		2.2.4	Jeremiah, H., Asok, F., Edwin, P., Iru, R., Marika, D. and E. Galore. 2016. Assessment of wood processing companies. Yara Timbers Ltd. 10 pp.	TR
		2.2.5	Jeremiah, H., Asok, F., Edwin, P., Iru, R., Marika, D. and E. Galore. 2016. Assessment of wood processing companies. Santi Forestry PNG Ltd. 16 pp.	TR
		2.2.6	Jeremiah, H., Asok, F., Edwin, P., Iru, R., Marika, D. and E. Galore. 2016. Assessment of wood processing companies. PNG Tropical Wood Products. 17 pp.	TR
		2.2.7	Jeremiah, H., Peki, M., Asok, F. and R. Iru. 2016. Assessment of wood processing companies. Masurina Timbers Ltd. 14 pp.	TR
		2.2.8	Jeremiah, H., Asok, F., Edwin, P., Iru, R., Marika, D. and E. Galore. 2016. Assessment of wood processing companies. Local Timber Supplies. 18 pp.	TR
		2.2.9	Jeremiah, H. 2016. Assessment of wood processing companies. Hamea Timbers. 15 pp.	TR
		2.2.10	Peki, M., Jeremiah, H., Asok, F. and R. Iru. Assessment of wood processing companies. Sarco Timber Yard Ltd. 24 pp.	TR
		2.2.11	Jeremiah, H., Peki, M., Asok, F. and R. Iru. 2016. Assessment of wood manufacturing	TR

		capabilities in PNG. South Pacific Timber Products Industries. 10 pp.	
		2.2.12 Asok, F., Ono, P. and E. Galore. 2016. Assessment of wood manufacturing capabilities in PNG. GS Model Ltd, Kerevat. 13 pp.	TR
		2.2.13 Galore, E. 2016. Assessment of wood manufacturing capabilities in PNG. Stettin Bay Lumber Company Limited (SBLC). 9pp.	TR
		2.2.14 Iru, R., Peki, M., Jeremiah, H. and F. Asok. 2016. Assessment of wood manufacturing capabilities in PNG. Craftsman Ltd – NGO Group of Companies. 11 pp.	TR
		2.2.15 Asok, F., Ono, P. and E. Galore. 2016. Assessment of wood manufacturing capabilities in PNG. A E S Timbers Ltd, Takurbar, Kokopo. 12 pp.	TR
		2.2.16 Asok, F, Jeremiah, H. and R. Iru. 2016. Assessment of wood manufacturing capabilities in PNG. Madang Timbers. 12 pp.	TR
		2.2.17 Ono, P. and H. Jeremiah. 2016. Assessment of wood manufacturing capabilities in PNG. Philco Joinery. 10 pp.	TR
		2.2.18 Jeremiah, H. and Ono. P. 2017. Assessment of wood processing capabilities in PNG. Niugini Tropical Woods. 14 pp.	TR
		2.2.19 Ken, J.B. 2016. Report on rejected export logs. 10 pp.	TR
		2.2.20 Jeremiah, H. 2017. Gap assessment of wood processing companies in PNG. 33 pp.	RR
		2.2.21 Asok, F., Jeremiah, H., and R. Iru. 2017. Assessment of primary wood processing operations in Papua New Guinea. Summary report. 21 pp.	TR
		2.2.22 Iru, R., Asok, F. and H. Jeremiah. 2017. Assessment of wood manufacturing operations in Papua New Guinea. Summary report. 38 pp.	TR
2.3	Conduct research to address identified practice and technology gaps.	2.3.1 Francis, L. and Hopewell, G. 2018. Pest protection prescriptions. DAF Manual for ACIAR project FST/2014/065: Development of durable engineered wood products in Papua New Guinea and Australia (projects information sharing as decided by the Projects Steering Committee). 25pp.	RR
		2.3.2 Redman, A., Fitzgerald, C. and B. Belleville. 2016. Identify, pilot and evaluate interventions for enhanced value-added processing systems – Report on waste grading rules. 51 pp.	RR
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			TR

		2.3.4 Spairong, M. 2017. Papua New Guinea Standard for visual timber grading.	TR
		2.3.5 Spairong, M. 2017. Papua New Guinea National sawn timber grading rules. 47 pp.	RR
		2.3.6 Fideles, J. and B. Ozarska. 2017. Standards and specifications for production and quality of solid wood and wood-based products. 33 pp.	RR
		2.3.7 IndustryEdge. 2017. Market Analysis. In support of ACIAR Projects in PNG: Enhancing value-added wood processing in Papua New Guinea & Development of durable engineered wood products in PNG and Australia. 55 pp.	RR
2.4	Support trial implementation of improved value adding processes.	2.4.1 Belleville, B. 218. Product ideas for wood waste utilisation per category. Fact Sheet. 2 pp.	TM
		2.4.2 Belleville, B. 2018. Wood waste fuel. Fact Sheet. 2pp	TM
		2.4.3 Belleville, B. 2018. Wood waste tips. Fact Sheet. 2pp	TM
		2.4.4 Belleville, B. 2018. Wood waste reformed fibre. Fact Sheet. 2 pp.	TM
		2.4.5 Belleville, B. 2018. Wood waste: short lengths. Fact Sheet. 2 pp.	TM
		2.4.6 Ozarska, B. 2018. Log handling checklist. 3 pp.	TM
		2.4.7 Ozarska, B. 2018. Racking sawn boards for drying checklist. 3 pp.	TM
		2.4.8 Ozarska, B. 2018. The sawmill log yard checklist.3pp.	TM
		2.4.9 Ozarska, B. 2018. Market for wood pellets. Report for Niugini Tropical Wood Ltd. 39 pp.	TR
		2.4.10 Belleville, B. 2018. Gluing checklist for operator. Quality control. 4 pp.	TM
		2.4.11 Belleville, B. 2018. Machining quality control checklist for quality controller. Quality control checklist. 17 pp.	TM
		2.4.12 Belleville, B. 2018. OHS machining checklist for machine operator. Quality control checklist. 2 pp.	TM
		2.4.13 Belleville, B. 2018. OHS machining checklist for supervisor. Quality control checklist. 4 pp.	TM
		2.4.14 Belleville, B. 2018. Machining with planning machine for Operator – Checklist. 2 pp.	TM
		2.4.15 Ozarska, B. 2018. Quality control checklist for finishing workers. Quality control checklist. 5 pp.	TM
		2.4.16 Ozarska, B. 2018. Checklist for quality controller of finishing process. Quality control checklist. 11 pp.	TM
		2.4.17 Jeremiah, H. 2018. Brief report on company visits and onsite training. 8 pp.	TR

		2.4.18 Training Guide: Chainsaw & Sawmill Operation. 2019. On-Campus Training for Timber Industry. 16pp.	TM
		2.4.19 Training Guide: Value-Adding. On-Campus Training for Timber Industry. 25pp.	TM
2.5	Pilot innovative approaches to enable greater landowner involvement.	2.5.1 Ono. P. 2016. Landowner involvement in the project – Innovative approaches in carving making. 15 pp.	RR
		2.5.2 Ozarska, B., Tsiritsi, C., Simeon, M. and Ono, P. 2019. Pilot innovative approaches to enable greater landowner involvement. Report on case studies with recommendations on value-added opportunities for communities. Research Report. 34 pp.	RR
		2.5.3 Simeon, M. 2018. TFTC Commercial Unit. ACIAR Project Summary Update 2018-2019.	TR
		2.5.4 Simeon, M. 2019. TFTC Commercial Unit. ACIAR Project Summary Update 2018-2019.	TR
		2.5.5 Simeon, M. 2019. List of Land Owner Groups Supplying Timbers. Current and Potential Timber Suppliers for Training and Commercial Unit Purposes.	TR
2.6	Work with PNG FA to operationalise the Central Processing Unit in Lae.	2.6.1 Komut, S. 2015. Networking of Central Processing Unit, Central Marketing Unit & Timber Producing Unit. 4pp.	TR
		2.6.2 Jeremiah, H. 2016. Proposed Central Processing Unit (CPU) models for trials at Timber Forestry Training College (TFTC). Power point presentation for discussion. 21pp.	TR
		2.6.3 Yakuma, D. 2018. Proposed business plan for central processing unit at timber & forestry training college. Final report. 33 pp.	TR
2.7	Developing public-private partnerships to support enhanced value-added wood processing in PNG.	2.7.1 Jenkihau, A, and D. Kaip. 2016. Interim report on Activity 2.7 “To identify, pilot and evaluate interventions for enhanced value-added processing systems”. 1p.	TR
Objective 3: To estimate the potential contribution and distribution of economic impacts to national and local economies from enhanced value-added wood processing.			
3.1 - 3.6	Results of research studies on the Activities 3.1-3.6 were reported in combined reports 3.1.1 and 3.1.2.	3.1.1a Smith, B. 2016. Progress Report Activity 3.1 of Objective 3 - January 2016. 5pp	TR
		3.1.1b Smith, B. 2017. Obj 3 Progress Report – Mid-term review.	TR
		3.1.2 Smith, B. 2019. Estimates of the potential contribution and distribution of economic impacts to national and local economies from	RR

		enhanced value-added wood processing. Final Research Report on Objective 3. 58 pp.	
Objective 4: To enhance the capacity of Government, institutional support bodies, industry partners and landowners to implement value added wood processing policies, strategies and practices.			
4.1	Training and technology transfer on value-added processing methods.	4.1.1 Ozarska, B. 2018. Report on training "Advanced technologies in wood processing and manufacturing of high-quality timber products" in Melbourne 21-29 March 2018. Report for the Crawford Fund. 9 pp. 4.1.2 Galore, E & C. Tsiritsi. 2018. Crawford Fund Training, 21st -29th March 2018. Summary of the travel, logistics and companies and industrial centers visited during the 5 days of training. 13 pp. 4.1.3 Tsiritsi, C. 2018. Timber processing training in Solomon Islands. A report on the visit to Solomon Islands, March 2018. 14 pp. 4.1.4 Gusamo, B and contributors. 2019. Diploma in Timber Processing and Wood Products. Revised Program. 4.1.5 Tsiritsi, C. 2016. Training and technology transfer review.	TR TR TR TR TR
4.2	In collaboration with Government and industry association working towards implementation of the national policy on the development of downstream wood processing.	4.2.1 Jenkihau, A., and D. Kaip. 2016. Interim report on Activity 4.2 "To enhance the capacity of Government, institutional support bodies, industry partners and landowners to implement value added wood processing". 5pp. 4.2.2 Jenkihau, A. 2018. Final Report on recommendations on major requirements for developing successful downstream wood processing industry. 11pp.	TR RR
4.3	Monitoring and regulating the timber industry to meet required quality standards and also impart technical and appropriate advice for improvement.	4.3.1 Dorries, S. 2017. Monitoring & Evaluation Plan for PNG Project. 3pp. FST/2012/092 4.3.2 Dorries, S. 2018. Monitoring and evaluation report No 1. Project –FST 2012/092. 87pp.	TR TR
4.4	Development of timber promotion materials such as wood sample and pamphlets.	4.4.1 Promotional materials: boxes with set of samples of 26 tested PNG species with description of wood properties, characteristics and potential uses (in preparation for demonstration at the Final Review). 4.4.2 Labels on wood samples	

11 Appendices

11.1 Appendix 1 - The data on wood properties and characteristics of 26 PNG tested species

The data on 26 species from secondary and plantations forests are presented in Table 6 (a-c)

Table 6 (a). The data on wood properties and characteristics of 26 PNG tested species – Part 1

Properties		Unit	Species name								
			Albizia, White	Basswood, PNG	Beech, Wau	Blackbean	Boxwood, PNG	Canarium, Grey	Cedar, Pencil	Cheesewood, White	Erima
ADD @ 12% MC		kg/m^3	321	356	339	792	718	464	381	296	276
MOE		GPa	6.7	7.8	6.1	11.5	13.1	9.3	7.5	5.1	4.8
MOR		MPa	42.7	44.9	48.5	85.2	94.2	62.3	50.8	33.4	31.5
Compression	Parallel to grain	MPa	25.5	29.5	25.4	48.2	47.7	33.5	25.4	18.7	18.5
	Perpend. to grain	MPa	4.1	4.2	5.6	12.7	13.6	7.2	4.5	3.5	2.7
Shear	Parallel to grain	MPa	5.6	5.4	5.5	10.9	10.6	8.5	5.5	4.6	3.6
Hardness	Radial	N	1094	1261	1110	4399	4692	2166	1242	884	658
	Tangential	N	1291	1361	1436	4581	5107	2189	1506	907	812
	Longitudinal	N	1773	2435	1998	5882	6261	3690	2227	1733	1138
	Janka	N	1192	1311	1273	4490	4899	2177	1374	896	735
Strength group			SD8	SD8	SD8	SD5	SD4	SD7	SD8	SD8	SD8
Treatability with preservatives	Absorption	L/m^3	297.8	680.8	403.5	111.0	265.3	529.8	333.2	645.1	641.2
	Permeability class		2	1	2	3	2	1	2	1	1
Machinability *		%	64 (DM)	99 (VW)	94 (VW)	97 (VW)	70 (MW)	89 (MW)	99 (VW)	100 (VW)	99 (VW)
Gluing	Dry use		No	Yes	Data not available	No	No	Yes	Yes	Yes	Yes
	Wet use		No	Yes		No	No	No	No	No	Yes
	Bondability		Difficult to bond**	Bond very well		Very difficult	Difficult to bond	Bond well	Bond well	Bond Very well	Bond Very well

* Percentages calculated based on total number of boards graded as “excellent” or “good” where an “excellent” surface is considered requiring “very light sanding” and a “good surface” requiring “light sanding”. Score 91-100% = the timber machine very well (VW), score 70-90% = timber machine moderately well (MW), score ‹ 70% = timber is difficult to machine (DM). ** Special care required in gluing procedures and selection of adhesives.

Table 6 (b). The data on wood properties and characteristics of 26 PNG tested species – Part 2.

Properties		Unit	Species name								
			Gum, Water	Hopea, Heavy	Kamarere	Kwila	Labula	Malas	Mersawa, PNG	Pangium	Pellita
ADD @ 12% MC		kg/m^3	495	932	562	758	418	800	685	618	779
MOE		GPa	9.6	20	8.6	14.2	7.7	15.4	14.6	12.1	15.6
MOR		MPa	68.1	136.9	62.1	116.6	56.5	128.4	86	70.1	120.6
Compression	Parallel to grain	MPa	38.3	69	31.3	64.1	31.4	58.6	51.2	36.7	52.7
	Perpendicular to grain	MPa	8.2	20.6	9.5	17.3	6.8	15.5	9.3	7.5	16
Shear	Parallel to grain	MPa	8.7	16.5	8.6	13.5	7.5	14.1	10.4	8	12.3
Hardness	Radial	N	2471	8731	2958	6215	2148	6708	3802	2965	6118
	Tangential	N	2349	8775	3306	6507	2209	7077	3792	3217	6312
	Longitudinal	N	4233	8805	3593	6312	3190	8312	3973	4311	7819
	Janka	N	2410	8753	3132	6361	2179	6893	3797	3091	6215
Strength group			SD6	SD2	SD7	SD3	SD8	SD3	SD4	SD5	SD3
Treatability with preservatives	Absorption	L/m^3	307.6	123.4	212.6	55.4	579.3	325.8	190.7	451.8	45.0
	Permeability class		2	3	2/3	4	1	2	3	2	4
Machinability *		%	99 (VW)	89 (MW)	98 (VW)	100 (VW)	100 (VW)	100 (VW)	100 (VW)	100 (VW)	Not available
Gluing	Dry use		No	No	No	No	Yes	No	No	Yes	Not available
	Wet use		No	No	No	No	Yes	No	No	No	
	Bondability		Difficult to bond**	Very difficult	Difficult to bond	Difficult to bond	Bond very well	Very difficult	Difficult to bond	Bond well	

* Percentages calculated based on total number of boards graded as “excellent” or “good” where an “excellent” surface is considered requiring “very light sanding” and a “good surface” requiring “light sanding”. Score 91-100% = the timber machine very well (VW), score 70-90% = timber machine moderately well (MW), score ‹ 70% = timber is difficult to machine (DM). ** Special care required in gluing procedures and selection of adhesives.

Table 6 (c). The data on wood properties and characteristics of 26 PNG tested species – Part 3.

Properties		Unit	Species name							
			Pine, Caribbean	Pine, Hoop	Pine, Klinki	Quandong, PNG	Rosewood, PNG	Taun	Terminalia, Brown	Vitex, PNG
ADD @ 12% MC		kg/m^3	525	496	473	385	557	664	433	591
MOE		GPa	8	8.1	10.6	7.7	10	11.1	6.9	11.5
MOR		MPa	67.2	60.1	68.9	50.5	76.1	91.1	54.4	80.8
Compression	Parallel to grain	MPa	29.1	24.4	31	28.6	45.7	36.9	29.9	45.9
	Perpendicular to grain	MPa	8.3	7.5	7.5	4.9	11.4	12.7	6	10
Shear	Parallel to grain	MPa	9	7.7	8.6	6.6	9.3	11.2	8.5	9.3
Hardness	Radial	N	2202	2197	2131	1481	3160	4637	2567	3247
	Tangential	N	2421	2261	2111	1628	3318	5171	2468	3407
	Longitudinal	N	3187	3618	3547	2479	3817	6214	4131	3832
	Janka	N	2311	2229	2121	1554	3239	4904	2518	3327
Strength group			SD7	SD7	SD6	SD8	SD6	SD5	SD8	SD5
Treatability with preservatives	Absorption	L/m^3	580.3	619.8	623.8	439.7	122.8	169.7	350.6	51.3
	Permeability class		1	1	1	2	3	3	2	4
Machinability*		%	91 (VW)	100 (VW)	84 (MW)	97 (VW)	100 (VW)	57 (DM)	97 (VW)	90 MW)
Gluing	Dry use		Yes	Yes	Yes	Yes	No	Yes	Yes	No
	Wet use		No	No	Yes	No	No	No	No	No
	Bondability		Bond well	Bond well	Bond very well	Bond well	Difficult to bond **	Bond well	Bond well	Difficult to bond

* Percentages calculated based on the total number of boards graded as “excellent” or “good” where an “excellent” surface is considered requiring “very light sanding” and a “good surface” requiring “light sanding”. Score 91-100% = the timber machine very well (VW), score 70-90% = timber machine moderately well (MW), score ‹ 70% = timber is difficult to machine (DM). ** Special care required in gluing procedures and selection of adhesives.

11.2 Appendix 2 - Potential uses of 26 PNG species based on wood properties and characteristics

Table 7. Potential uses of PNG species based on wood properties and processing characteristics

Species name	Type of products and their service conditions				Comments
	Non-structural		Structural		
	Dry use (MC ≤ 16%)	Wet use (MC > 16%)	Dry use (MC ≤ 16%)	Wet use (MC > 16%)	
Albizia, White	Furniture, joinery, mouldings, panelling, doors, architectural decorative products, carvings.	Windows, retaining walls, pergolas, cladding.	Not suitable for structural applications as the strength group is only SD8.		Species is difficult to glue: special care is required in gluing procedures and selection of adhesives.
Basswood, PNG	Furniture, joinery, mouldings, panelling, doors, architectural decorative products, carvings.	Windows, retaining walls, pergolas, cladding, pallets.	Not suitable for structural applications as the strength group is only SD8.		Timber can be easily treated (Class 1) and bonds very well but has low strength, stiffness and hardness.
Beech, Wau	Furniture, joinery, mouldings, panelling, doors, architectural decorative products, carvings.	Windows, retaining walls, pergolas, cladding, pallets.	Not suitable for structural applications as the strength group is only SD8.		Data on gluing not available as there was not enough timber for the tests.
Blackbean	Furniture, domestic flooring, commercial flooring, joinery, mouldings, panelling,	Garden furniture, decking, fencing, exterior stairs, windows, retaining walls, pergolas, cladding, light boat	Architectural roof trusses, framing, portal frames, shear walls, packaging, structural	Framing, packaging, railway sleepers, fencing and power poles, boat and ship	Timber is very difficult to bond. It is recommended to apply a surface treatment prior to gluing or use mechanical

	stairs, rails and balustrades, doors, architectural decorative products.	building, pallets, street benches.	timber poles, columns and beams.	construction, exterior lining, bridges.	fasteners for jointing timber components.
Boxwood, PNG	Furniture, domestic flooring, commercial flooring, joinery, mouldings, panelling, stairs, rails and balustrades, doors, architectural decorative products.	Garden furniture, decking, fencing, exterior stairs, windows, retaining walls, pergolas, cladding, light boat building, pallets, street benches.	Architectural roof trusses, framing, portal frames, shear walls, packaging, structural timber poles, columns and beams.	Framing, packaging, railway sleepers, fencing and power poles, boat and ship construction, exterior lining, bridges.	Species is difficult to glue: special care is required in gluing procedures and selection of adhesives.
Canarium, Grey	Furniture, domestic flooring, joinery, mouldings, panelling, doors, architectural decorative products.	Garden furniture, fencing, windows, retaining walls, pergolas, cladding, light boat building, pallets, street benches.	Architectural roof trusses, lightweight framing, shear walls, packaging, beams.	Lightweight framing, packaging, fencing and power poles, exterior lining.	Very easy to treat and glue.
Cedar, Pencil	Furniture, joinery, mouldings, panelling, rails and balustrades, doors, architectural decorative products, carvings.	Retaining walls, pergolas, cladding, light boat building, pallets.	Light construction, protected framing and boards.	Not suitable, very low strength group SD8.	
Cheesewood, White	Furniture, joinery, mouldings, panelling, doors, architectural decorative products, carvings, turnery.	Windows, treated fascia, outdoor treated decorative products.	Not suitable for structural applications as the strength group is only SD8.		Timber can be easily treated (Class 1) and bonds very well but has low strength, stiffness and hardness.

Erima	Furniture, joinery, mouldings, panelling, architectural decorative products.	Cladding, light boat building.	Not suitable for structural applications as the strength group is only SD8.		Timber can be easily treated (Class 1) and bonds very well but has low strength, stiffness and hardness.
Gum, Water	Furniture, domestic flooring, joinery, mouldings, panelling, doors, architectural decorative products.	Garden furniture, decking, fencing, windows, pergolas, cladding, light boat building, pallets, street benches.	Architectural roof trusses, framing, portal frames, shear walls, packaging.	Packaging, power poles, boat and ship construction, exterior lining.	Species is difficult to glue: special care is required in gluing procedures and selection of adhesives.
Hopea, Heavy	Furniture, domestic flooring, commercial flooring, joinery, stairs, rails and balustrades, doors.	Garden furniture, decking, fencing, windows, pergolas, cladding, light boat building, pallets, street benches.	Architectural roof trusses, framing, portal frames, shear walls, packaging, structural timber poles, columns and beams.	Framing, packaging, railway sleepers, fencing and power poles, boat and ship construction, exterior lining, bridges.	Timber is very difficult to bond. It is recommended to apply a surface treatment prior to gluing or use mechanical fasteners for jointing timber components.
Kamarere	Furniture, domestic flooring, joinery, mouldings, panelling, doors, architectural decorative products.	Garden furniture, decking, cladding, light boat building, pallets, street benches.	Architectural roof trusses, lightweight framing, portal frames, shear walls, packaging.	Lightweight framing, packaging, exterior lining.	Species is difficult to glue: special care is required in gluing procedures and selection of adhesives.
Kwila	Furniture, domestic flooring, commercial flooring, joinery, mouldings, panelling, stairs, doors.	Garden furniture, decking, fencing, exterior stairs, windows, cladding, light boat building, street benches.	Architectural roof trusses, framing, portal frames, shear walls, packaging, structural timber poles, columns and beams.	Framing, packaging, railway sleepers, fencing and power poles, posts, boat and ship construction, exterior lining, bridges.	Species is difficult to glue: special care is required in gluing procedures and selection of adhesives. Kwila is known for its high natural durability.

Labula	Furniture, joinery, mouldings, panelling, doors, architectural decorative products, carvings.	Windows, retaining walls, pergolas, cladding, pallets.	Not suitable for structural applications as the strength group is only SD8.		Timber can be easily treated (Class 1) and bonds very well but has low strength, stiffness and hardness.
Malas	Furniture, domestic flooring, commercial flooring, joinery, mouldings, panelling, stairs, rails and balustrades, carvings.	Garden furniture, decking, fencing, windows, retaining walls, pergolas, cladding, light boat building, pallets, street benches.	Architectural roof trusses, framing, portal frames, shear walls, packaging, structural timber poles, columns and beams.	Framing, packaging, railway sleepers, fencing and power poles, posts, boat and ship construction, exterior lining, wharf and bridge decking.	Timber is very difficult to bond. It is recommended to apply a surface treatment prior to gluing or use mechanical fasteners for jointing timber components.
Mersawa, PNG	Furniture, domestic flooring, commercial flooring, joinery, mouldings, panelling, stairs, doors, architectural decorative products, carvings.	Suitable for exterior uses but under cover.	Architectural roof trusses, framing, portal frames, shear walls, packaging, structural timber poles, columns and beams.	Not suitable for structural products in wet conditions as it is difficult to treat and has low natural durability.	Species is difficult to glue: special care is required in gluing procedures and selection of adhesives.
Pangium	Furniture, domestic flooring, joinery, mouldings, panelling, stairs, rails and balustrades, doors.	Garden furniture, decking, fencing, cladding, light boat building, pallets, street benches.	Architectural roof trusses, framing, portal frames, shear walls, packaging, columns and beams.	Framing, packaging, power poles, boat and ship construction, exterior lining.	Timber bonds well and can be treated well (class 2).
Pellita	Furniture, domestic flooring, commercial flooring, joinery, mouldings, panelling, stairs, rails and balustrades, doors.	Garden furniture, decking, fencing, cladding, light boat building, pallets, street benches.	Architectural roof trusses, framing, portal frames, shear walls, packaging, structural timber poles, columns and beams,	Framing, packaging, fencing and power poles, boat and ship construction, exterior lining	Gluability has not been assessed due to lack of enough timber available for the tests. Timber is very difficult to treat (class 4) but has high natural durability.

Pine, Caribbean	Furniture, domestic flooring, joinery, mouldings, panelling, architectural decorative products.	Garden furniture, decking, fencing, retaining walls, pergolas, cladding, light boat building, pallets, playground equipment.	Architectural roof trusses, lightweight framing, columns and beams, preservative-treated poles for pole-frame construction.	Framing, packaging, fencing and power poles, exterior lining.	Timber can be easily treated (Class 1) and bonds well.
Pine, Hoop	Furniture, domestic flooring, joinery, mouldings, panelling, architectural decorative products, musical instruments.	Garden furniture, decking, fencing, retaining walls, pergolas, cladding, light boat building, pallets.	Architectural roof trusses, lightweight framing, columns and beams, poles for pole-frame construction.	Framing, packaging, fencing and power poles, exterior lining.	Timber can be easily treated (Class 1) and bonds well.
Klinki, Pine	Furniture, joinery, mouldings, panelling, architectural decorative products.	Garden furniture, decking, fencing, retaining walls, pergolas, cladding, light boat building, pallets, light aircraft.	Architectural roof trusses, lightweight framing, columns and beams, poles for pole-frame construction.	Framing, packaging, fencing and power poles, exterior lining.	Timber can be easily treated (Class 1) and bonds very well.
Quandong, PNG	Furniture, joinery, mouldings, panelling, carvings.	Cladding, light boat building, pallets.	Not suitable - low strength group (SD8)		Timber bonds well and can be treated well (class 2).
Rosewood, PNG	Furniture, domestic flooring, joinery, mouldings, panelling, stairs, architectural decorative products, musical instruments (guitar making).	Light boat building.	The attractive appearance of rosewood has made it highly prized for furniture, sliced veneer, turnery, and paneling although it could be used in lightweight construction (SD6).		Species is difficult to glue: special care is required in gluing procedures and selection of adhesives.

Taun	Furniture, domestic flooring, commercial flooring, joinery, mouldings, panelling, stairs, turnery, carvings.	Light boat building, pallets.	Architectural roof trusses, lightweight framing, portal frames, shear walls, structural timber poles, columns and beams.	Framing, exterior lining.	Only heartwood can be used for wet conditions because sapwood is difficult to treat.
Terminalia, Brown	Furniture, domestic flooring, joinery, mouldings, panelling, doors, architectural decorative products.	Garden furniture, decking, fencing, windows, retaining walls, pergolas, cladding, light boat building.	Not suitable for structural applications as the strength group is only SD8.		Timber bonds well and can be treated well (class 2).
Vitex, PNG	Furniture, commercial flooring, joinery, stairs, rails and balustrades, doors.	Garden furniture, decking, fencing, window frames, street benches.	Framing, timber poles, columns and beams,	Posts, railway sleepers, fencing and power poles.	Timber is very difficult to treat (class 4) but is very durable. Timber is very difficult to glue.

11.3 Appendix 3 – ACIAR and CPU Project analysis report

THE PAPUA NEW GUINEA UNIVERSITY OF TECHNOLOGY

TIMBER & FORESTRY TRAINING COLLEGE

P.O.BOX 2132
LAE 411
MOROBE PROVINCE
PAPUA NEW GUINEA

Telephone: (675) 472 4600
(675) 472 1083
(675) 472 3886
Facsimile: (675) 472 3586

COMMERCIAL UNIT

ACIAR & CPU PROJECT ANALYSIS REPORT – 2019

Author: Mr. Morean Simeon, TFTC Commercial Manager

Date: 22/02/2019

INTRODUCTION

The development of TFTC Business Plan known as Central Processing Unit (CPU) in 2017 became evident after years of analysis, from previous records of potential business activities through the training and other planned small-scale commercial activities.

The Central Processing Unit (CPU) was introduced as the vehicle to implement some of the potential business areas within the institution for the purpose of sustaining the training programs in the long run. Although it may be viewed as a new concept, it was anticipated to draw new dimensions for realigning, rebranding and transforming the current sleeping giant which was seen as a liability to the institution and transform into a viable business hub for the next five (5) to ten (10) years or so.

The dawn of CPU connects the Commercial Unit and ACIAR projects through the lances of thoughtful officers knowing well that these specialised skills taught at TFTC hold the strength for the weak, hope for the hopeless and poor, light for the blind and the financial sustainability as a technical training institution.

The main objectives of the CPU are:

- Acting as the centre point for Market Access between the major customers and the enterprising local timber suppliers;
- Creating new grounds as an Industrial training provider;
- Creating new market access for the local suppliers;
- Driving factor for the financial sustainability for the training institution;
- Becoming the gateway for market access abroad.

Timber & Forestry Training College being the only National Institution in Papua New Guinea specialised in Timber Industry Training has the potential in capturing the attention of Timber

Companies and even Investors within and abroad in terms of training as well as Business opportunities.

The need to diversify training and business is paramount at this time where the economy of the nation is struggling to withstand the global economic pressure.

As a Government training Institution, TFTC is grateful to have the partners and stakeholders supporting the institution in achieving the Vision of the Government. In doing so, it is believed to contribute meaningfully to the lives of the students, communities and the nation as a whole.

The main purpose of this presentation is to highlight these key areas briefly and in acknowledgment of the ACIAR Project towards training being the core business of TFTC;

ALIGNMENT OF ACIAR PROJECT TO ACHIEVING GOVERNMENTS VISION

It is with great pleasure to thank the Government of Australia for such initiatives in supporting this institution through this research project. The long-term results of this program will benefit the current and future students, staff development, the institution status, communities and the nation as a whole.

ACIAR project has contributed enormously into the fulfillment of PNG Vision 2050; Pillar No: 1.10, The Vision 2050 focuses on 'Seven Pillars' from 2010 to 2050: Below is the outline of Vision 2050 being fulfilled through the ACIAR project which includes the following;

1.10.1 Human Capital Development, Gender, Youth and People Empowerment;

1.10.2 Wealth Creation;

1.10.3 Institutional Development and Service Delivery;

1.17.4.2 Forestry;

1.17.4.2.1 Eliminate the export of round logs by 2010;

1.17.4.2.2 Ensure the downstream processing of all logs onshore; and

1.17.4.2.3 Develop forestry plantations in suitable areas, with landowner participation.

The outlined pillar and the guiding principles of vision 2050 become so fitting whereby the ACIAR project has enhanced the vision of the government.

PRODUCTION CAPACITY

The ACIAR project in its initial introduction used Lucas Portable Mills from the College Small Sawmill Section and the engagement of Small Holder Timber Suppliers by supplying rough sawn timbers for the purpose of the study program. The program was very successful since the launching through these years. The ACIAR project became alternative support to the college training programs as well as financial sustainability.

The production capacity from Lucas Sawmills by the college and the smallholders were estimated between 1.5m^3 to 2.5m^3 per day, with a projected weekly capacity of 7.5m^3 to 12.5m^3 per week. The estimated daily and weekly capacity gives the monthly production of 30m^3 to 50m^3 on a monthly bases.

The financial projection from the above production capacity is estimated on a monetary value of K 2,700 – K 4,500.00 on daily sales. The estimate on a weekly sale is at K 13,500.00 – K 22,500.00 per week and the monthly sales value from K 54,000.00 – K 90,000.00 per month.

The financial value of operating a Lucas sawmill is equivalent to K 648,000.00 – K 1,080,000.00 gross sales value per year on the sales volume of 360m^3 – 600m^3 per year

The ACIAR Trial project presented as a model project to give a glimpse of the reality of Central Processing Unit (CPU) should it be accurately and properly managed at the expected rate and level that is anticipated.

ENGAGEMENT OF LOCAL TIMBER SUPPLIERS

The ACIAR Project has brought hope not only within the institution but to the most neglected and marginal citizens. Although they are rich in resources, it was and is difficult for them to transform those resources into end use.

With this short period of the project lifetime, the outcome has undoubtedly given a lot of support and improvement of the knowledge, skills and empowerment to the local communities to utilise the research result to improve their livelihood.

The interest of the local timbers suppliers has demonstrated that people are willing to work and develop their resources; however, financial/capital and sustainability is a major obstacle and constraints experienced.

There is a great need for technical support through ACIAR project to the communities. Some of the areas of importance that can be considered are;

- Skills training (Operator course)
- Management training
- Financial literacy
- Safety training
- Conflict resolution
- Arts and crafts – Value Added

The above matters of importance can be seen as some of the strategic issues that can be improved as a way forward to create a positive environment to support the local timber suppliers to produce quality output.

TIMBER SUPPLIER RECORDS (Local Communities/ Land Owners)

There has been a very positive indication from the local communities, families and landowner groups coming and openly inviting the College to partner these groups to develop their own resources. The records of interested people and groups show that people have confidence and trust to work with the Institution in developing their resources as well as bringing training to the level of the communities.

As a National Training Institution, the focus of training is not only for the currently registered students but also for those who are unfortunate and marginalised citizen who have the resources to develop and sustain their livelihood and communities at large.

There are a total of 48 local timber suppliers recorded from July 2018 – January 2019, who are interested to partner these national institutions into developing their forest resources. The figure includes people with Small Sawmills/Lucas Mills, those that do not have the machinery to carry their operations and people who are also enquiring that TFTC obtains Timber Authority (TA) from PNG Forest Authority to harvest timbers within their local areas.

See attachment below to prove that these people are serious

These interested groups have the resources, however disadvantaged in technical knowledge, equipment and the capital to fully utilize these resources to benefit their communities.

The interest from the communities has become the major objective of Timber College (TFTC) into establishing a market to support these communities

SALES AND MARKETING

Sales and Marketing Team strategized into reviewing current proposed Marketing Plan to guide with the sales activities. The team has reviewed the current Marketing Plan for Timber Products for TFTC 2007; several strategies have been identified that will best guide the

sales sections to fully explore other market opportunities for the college and the communities registered.

ACIAR TRIAL LOAN PROJECT

The ACIAR Project made a trial on Internal Loan arrangements where the research funds were loaned to the sales team for timber purchase and resell. The exercise was very successful and effective in terms of community involvement.

Certain small scale timber producers were engaged to supply timbers to the sales section apart from the research project. The sales team further calculated mark up and sold at a higher price that catered for all the costs and profit margin and arrived with the sales prices.

The sawn timber model is a viable method of creating supply and market demand.

SALES MARKET TARGETS

The market targets that are now focusing basically lays on the customer needs and demands. However there may be opportunities that can be explored. Basing on the current customer trend, it can be projected that the need for timber out there is gradually increasing as more people are beginning to improve their living in terms of housing, school fees support, etc.

These demands are driven by more employment opportunities in the city, the influx of people moving from rural areas to urban in search of better life that the city can offer, more employees are choosing to have their private homes than just relying on their employers to provide. More retrenched officers finishing from service are building private homes or rental housing for their family sustainability.

Taking into account of all these, it has now forced the marketing team to capture the market opportunity.

One of the significant achievements towards the end of 2018 was securing a major customer for the business opportunity in which ACIAR is a major player in the business game for 2019. The expectations from the customer are for TFTC to supply a total Volume of 100 – 150 m3 of fully processed timber to the market per month.

Should Timber College maintain the expected production target, it is most likely that the business unit will be making revenue of K 138,000 – K 207,000 per month to

K 190,000.00 – K 285,000.00/ month.

The yearly production target is 100 m^3 x 12 months = 1,200 m^3 – 1,800 m^3 / month

With an expected revenue of K 1,656,000.00 – K 2,484,000.00/ Year – K 2,484,000.00 – K 3,420,000.00

This projection is specifically on a secured special business partnership for 2018 – 2019 between TFTC and the customer.

SALES REVENUE FORECAST

The projected sales forecast is now one of the critical points for consideration, in the sense that in order for the organization to survive in these crucial times, long term revenue focus should be the target. This projection should give the target goals to work for rather than just taking a casual approach.

The current average sales combining the Small Sawmill (Lucas Mill) and the Main Sawmill looks promising, by way of steady improvements so far with improvements on customer daily turn out.

From observations on customer daily turnouts, it’s almost an average of K 10,000.00 to K 15,000.00 daily sales revenue. The statistics can be a good data to predict that, if the

sales can be maintained at the average revenue as displayed, it is more likely to get an average of K 50,000.00 – K 75,000.00 weekly revenue, and by the end of each month, the projected revenue will be expected about K 200,000.00 – K 300,000.00

The above projections are based on the current daily average timber sales alone, not including all the services from the 4 sections.

The above statistics indicate that should and when there is an opportunity for any market availability in the future, it is more likely to make a very healthy and promising steady progress.

BENEFITS FROM EXTERNAL PROJECTS

The opportunity for external projects is more likely to be an advantage for the organizations because the institution is at a very strategic location to capture the market. The supply of timber materials to other customers has an excellent advantage for TFTC to get into exploring other building and maintenance projects from outside. Current Infrastructure developments and construction boom within Lae City and neighbouring provinces give an option to think outside of the box to capture the market.

The success of this activity will directly benefit the registered local groups to grow their small Business activities in a long run because the more timbers are sold to the customers, there will be more supply received from the local suppliers.

TFTC becomes the centre of the market, Central Processing Unit (CPU). In doing so, Timber College will fulfill the proposed Business Plan of 2017 as Timber & Forestry Training College Central Processing Unit (CPU)

POTENTIAL BUSINESS SUSTAINABILITY THROUGH ACIAR PROGRAM

This summary update demonstrated clearly that there is a high potential for business development within this Institution. The summary report as presented in the previous report and current production capacity as outlined clearly shows that there are a 100 % guarantee and high potential for business opportunities.

Commercial Unit and the Sales of this institution are willing to explore all options for business opportunities with the support of the Administration and all Sections to realise the dream. Details will be reflected from the revenue forecast given as an overview of potential areas to consider.

The viability of ACIAR Project that can make a great impact within the institution, the communities and the nation include but not limiting to:

a. Market penetration

b. Market development

c. Product development

d. Unrelated diversification

e. Business Partnership with Business Community

The above opportunities can be seen as a potential area to nurture and grow the business gradually to the point that can fully realise its capacity as an independent, reliable and successful entity.

RECOMMENDATIONS

From the current observations and experience, maintaining consistency in supply and quality product control, several measures have to be taken on board. These include but are not limited to:

a. Training

b. Technical assistance
c. Market access

Training will provide well-skilled personnel within technical and management teams; technical aspects will focus on facilities while the market access will mainly be looking at getting all the processed products to the finishing end users.

CONCLUSION

The trial project shows to be consistent in developing and enhancing the production and sales targets.

The production team and the sales team are the two core factors to monitor and control with the supply and demand. It has also been identified that maintaining dialogue and relationships with the local suppliers is helpful for both parties in the long run.

The efforts of every staff are slowly paying with a positive result and will soon be realised in terms of productivity and market sales. Having a more organized and manageable team gives confidence not only within the organization but to the general customer perspective.

The outside market also determines the size of operation and personnel required for the entire production team and the outcome of sales.

It is also anticipated that securing a long-term market also gives the chances of improvement and stable market target. All the success depends on the team itself.