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Final report

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1 Acknowledgments

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In addition to our formal project partners, the project manager would like to acknowledge the valuable contributions of the following:

In Australia:

- DGI Glass Industries
- BORAL Timbers
- The Crawford Fund board
- The Allwright Fellowship board
- Northern Suburbs Timber Flooring
- Australian Timber Flooring Association (ATFA)
- Engineered Wood Products Association of Australasia (EWPAA)
- TimTech Chemicals Pty. Ltd.
- Kennedys Classic Aged Timbers

In Fiji:

- Palmwood Fiji
- Sustainable Forest Industries Limited

In France:

- Planet Coconut
- Centre de Coopération internationale en Recherche Agronomique pour le Developpement (CIRAD)

In New Zealand:

- Zelam Ltd.

In Switzerland:

- Berne University of Applied Sciences, School of Architecture, Wood and Civil Engineering

2 Executive summary

The coconut palm, regarded as the 'tree of life', is a source of food and saleable commodities which provide essential nutrition and income for many smallholders across the tropics. In the Pacific there are large areas of senile coconut palms which no longer yield economic returns. The project's main aim was to create a valuable commodity from the stems of senile non-productive palms to enable the development of a palm removal (utilisation) and replanting system.

The project researched the key technical issues related to processing the fibre from harvested stems - known as cocowood- and found that it can be successfully processed using traditional wood machinery to produce a high value flooring product. Only the outer annulus of hard fibre is suitable for this product, so secondary products derived from the softer core portion of the stem were also investigated and developed.

The structure of cocowood material is distinctly different to normal wood, due to the palm being an erect monocot (grasses, bamboos, palms) whereas normal wood is produced from dicotyledonous trees (hardwoods and softwoods). As a result cocowood is highly variable and requires segregation into density grades to meet product specifications. The project developed a visual grading template to assist with this grading process.

In order to design a high performance flooring product, the properties and behaviour of the cocowood material were first determined. Earlier studies on cocowood processing and product development treated the material in the same way as normal wood, however this project involved a material science approach and described the anatomical architecture and growth stress before applying design principles to the development of the flooring products. New information about the coconut palm material included the determination of mineral content (previously thought to be high in silica, causing the rapid blunting of tool edges) and the description of the triple helix structure of growth (providing excellent wind resistance for the living palm, but problematic in processing and product performance).

A complete determination of physical and mechanical properties of the cocowood material was undertaken and the results published in a Technical Report (Cocowood Users Manual – Processing flooring products from cocowood). Workability trials determined the most suitable tools and machine operating speeds required to produce quality cocowood. Anecdotal information about differences between coastal lowland palms and upper slope inland palms, was disproved and it was found that similar variation occurs within a site. Effective anti-stain and insecticide treatments were developed and it was found that cocowood can be dried using conventional kiln drying techniques, but it must be heavily weighted to prevent twisting. Designs for a high performance, engineered flooring were trialled and a feature floor demonstrating the final design was installed in an office.

The softer core material was found to have the physico-chemical attributes suitable for growing media and it could be used to bolster the organic composition of poor soils in Pacific Islands where this is a problem as well as in the development of floriculture and horticulture industries.

Real world marketing case studies were conducted with the co-operation of a European importer and a Fijian processor. These negotiations proved the high demand and economic feasibility of a cocowood flooring industry; however palm supply issues prevented fulfilment of the sale of commercial quantities of engineered cocowood flooring.

Training workshops supported by the Crawford Fund were conducted in Fiji and Brisbane. The project website www.cocowood.net has provided an international forum and centre for project information and results.

3 Background

In the Pacific region, as is the case elsewhere in the tropics, large areas of coconut palm (*Cocos nucifera*) have senesced and consequently, copra yields have significantly reduced below economically viable levels of production. The Asia-Pacific region, representing 90% of the coconut plantations across the globe, has approximately 360 million non-productive, senile palms (Arancon, R. N., 2009- *The situation and prospects for the utilisation of coconut wood in Asia and the Pacific.* FAO). Of this potential resource, the ACIAR project partner countries Fiji and Samoa have an estimated area of more than 150,000 ha under plantation which may include up to 5 million senile palms (*Ibid*). This unproductive area is poorly utilised and requires clearing to enable replanting with coconut, taro or other food crops.

During a Heads of Forestry meeting in May 2003, ACIAR noted the commonality of the senile palm problem across many Pacific island countries and sponsored a workshop in Fiji during 2004. The primary recommendation of this workshop, attended by representatives of 11 Pacific Island countries, was to pursue the development of a project to address the technical impediments to processing coconut palm logs into high-value flooring products. Additionally, it was suggested that a range of feasible options be determined for the proportion of stem not suited to flooring applications.

The cost and phytosanitary implications of clearing senile palms are real impediments to replanting, leading to inefficient use of agricultural land while the plantations remain standing. This ACIAR project was instigated to analyse the material properties of the wood substitute fibre processed from the harvested stems of senile palms and develop suitable processes and designs for high value flooring from senile stems. It was hoped that the successful development of processes and products would create demand for the senile palms, leading to their removal and utilisation for the benefit of the landholders, processors and consumers. This in turn would have a multiplier effect, generating employment and skill development in regional areas across the Pacific islands.

Natural flooring products such as those manufactured from conventional wood species maintain high levels of demand in housing and commercial markets, especially in Asia, North America, Europe and Australia. Globally this market is worth over USD 5B per annum (Catalina Research, 2004- *Wood flooring* Catalina Report CR027, Florida) and despite the plethora of synthetic alternatives available to consumers such as ceramic tiles, linoleum/vinyl and synthetic carpets, the timber flooring sector continues to hold its market share due to the attributes of sustainability (renewable and recyclable resource), warm natural aesthetics and ease of installation and rejuvenation with simple tools.

The conundrum for the flooring sector though is that while demand remains high, supply of suitable and ecologically sound resources is decreasing, particularly for hard, dark hued timbers from sustainable resources. Substitutes for traditional timber species used for flooring will be sought to fill this void and cocowood is well-placed to absorb some of the deficit.

Market appraisals conducted by DEEDI during the development of the project indicated that the unique and attractive appearance of cocowood, combined with its hardwearing properties and sustainable plantation origins, should garner high levels of consumer demand. It has long been recognised that cocowood is an attractive material, highly suitable for appearance applications (Meadows, D. J., 1979 - *The current state of coconut stem utilisation from palm felling to the end-products*. FAO). This implies that the attractiveness is not just due to transient fashion trends. Meadows noted that further research and promotion would enable cocowood to become an extremely valuable commodity, playing an important role in the economies of coconut-growing nations. The ongoing business success of Pacific Green for almost 20 years in the highly competitive interior furniture market attests to the enduring aesthetic qualities of the material.

To facilitate the development of a research program specifically targeted to improve coconut wood utilisation in the Pacific, a literature review was undertaken by DEEDI. This initial review was intended to provide a broad overview of global coconut wood utilisation technologies in the context of potential applicability specifically for the Pacific region. Key knowledge gaps and associated research and development priorities were elucidated.

Despite considerable past research, investment in processing technologies and the commercialisation of coconut wood products has been limited. However small volumes of coconut wood flooring have been produced in Indonesia and exported to Europe, where, because of its unique appearance and properties comparable to top-grade hardwoods, this product found ready acceptance. Nevertheless technical improvements are required to ensure that coconut products achieve and maintain niche status in an expanding flooring market. This project therefore aimed to develop appropriate processes and provide the technical information to underpin the manufacture and broad acceptance of coconut wood in the international high value flooring market.

At the time of project development both project partner countries had policies in place to support the development of coconut palm industries. In Fiji the Coconut Industry Development Authority (CIDA, now absorbed into the Fiji Ministry of Agriculture) was formed to promote the industry and develop a range of products on behalf of growers across the Fiji Islands. CIDA obtained Fiji government approval to develop a pilot coconut wood processing plant as an extension to an existing copra factory. An investment of $150 000 provided the installation of: portable sawmill, four-sider planer, sawdust extraction, rudimentary kiln /smoke treatment, custom built lathe for decorative column production, wax emulsion treatment tanks, sharpening and various ancillary equipment. The factory was strategically located next to an existing sawmill and it was planned to develop some synergies with this business.

In Samoa a replanting scheme was developed in 2005, supported by investigations into certification and labelling options for a diverse range of coconut palm products. Strickland Brothers Ltd., a fully integrated family-owned wood processing enterprise based in Apia, joined the project with a view to converting from native Samoan forest resources to senile coconut palm plantation resources for their feedstock.

The ACIAR project added impetus to these in-country policies through developing technical solutions, high value product designs and markets for senile coconut palm stems.

Previous research and development programs have treated coconut palm material as if it were true wood. However palm stem coconut 'wood' (cocowood) produces a significantly different material in physical, chemical and physiological characteristics and subsequently behaves in a different way. These differences are close enough to true wood for cocowood to be processed with the same tools but far enough to diverge from known practices. New approaches to processing and product design were required in order for coconut wood to be processed efficiently and provide satisfactory performance in service.

The project addressed the key questions underlying the broad acceptance of coconut wood into the high value flooring market, in particular the development of processing systems and profiles for high quality flooring, and the definition of appropriate grading standards, product specifications and quality control systems. Additionally, examination of variation in the resource, and the development of utilisation options for low-quality portions of the stem were undertaken.

The project aligned well with priorities identified for Pacific Island countries in ACIAR's Annual Operational Plan at the time of proposal development, in particular 'Value-adding processing of forest products, including coconut wood and lesser-known species, mahogany branch and salvage wood, and use of mobile sawmills for processing'. The project represented a multi-country program of research and development addressing a common problem in the region and probably in most of the coconut growing areas.

4 Objectives

The aim of the project was to facilitate the entry of coconut wood into the Australian and international flooring market, resulting in economic, social and environmental benefits to Pacific communities.

4.1 Characterise coconut 'wood' resource properties relevant to the design and manufacture of high quality flooring

The initial objective was to determine the physical, mechanical and workability properties of coconut wood relevant to manufacture of and performance in the high-value overlay flooring market and potential by-products, including variation horizontally and vertically within the stem, between growing site types and with tree age, through appropriate sampling. This information enabled processing systems to be developed to handle a sufficiently wide range of input raw material.

Degrade due to fungal attack occurs during air-drying, primary processing and shipping of partially dried products. The project aimed to identify the organisms responsible for the aesthetic degrade (staining and insect damage) to facilitate development of adequate prophylactic systems.

4.2 To identify and/or develop processing systems and design profiles for high quality flooring

The project investigated the optimum parameters and systems for sawing technologies, stain and insect treatment systems, machining and sanding techniques and drying systems. In addition to sawn components, veneer production was considered.

4.3 Define appropriate grading standards, product specifications and quality control systems

For acceptance by large international flooring distributors it was essential to develop product standard specifications, grading rules and quality control procedures that meet consumer requirements. The requirements for Australian and European markets were explored. This included packaging and market pricing data.

4.4 Develop utilisation options for the low-quality portion of the stem

The inner portions of the stem are of very low density and high moisture content. In order to improve raw material utilisation and process economics, suitable low-cost products from this portion of the stem are desirable. This material could be useful for: growing media and soil conditioning; substitution of imported building products; core and substrate material in composite flooring and door products; local use in temporary structures such as animal pens.

5 Methodology

5.1 Objective 1: To characterise coconut wood resource properties relevant to the manufacture of high quality flooring

5.1.1 Activity 1.1 – Sampling strategy; representative sample of cocowood variability

Initial work on this activity was undertaken during the second half of 2005 providing valuable initial information on density, moisture content and hardness variation within and between stems from one location in Fiji. Subsequent sampling involved selection of 40 palms from Fiji and 40 palms from Samoa. In each country 10 senile palms were selected from coastal lowlands and 10 from the upper slopes inland. Due to delays in transportation after felling in Fiji leading to extensive decay in one batch of logs, 10 additional palms were required. Out of 40 Samoan palms only 14 were fully exploited due to massive fungi attack during unexpected quarantine storage period in Samoa. Overmature palms were selected by local experts.

Plate 1. Sampling senile palms from upper slope inland site in Samoa.

5.1.2 Activity 1.2 – Testing; determination of physical, mechanical and workability characteristics

Researchers in Fiji conducted the tests for air-dry density, moisture content (green and dry) and Pilodyn 'hardness'. The specimen preparation, testing and data collation were conducted at the Forestry Department's Nasinu Utilisation centre near Suva.

The remaining cocowood property tests were conducted in the NATA accredited laboratory in DEEDI's Salisbury Research Centre, Brisbane. These included hardness values, shrinkage, stability, strength and stiffness and were conducted in accordance with the standards and codes used to determine conventional timber properties.

Workability (planing, moulding and sanding) tests were performed in a commercial wood machining centre and supervised and evaluated by DEEDI technical staff. The trials were aligned with the protocols described in the American Standard for Testing Materials as applied to normal wood. Replicates of competitor commercial hardwood species were included in the trials for comparison to cocowood. The resulting data were presented and discussed in technical reports.

Plate 2. Workability trials, Brisbane.

5.1.3 Activity 1.3 – Cocowood aesthetic deterioration analysis

Identification of the staining organisms and characterisation of the discolouration was to be undertaken by interrogation of DNA sequencing cards prepared from samples collected in the partner countries. Unfortunately the Australian Quarantine Inspection Service (AQIS) were unable to release the samples within in the timeframe of the project and it wasn't possible to complete the work program to the level initially planned. The ultimate verdict by AQIS was not to approve the release of the samples.

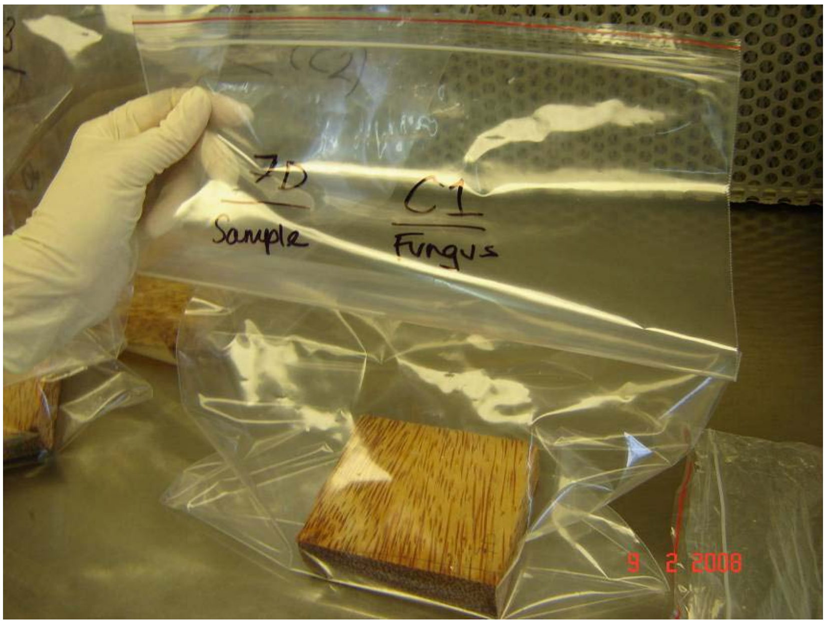

Plate 3. Sample preparation for fungi identification.

Some organisms were able to be identified to genus level through standard microscopy. Published identification keys were used to determine the genus where possible.

5.2 Objective 2: Development of primary and secondary processing techniques

Primary and secondary processing techniques

Earlier studies indicated that it is feasible for cocowood to be graded according to stem position. Grading based on green density is inappropriate as green weight is basically consistent throughout the cross-section due to the high moisture content of freshly sawn boards. A range of testing tools used in concrete and timber industries were trialled for effectiveness in predicting hardness and the results from these portable tools were correlated to actual hardness data obtained from Janka testing on matched samples.

DEEDI scientists consulted with industry experts to select and trial woodworking equipment and tooling options to determine the most appropriate equipment and operating parameters for coconut conversion. A range of the recommended metal tool tips and cutting edges were procured for use in the trials and a commercial wood machining contractor performed feed speed and surface quality trials which were supervised by DEEDI technicians. In addition to machining and sanding trials, glue bond trials were conducted at various stages of the trial to confirm cocowood's suitability for engineered flooring profiles which rely on laminated sections.

Green cocowood logs and boards are unable to be imported into Australia due to quarantine restrictions and Samoa currently has no suitable kiln drying infrastructure, so drying trials were conducted in Fiji. Delays in delivery and installation of the kiln meant that limited kiln drying trials were able to be undertaken during the project's timeframe, however important data were generated as a result of this work.

A small quantity of Queensland-grown coconut palms was sourced for a veneering trial. Billets were steamed and heated in an experimental kiln then loaded into a spindle-less lathe and peeled to produce a 3-4 mm thick veneer. This thickness represents a typical engineered flooring top layer. The veneer was graded by EWPAA and recovery noted.

Plate 4. Coconut palm peeling trial, Brisbane.

Anti-fungal treatments and associated seasoning practices

The coconut palm growing regions, and therefore the primary processing locations are located in tropical environments which are very conducive to fungal activity. Some fungi cause discolouration, mould and/or decay, all of which are unacceptable in high value flooring products, necessitating rapid conversion and drying or protection by dipping with a suitable prophylactic treatment.

Although used successfully in the past, anti-stain treatments such as pentachlorophenol (PCP) and dieldrin are no longer approved for use in wood protection formulations due to their high human toxicity and environmental risk. The project included a series of trials in Samoa and Fiji to evaluate the efficacy of less toxic, novel formulations as well as traditional island treatments.

In Samoa, a total of 10 treatments plus untreated controls were trialled and assessed. This trial was followed by an experiment in Fiji with seven treatments plus untreated controls. Commercial hardwood and softwood timbers regarded as highly susceptible to stain degrade were included in the trial for comparison. The level of staining was measured as the percentage of surface area affected by discolouration (worst face), assessed at three time intervals during a four month timeframe.

The cocowood specimens used in the trials were based on typical flooring feedstock dimensions (100 x 25 mm) and cut to 1.0 m lengths for ease of handling and assessment. The specimens were dipped in solution for 10 seconds, then allowed to drain before being placed in an air-drying stack. A subsidiary trial using 0.3 m long boards was also conducted in block stack format to replicate a worst case scenario. All treatments and controls were assessed and ranked based on their ability to resist the development of staining organisms.

Plate 5. Anti-sapstain dipping treatment, Fiji Islands.

Product design and performance testing

DEEDI developed several flooring product designs based on the properties established in the initial project activities. Varied flooring profile construction methods were used to manufacture innovative overlay and strip flooring designs with the aim of minimising or eliminating the potential performance problems inherent in solid cocowood flooring due to its anatomical structure. Examples of the designs trialled are:

- Split inside reversed- feedstock split, dressed, top half replaced under bottom half (plate 7).

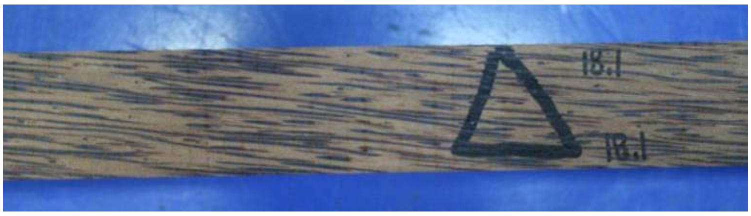

Plate 6. Original feedstock prior to ripping

Plate 7. Split, inside reversed- top layer replaced under bottom layer

- Split top side reversed- feedstock split, dressed, top reversed and placed back onto bottom half (plate 8).

Plate 8. Split, top side reversed

- Thin sawn top layer laminated to plywood substrate

- Re-sawn laminated beam to provide feature/wear surface of engineered flooring

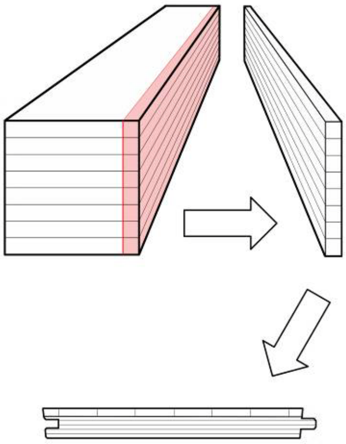

Plate 9. Resawn laminated beam, adhered to plywood substrate.

Detailed descriptions of the designs are provided in the appended report *Secondary machining properties and appropriate flooring design development for coconut palm wood.*

The designs were tested by placing in environmental conditioning chambers with reference samples of commercial flooring. After several refinements, the final prototype design was manufactured in a world-class engineered flooring facility in New South Wales and installed into an office environment in Brisbane to monitor performance and generate interest and awareness for the product.

Plate 10. Engineered cocowood flooring installation, Brisbane.

5.3 Objective 3: To define appropriate grading standards, product specifications and quality control systems

5.3.1 Activity 3.1 - Determination of specifications and requirements for targeted market

The necessary aesthetic and technical parameters, such as finish quality, colour grading, dimensions, moisture content and packaging requirements, were determined through consultation with Australian, Fijian and European wood flooring market experts. Meetings were conducted with the Australian Timber Flooring Association's Technical Manager, owner/manager of Northern Suburbs Timber Flooring (Brisbane's largest operator), Sustainable Forest Industries Limited (Fiji's leading flooring producer), BORAL timber (Australia's largest engineered flooring manufacturer) and Planet Coconut (Europe's largest importer of coconut palm products). Australian Standards for timber flooring were consulted to compare normal grade quality parameters for hardwood flooring products to those generated by the cocowood consultative group. The recommendations and concerns of all parties were considered against the technical limitations of cocowood manufacturing and in-service performance as determined during the trials.

Plate 11. Feature flooring- engineered cocowood installation, Brisbane.

5.3.2 Activity 3.2 - Provide technical data in a format suitable for marketing communication

All technical data generated from the trials have been summarised into a technical brochure which is available on www.cocowood.net and included in the User Manual document (appended). The fully detailed experimental reports behind the technical data summary are also available to project partners and registered members on the website.

The website has provided a two-way portal, establishing contact and acquiring feedback from the market, facilitating advertising and product awareness and creating a brand identity for cocowood.

Figure 1. Cocowood project website homepage.

5.3.3 Activity 3.3 - Definition of standards and specifications that will meet industry requirements

Grade quality standards for classifying coconut material were developed as described above. A quality control system with clear, step-by-step guidelines for all aspects of quality assurance for coconut processing and production, grade quality descriptions and product specifications has been included in the cocowood User Manual in order to assist producers in meeting the requirements of target export markets.

5.3.4 Activity 3.4 - Development of quality control systems that will deliver these standards reliably

The quality assurance system forms part of the User Manual and was written to provide recommendations for monitoring systems to ensure product consistency and quality. The quality control manual incorporates all stages of production from sawmilling (storage, handling and treatment of roundwood, sawing patterns, sawing equipment, green sorting and grading), drying (pre-treatment, drying method, dry sorting and grading), secondary processing (machining, sanding) and packaging.

Plate 8. Portable sawmilling trials, Fiji islands.

5.4 Objective 4 - To develop utilisation options for the low-quality portion of the stem

Review of products that might be suitable

Based on the initial sawing recovery studies and wood property assessments, product options for the low density core portion of the stem were evaluated. Options considered included import substitution, ethanol distillation, compost and growing media, coreplate for door manufacturing. The properties of low density cocowood were assessed against the requirements for each of these products and where relevant, quantitative data were determined to ensure cocowood's suitability.

Candidate products for import substitution were nominated by in-country experts in wood utilisation and local building markets. The first trial for ethanol feasibility was an analysis of starch content by a commercial grain biorefinery laboratory. The growing media assessment was performed by DEEDI horticulture and wood experts by determination of the physico-chemical characteristics relevant to plant growth and health. The requirements for coreplate in door construction were derived from the relevant Australian Standard and through discussions with Australia's largest door manufacturer.

Plate 9. Water retention efficiency trial with ground cocowood potting mix, Brisbane.

6 Achievements against activities and outputs/milestones

Objective 1: To characterise coconut wood resource properties relevant to the design and manufacture of high quality flooring

No.	Activity	Outputs/ milestones	Completion date	Comments
1.1	Sample collection, preparation, conditioning and testing to standard protocols	PC: 40 palms from Fiji and Samoa were selected and harvested. Samples were prepared and dried in Fiji. Some re-sampling was required due to delays between harvesting and processing of the initial batch which allowed extensive decay of 10 palms. A: Samples for trials in Australia conditioned in Salisbury. A report describing the production of experimental specimens and feedstock for flooring was prepared.	Stage 1 01/08 Stage 2 11/09	Despite prolonged delays for sample collection and preparation early in the project, all prescribed trials were conducted in accordance with the project plan.
1.2	Determination of physical, mechanical and workability properties of cocowood relevant to manufacture and performance in the high-value overlay flooring market and potential b-products, including variation horizontally and vertically within the stem, between growing site types and with tree age, through appropriate sampling.	PC and A: growth strain, Pilodyn 'hardness', density, moisture content, shrinkage, grain deviation, mechanical properties, workability- all data were determined during the project in accordance with recognised standards and protocols.	A: 06/08 to 02/09	A suite of technical reports were published describing the trials and resulting data. A full list of final reports is included in Section 10.2.

1.3	Identification and characterisation of staining organisms; aesthetic deterioration analysis and potential prevention methodologies.	Report detailing identification and attributes of stain organisms.	A: 05/10	AQIS refused to release the DNA sequencing cards. Some organisms were identified to genus level through microscopy and cultural characteristics. An article on protection will be submitted to the Pacific Agriculture Journal.
1.4	Provide a report and technical manual	User Manual for cocowood flooring manufacturing. Technical brochure listing important properties and characteristics of the material.	A: 05/10	A user manual was prepared for use in Pacific Islands. All processes are covered in concise step-by-step descriptions. A Technical brochure/fact sheet (appended) was prepared, summarising the important 'wood' properties of cocowood. The technical reports which provide the rationale for the user manual and tech brochure are listed in Section 10.2.

PC = partner country, A = Australia

Objective 2: To identify and/or develop processing systems and design for high quality flooring

No.	Activity	Outputs/ milestones	Completion date	Comments
2.1	Development of primary and secondary processing techniques, e.g. for sawing, anti-stain treatments (logs and green boards), drying, planing, sanding.	User manual detailing recommended handling and processing techniques. Local staff skilled in application of these techniques.	5/2010 PC and A	Optimum parameters were identified through experiment and the results described for all stages of processing. The key findings are presented in the User manual (appended).
2.2	Development of two designs of flooring products viz solid T&G and engineered composite flooring.	Design documentation. Demonstration floor in service.	02 / 2009 PC and A	Australian manufacturing, installation and technical experts consulted to augment the final designs. Demonstration products manufactured and the preferred profile (engineered flooring) installed in a working office environment (Team Leader's office, Salisbury Research Centre, 50 Evans Road Salisbury Brisbane). Flooring specifications and packaging requirements fully described to partners in Fiji and Samoa. These are included in the User Manual.
2.3	Prepare report on definition and justification of 2 or 3 economically viable products.	Technical and economic report.	05/10: A, PC	A financial analysis was undertaken by DEEDI economists with data provided by Fiji forestry and industry. The findings were presented at the final project workshop and seminar in Fiji and the report is appended (*Cocowood flooring products- a financial analysis*)

2.4	Training in Fiji and Samoa	Local staff are competent in the organisation and conduct of research trials and related investigations.	06 / 2009 PC 12 / 2009 A	Training activities covered sampling, sawmilling, research tests, market processes, drying and technical writing. Two Crawford Fund workshops were held allowing specialist training in Fiji and Australia. Fiji Forestry Training Officer / Allwright Fellow spent 2 years based at the Salisbury Research Centre in Brisbane receiving detailed training in experimental method, testing protocols and technical writing. Fiji Forestry Utilisation Officer received training in engineered flooring manufacturing and growing media test protocols during a visit to Australia.

PC = partner country, A = Australia

Objective 3: To define appropriate grading standards, product specifications and quality control systems

No.	Activity	Outputs/ milestones	Completion date	Comments
3.1	Determination of specifications and requirements for targeted markets.	Report detailing market opportunities and accessibility including technical specifications.	6/09 PC and A	The thresholds for density/hardness, moisture content and distortion were determined and are listed in the User manual. Communication was established with a highly motivated European importer who travelled to Fiji to meet with the Project Leader and local suppliers to negotiate a supply arrangement. The results of these negotiations provided the basis for one of two market case studies presented during the final workshop seminar.
3.2	Provide technical data in a format suitable for marketing communication.	Accurate and informative technical communiqués are available on the project website.	05/10 A	The members' area of the project website is a repository for all technical reports generated during the research. A cocowood technical brochure and a User manual were prepared and are available on the website. Technical advice has been provided to interested parties from coconut growing regions around the tropics and potential customers in Europe, America and Australia.
3.3	Definition of standards and specifications that will meet industry requirements.	Documented set of standards and specifications, accepted by Australian authorities and used by plants in Fiji and Samoa.	1st draft 6/09 PC Ratified 4/10 A	Written specifications for cocowood flooring products and packaging requirements for export were developed. The specification includes details of moisture content, density, distortion limits and dimensions. These specifications conform to Australian and CE standards (Conformité Européenne) and are included in the User Manuals.

3.4	Development of quality control systems that will deliver these standards reliably.	Recommendation on quality control systems in use by plants in Fiji and Samoa. Local staff skilled in their application.	5/10	Quality control protocols are merged with the user manual.

PC = partner country, A = Australia

Objective 4: To develop utilisation options for the low-quality portion of the stem.

No.	Activity	Outputs/ milestones	Completion date	Comments
4.1	Review of products suitable for local construction (import substitution) and flooring substrate.	Report recommending product options, under development/ in production by plants in Fiji and Samoa.	4/10 PC	Sawn cocowood has been deemed suitable for substituting imported or indigenous timbers in weather-protected sawn timber applications as soffit 'heat' battens, lining and flooring in light traffic areas. Local short term applications include temporary animal enclosures. It is uneconomical to transport any products sawn from the lower density core material too far from the sawmilling site due to the relatively low value of these products. The partners recommended that no report was necessary to recommend these applications as each mill will develop its own market depending on opportunities.
4.2	Review of export options such as feedstock for blockboard.	Report on product viability and influence of relevant parameters.	4/10 A	Ground cocowood particles have suitable properties for growing media and cocowood chips could provide a source of organic matter for poor soils in the smaller islands. The detailed report on this component of research is appended. Low to medium density cocowood boards meet the requirements for feedstock for coreplate for blockboard in accordance with the relevant Australian Standard AS 2688. Although technically feasible, it would be difficult for low density cocowood to compete with existing coreplate species such as low grade radiata pine used in door manufacture. No further investigations were conducted for this product.

7 Key results and discussion

7.1 Characterisation of cocowood resource properties

From representative samples of senile coconut palms sourced from a range of sites in Fiji and Samoa it was found that there were no significant variations in key properties between sites for similar age material. Although outliers occur within a single site, it was determined that these palms were replants and much younger than the original plantation resource. There is a wide range of within palm variation and the extent of this range is similar from site to site.

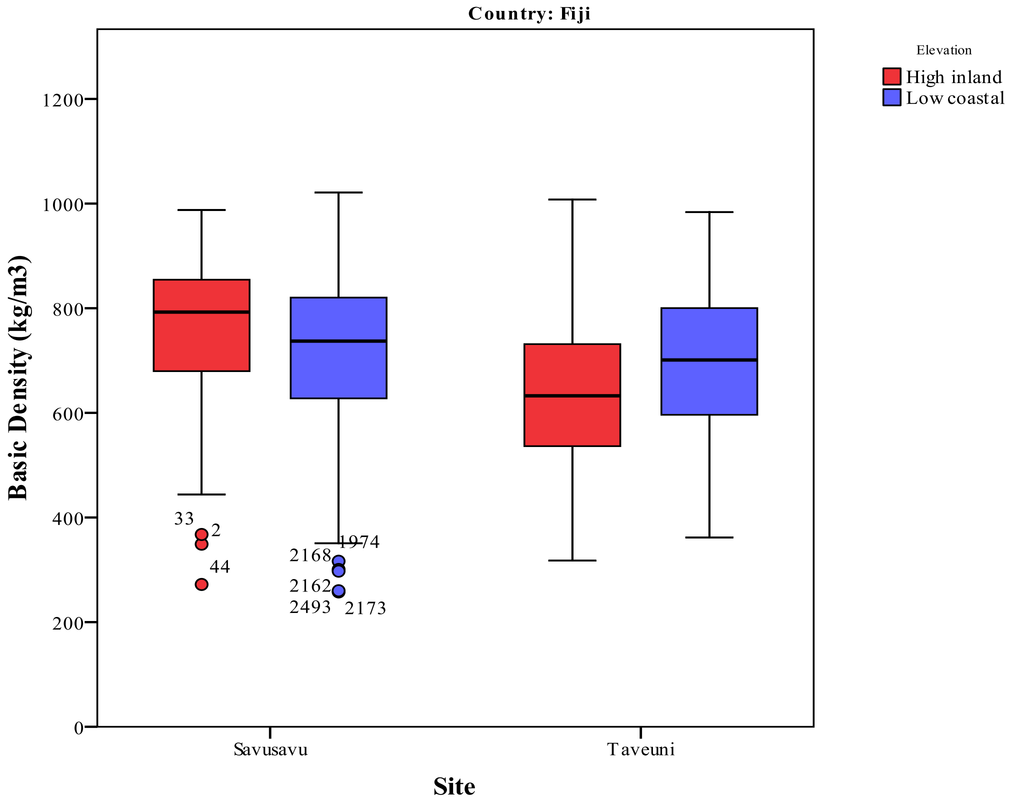

Figure 2. Box plots of basic density for two islands and elevations in Fiji. Sample filtered to a maximum of 50 mm in depth and 3 m in height.

As earlier researchers noted, coconut palms have a high radial density and colour gradient increasing in density, hardness and tonal colour from the low density core outwards to the high density peripheral fibre. Contrary to previous assumptions, the project proved that colour is not the best indicator of density and younger, paler coloured cocowood occurring higher in the stem can still achieve suitable hardness for high value flooring. This is an important finding as it has positive implications for recovery and economic feasibility.

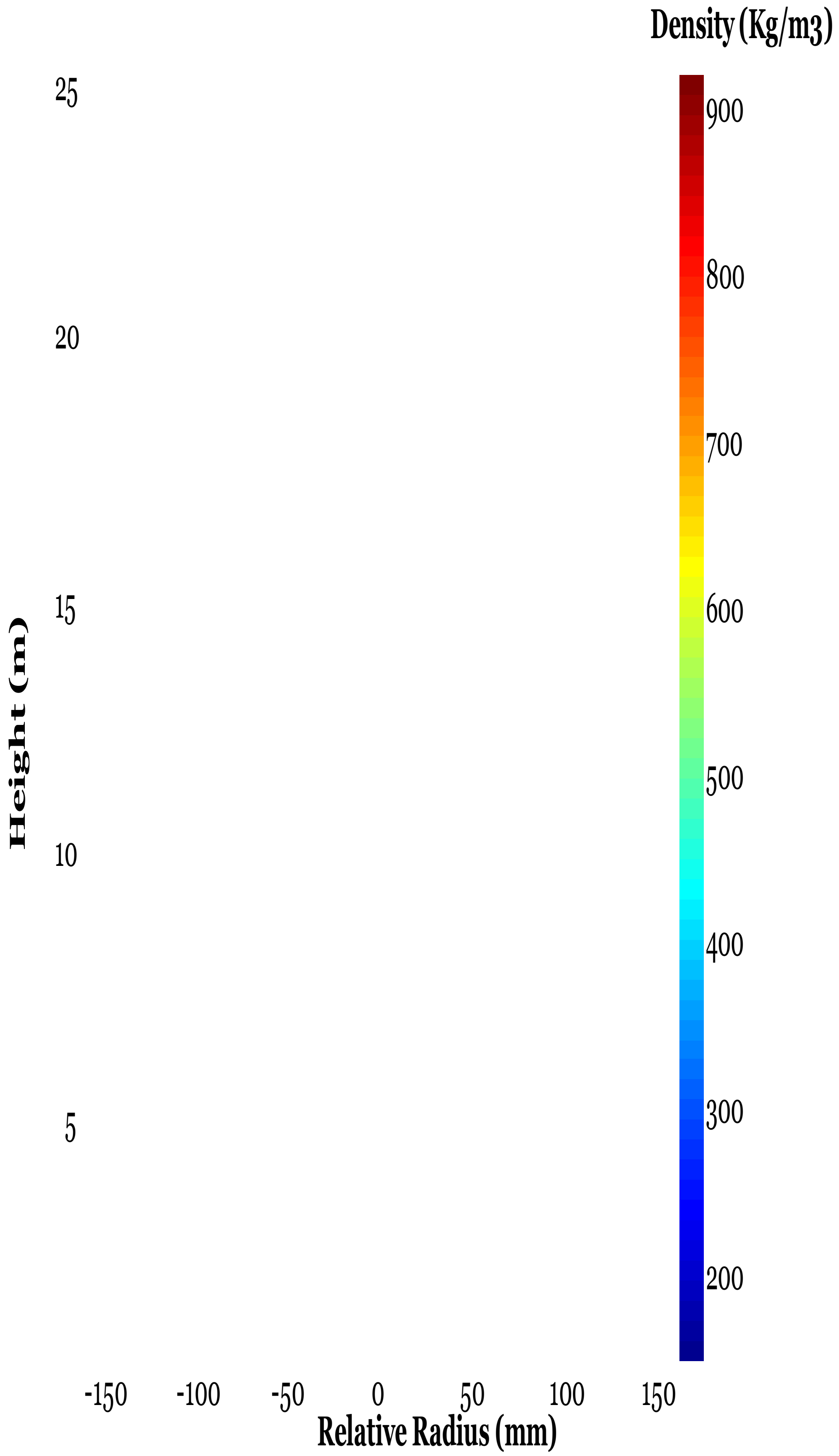

Figure 3. Colour map of basic density variation within one palm based on 143 measurements.

A study of the anatomy of the palm revealed that the fibrovascular bundle architecture (grain angle) follows an interlocked, triple helix formation. This spiralling composition provides the coconut palm's excellent tolerance to high winds occurring during cyclonic and monsoonal seasons in exposed locations, but has important implications for processors as it gives the sawn boards a propensity for twisting during drying.

Plate 10. Grain angle variation within one coconut palm after splitting a disk.

Early cocowood researchers commented that cocowood was abrasive and assumed that this was due to high silica content. This would seem to be a logical conclusion due to the location of many coconut palm plantations on siliceous sands, however the project analysed cocowood samples and determined that the silica content was not significantly higher than many other commercial timbers and was less than well known siliceous woods. The analysis detected a range of minerals in addition to silica and this combination (total mineral content 3%), compounded by the high density and changing angles of the bundles in cocowood are responsible for its abrasiveness to tool edges.

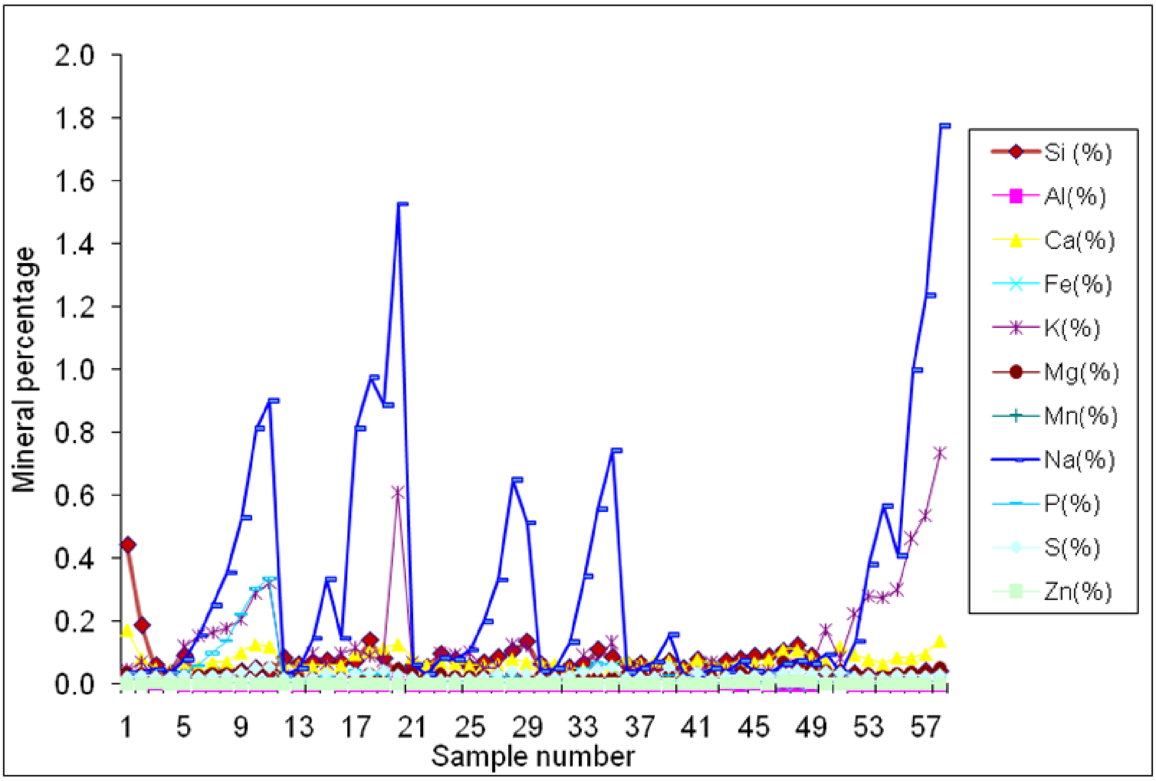

Figure 4. Mineral content for 57 subsamples covering a wide range of density.

Growth strain measurements had previously been poorly described for coconut palms and the research team determined that the fibre in the lower portion of the stem is in tension, whereas beneath the frond break high in the stem the fibre is in compression. The intensity of the stresses were very low comparing to woody species. Consequently unlike hardwood or softwood logs of similar size, releasing the tension by felling the palm doesn't result in splitting or distortion as seen in eucalypts for example.

Freshly felled and sawn cocowood was host to a range of staining and decay fungal organisms. Many of these were able to be identified to genus level and included *Penicillum* spp., *Rhizopus* spp., *Acremonium* spp., *Scopulariopsis* spp., *Aspergillus* spp., *Paecilomycess* spp. and *Fusarium* spp.

Plate 11. Fungal fruiting bodies growing on untreated cocowood boards.

The physical, mechanical and chemical properties of cocowood material were collated into a technical brochure. The data highlights the different material characteristics of cocowood from normal commercial timbers. For example the moisture content profile shows an opposite pattern compared to green dicot wood, with high moisture content in the core, decreasing towards the periphery, contrary to the pattern generally observed in typical green wood. The major differences to true wood are the highly significant density gradient and strong pattern of interlocking spiral grain. Based on these properties, a minimum threshold for material suitable for high value flooring was set at an air-dry density 700 kg/m^3 in order to obtain a minimum 7 kN for Janka hardness Cocowood flooring with density equal to and higher than this value will have the appropriate levels of hardness (resistance to indentation) to provide satisfactory performance in normal flooring applications. Although this is lower and therefore softer than most Australian hardwoods, it is similar to typical European and American hardwood flooring timber species. Cocowood density can be as high as 1000 kg/m^3 which is similar to many commercial Australian sub-tropical hardwoods.

Termite degradation in buildings is becoming an increasingly costly and important problem in Pacific Islands and termite resistance tests were conducted on dry cocowood samples in a high hazard tropical test site in Queensland. It was found that termite resistance is strongly correlated with density; however the conclusion was that untreated cocowood cannot be classified as termite resistant (report appended).

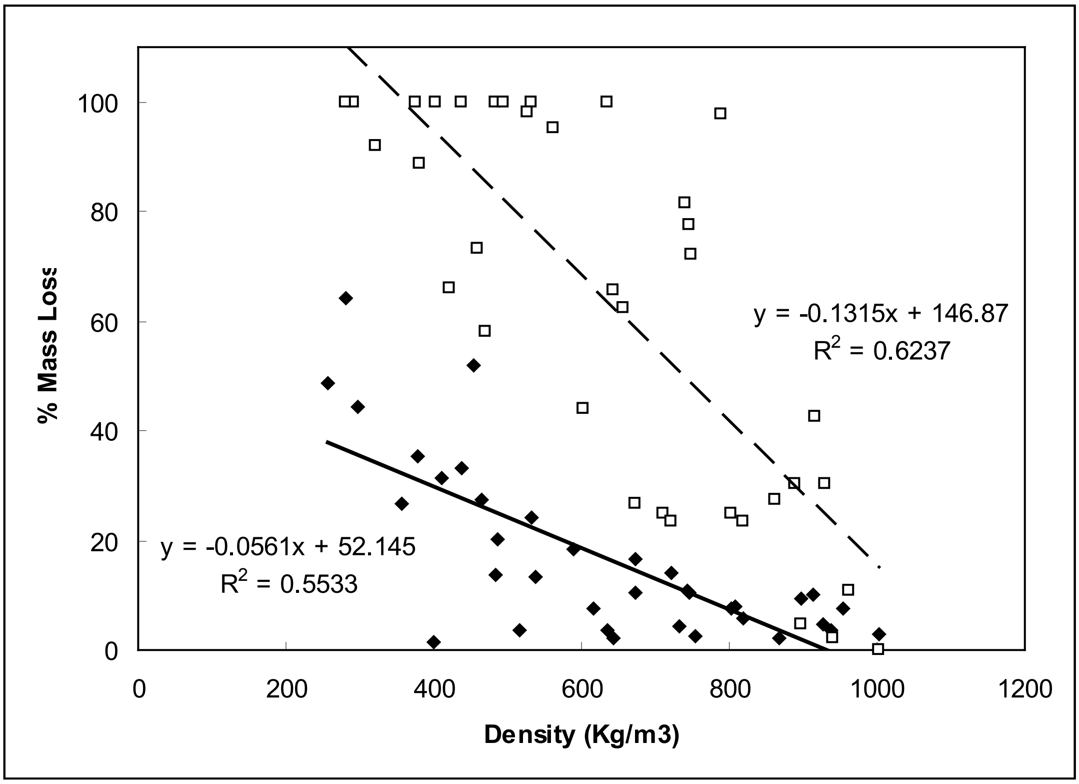

Figure 5. Variation of percentage mass loss of test specimens with cocowood density due to *Coptotermes acinaciformis* (♦) and *Mastotermes darwiniensis* (□) feeding. Trend lines for *C. acinaciformis* and *M. darwiniensis* are included.

Ground cocowood was assessed for the properties required for use as a growing media for plants. It was found that cocowood properties for bulk density (0.09 g/vol), water retention efficiency (61%), wettability (55 sec), water holding capacity (44%), electrical conductivity (1727 µS/cm) and pH (6.2) are all within the range of accepted values or similar to other products currently used by the industry. Air-filled porosity (34%) was higher than desired by the horticulture industry, however the blend tested was fine ground, and a coarser particle size may improve this result.

Samples of ground cocowood were analysed for starch content to assess the suitability of low density cocowood from the core of the stem for ethanol distillation. The results indicate that cocowood has a low starch content (4-5%) and would not be a viable feedstock for ethanol. This result should be confirmed by further analysis as recent publications indicate that old oil palm trunk becomes a promising source of sugars by proper aging after logging and, thus, its sap can be a good feedstock for bio-ethanol.

7.2 Communication and networks

The project sponsored a dedicated cocowood website, launched in February 2008. It has delivered information and news about the project to a wide audience and enabled communication between researchers, growers, processors and customers from around the world. The website will be fully maintained and administered by the project manager for 12 months after the project is completed. Within this timeframe a decision will likely be made regarding a follow-on project (allowing the manager to continue with the website) or the website will be transferred to the Secretariat of the Pacific Community (SPC) for administration. The project received favourable media reporting, including television, radio and printed coverage. Detailed statistics on the website and media coverage are provided below in 8.4.

Initiation meetings and visits to partner and industry facilities throughout Australia, Fiji and Samoa were undertaken and continued throughout the project. Plantations were visited and assessed for harvesting of samples, processing facilities and manufacturing plants were toured and a cocowood network maintained throughout the project. Workshops were delivered in Fiji and Brisbane through support by the Crawford Fund, strengthening networks.

Communication with European importers was maintained for the duration of the project and a French company representative travelled to Fiji to negotiate product specifications, prices and shipping logistics with the project leader and local producers. This network enabled real-world financial data to be obtained and used for a financial analysis of cocowood flooring production.

With decreasing availability of traditional hardwood timbers for high value flooring and parquetry, key industry stakeholders maintained links with the project team for the duration of the project in order to assess the potential of cocowood as a new option in Australian flooring markets. Australia's largest manufacturer of engineered flooring was involved in all stages of product development and assisted with manufacture of the feature floor now on display in Brisbane. Queensland's largest hardwood flooring installation business and the technical manager for the Australian Timber Flooring Association were kept informed of the project's developments and provided technical and marketing advice to support the development of cocowood flooring.

7.3 Processing systems and profiles for high quality flooring

The need for careful planning in timing harvesting to allow for rapid conversion was demonstrated during the Samoan sampling component of this project. The tropical environment is very conducive to fungal activity and delays in the supply chain will almost certainly lead to non-recoverable degrade. This is also be the case if attention is not payed to appropriate handling and pre-treatment tasks such as air drying and/or antisapstain preventive treatments.

Cocowood material is abrasive to tool edges and cutting teeth due to it's structure and composition. The external cortex layer is difficult to remove compared to normal wood species due to its hardness and interlaced structure. The project determined the most effective methods for bark removal to be sawing to expose the first board face in lieu of manual or mechanical debarking. Coconut palms need careful inspection prior to sawing due to the possibility of presence of nails and other fasteners in palms harvested from community plantings and near settlements. The palms can be processed through standard portable sawmill plant and equipment, however regular blade sharpening is necessary.

The anti-stain trials revealed that the best performing, approved chemical treatment system is a solution of carbendazim and chlorothanonil. Dipping will be necessary in any process where sawn cocowood boards cannot be graded and kiln dried within several days after harvesting and sawing. The optimum process involves removing the high density boards directly off the saw and into a dip tank for 10 seconds, allowing excess liquid to drain, then placing in a drying rack. Low density boards for use in local markets and core material to be chipped for growing media won't require dipping. Insecticide treatments with imidicloprid or permethrin can be used to prevent infestation by timber borers and beetles.

Air-drying conditions in the tropics are not conducive to preparing sawn cocowood for export products due to the lower equilibrium moisture content (EMC) in key market locations. For example the EMC in Fiji and Samoa ranges from 15 to 18% during the year, whereas flooring destined for use in Australia is required to be within the range 9 to 14%

and for Europe and America, 6 to 9%. These specifications are designed to ensure that flooring is 'pre-shrunk' prior to installation thus minimising the movement of boards in service.

In order to dry down cocowood boards to the appropriate moisture content for high value flooring markets, a kiln drying schedule and recommendations for weighting the kiln stack to minimise distortion during drying were ratified by the project team.

In addition to simple tongue and groove (T&G) profiles and parquetry profiles, a range of engineered designs taking into account the unique structure and characteristics of cocowood fibre were trialled (see appendix document *Secondary machining properties and appropriate flooring design development for coconut palm wood*).

Further consideration was given to market preference for wide boards for ease of installation. The final prototype flooring design was manufactured from a laminated beam composed of 8 @ 100 x 20 mm high density cocowood boards. After curing the beam was resawn perpendicular to the glueline to produce wide surface layers to be adhered to a plywood substrate. This design met all the requirements for a high performance, natural, hard wearing feature floor product and a demonstration floor was installed in a prominent office location for display and monitoring purposes.

Plate 11. Engineered, pre-finished cocowood flooring ready for installation.

Plate 12. Engineered, pre-finished cocowood flooring in service, Brisbane.

The metal cutting edges and corresponding feed speeds to give the best quality finish for high density cocowood boards were determined. When tungsten carbide is used, 12 m/min feed speed provides the best quality finish and when Stellite is utilised, feed speeds should be set to 24 m/ min. Lower feed speeds are recommended if the material being processed is prone to torn grain or soft tissue roughness and are recommended when profiling, for example when producing a tongue and grooved profile. Tear out occurs where bundles meet the surface at an angle rather than align parallel to the surface.

Cross-cutting trials were conducted in order to determine the best blades for docking. It was found that both negative and positive cutting angle blades provide similar results.

Straight blades provided a better result than bevelled blades when rip sawing (where a board is cut longitudinally), with the former style producing less splinters and tear out.

The sanding trials revealed that cocowood is easy to sand with a range of grit-size abrasives and a range of feed speeds. The optimum feed speed was 12 m/min.

Peeling trials provided a preliminary view of the potential of this method of processing to produce a surface layer for a composite flooring product, however the equipment used was not optimal for handling coconut palm billets and more work is required to determine suitable processing parameters.

A range of utilisation options for the low density core section of the palm stem was considered, based on the physical and chemical properties of the material as well as potential for commercialisation. Simple building products for rural buildings and animal pens were deemed suitable by local sawmillers familiar with such markets, however no formal trials were conducted for these. In country partners suggested that rather than a technical issue this level of product development falls in normal domestic market activities.

The properties of the material fall within the requirements for coreplate, a product manufactured for use in doors, however a willing Australian partner could not be found to trial doors manufactured from cocowood due to the perception of assisting potential competitors.

Ground low density cocowood was tested for properties relevant to growing media and it was found that the material does have the required physical and chemical properties necessary for horticulture, nursery and related industries. Further plant health trials are recommended. This could lead to suitable products being developed for use in smaller islands, where soils lack organic matter and there is potential for floriculture industries.

7.4 Training

A workshop presenting an overview of primary processing and cocowood properties was conducted in Fiji during September 2007 with delegates from the private and government sectors form both Fiji and Samoa attending through support of a Crawford Fund bursary.

Harvesting and primary processing training was conducted in both Samoa and Fiji. Fiji Forestry's experienced Utilisation officer conducted the training and supervised operations in both countries at several stages of the project.

A second Crawford Fund workshop was conducted in Brisbane, with delegates from Samoa (Joe Strickland and George Strickland Jr) and Fiji (Seva Tawake and Sailosi Kinivuae) receiving certificates in Drying Operations after completing a 4 day course with the Queensland Forest Industry Training and Education Consortium (FITEC). Following the course, the delegates attended seminar presentations by the project team covering all activities conducted during the first half of the project (article appended).

Plate 13. Crawford committee members and trainee delegates, Brisbane 2008.

A Fijian forester successfully applied for a John Allwright Fellowship, enabling him to live in Australia and work alongside DEEDI project staff for two years. During this time the Fijian officer was trained in all aspects of sampling, experimental design, mechanical properties testing, use of relevant software, technical report writing and oral presentation.

The DEEDI pathology scientist provided training in microbiology methods and protocols for data compilation, analysis and presentation to University staff in Samoa.

The DEEDI drying scientist provided training kiln operation, experimental design for drying trials, and dried quality assessment to Fijian Forestry staff.

Industry experts were consulted on various aspects of processing and manufacturing including veneer grading, adhesive selection, marketing intelligence, historical flooring performance problems, European standards and specifications and shipping logistics. The information obtained during these discussions has added to the knowledge base of Fijian, Australian and Samoan technical and industry personnel.

7.5 Grading standards and product specifications

Coconut palms do not have the typical natural features that require careful grading when present in normal wood such as knots, gum veins and resin pockets. Grading therefore is concerned with density sorting, grain angles and board straightness. Detailed assessments of cocowood density and corresponding Janka hardness were undertaken during the project. It was found that density and hardness are strongly correlated for lower density values but the correlation is weaker at higher densities. A minimum threshold was nominated as 700 kg/m^3 which was found to provide a corresponding minimum Janka hardness value of 7 kN. This is the desirable minimum value for feature flooring for most applications and will provide a suitable resistance to indentation to normal foot traffic.

Distortion in dried boards is problematic in manufacturing and installation of flooring products and is therefore not acceptable. Preventing twist in boards during drying is achieved by loading concrete weights onto the stack. Boards exhibiting twist are discarded during the grading process.

Plate 14. Sawn timber stack loaded with concrete weight to retain flatness.

Moisture content specifications for all major high value markets were determined with the appropriate ranges given as 9 to 14% for Australia, and a target of 9% for Europe and North America. Air conditioned environments also require cocowood flooring to be installed at approximately 9%.

Results from various test protocols demonstrated that cocowood moisture migration is faster than within true wood. Consequently where cocowood is processed through to the end of the drying stage in a tropical location such as Fiji, the finished goods need to be plastic wrapped immediately after drying to ensure they retain the specified moisture content for the destination market. Dried stock left unwrapped in humid tropical conditions will rapidly re-absorb moisture from the environment resulting in an increase in timber moisture content to an unacceptable level. Specifications for plastic and carton packaging were designed with the requirements of high value export markets in mind.

8 Impacts

8.1 Scientific impacts – now and in 5 years

The discovery of the triple helix spiral grain formation early in the project provided a valuable insight to the direction of product design in the second stage of the project. This structure, whilst providing a high degree of strength and wind firmness in the living palm is problematic when considered in the context of processing into sawn boards and designing flooring products.

A detailed analysis of the density patterns within coconut palm stems enabled production of 3D density profile maps. These were used to develop appropriate sawing patterns that will maximise recovery of high value cocowood.

The assessment of a range of anti-stain chemicals resulted in a recommendation for the most effective treatment solution for high value cocowood products. Traditional solutions used in the Pacific such as salt water were shown to be ineffective when tested.

Kiln drying schedules have been validated and it has been confirmed that this will be a necessary process to achieve the required moisture content specifications for export markets. Relatively high mass pack weights are also necessary to minimise distortion during drying of sawn boards. The drying trials have provided clear evidence that kiln drying infrastructure including the facility to load and unload concrete weights on packs for drying will be necessary for successful production of export quality cocowood flooring.

Empirical evidence for machining and sanding processes have been published in the cocowood User Manual, taking the results from these materials science experiments into industrial processing centres in the Pacific.

The technical impediments to processing and manufacturing as well as design considerations for a high value flooring product have been satisfactorily concluded. The problem of regular log or sawn board supply needs to be addressed and remains a major impediment to progressing the industry.

The chemical and physical properties of the low density component of coconut palm stems were found to meet the requirements for organic growing media and chipped low density cocowood could provide much needed organic matter to poor soils typical of many small Pacific Islands as well as form a base material for new industries such as tropical floriculture.

8.2 Capacity impacts – now and in 5 years

The project enabled industry representatives from both the government and private sectors to undertake training in properties, characteristics, processing parameters and drying technologies for cocowood.

The initial project plan relied on the Coconut Industry Development Association to develop a pilot plant to produce cocowood products, including flooring for export markets. Unfortunately this facility ceased cocowood processing operations early in the life of the project to concentrate on copra production. An alternative industrial facility was found in an enterprise arrangement involving Palmwood Fiji who were to supply rough sawn feedstock to Sustainable Forest Industries Limited in Suva. Firm orders for regular shipments of cocowood flooring to Europe were negotiated as a direct result of this project based on discussions with all stakeholders. It was hoped that this would provide incentive to create an effective supply chain, pulling the product through all stages from harvesting to shipping. The European importing company has established markets and previous experience in cocowood products. All parties agreed on all details of the initial shipment order, however the Fijian suppliers were unable to manage the harvesting and primary processing of sufficient coconut palm stems to allow secondary processors in the chain to fulfil the order.

Although the export shipment hasn't been able to be fulfilled as yet, the training and experience with export customers, may lead to a better understanding of the requirements for products, packaging, logistics prices and acceptable timeframes for future export opportunities. During the final workshop presentations in Suva 2010, representatives of the interim Fijian government proposed to investigate incentive schemes to facilitate the development of the supply chain.

A the time of writing a joint venture between Strickland Bothers (Samoa), South Seas Timber Traders (Fiji) and Planet Coconut (France) is in progress with an initial shipment to Europe expected to occur before of the end of 2010. Additionally a Fijian business man (trading under Vanua Levu Investment) would like to venture in cocowood processing & export in Fiji. He is the owner of 2 estates (350 Ha) in Taveuni and he would like to set up a sawmill and processing facility in Vanua Levu. After a series of meeting with SPC/Vanua Levu Investment/Forestry, he has submitted his application for a cocowood sawmill. The sawmill site inspection and assessment of the palm has been conducted and he is awaiting the Conservator of Forest approval for Provision License.

Fiji's capacity to consider broader utilisation options than traditional wood products have been improved through exposure to the testing and requirements for growing media. The Fiji Forestry Utilisation Officer Mr Tawake visited Brisbane during the establishment of growing media trials. The results from these trials indicate that in particle form, the low density portion of coconut palm stems is suitable as a growing media and it could be possible to establish a mulch product industry for vegetable and flower crops in the Pacific.

8.3 Community impacts – now and in 5 years

The project provided a demonstration to communities of the potential benefits of supporting a cocowood industry. The sampling process enabled several small landholders in Fiji and Samoa to sell senile, non-productive palms and have them removed to make way for replanting. Over 100 palms were purchased during the project and flow-on employment and skills training were generated through harvesting, transport, processing stages.

During the final project seminar, interim government representatives proposed an initiative to build on the project activities through the provision of training programs and incentive schemes subsidising portable operations in the outer islands. Examples of incentives were cited as 2:1 subsidy for sawmilling equipment, free training and tax-free status for regional operations. It was suggested that this policy could be adopted within 12 months.

Demand for cocowood flooring products was proven during the project and the beneficial impacts for communities such as employment, skills, income and more productive land use could emerge from a sustainable, harvesting and primary processing sector.

8.3.1 Economic impacts

A financial analysis was conducted which determined that a cocowood flooring processing plant could be profitable as long as log supply was consistent and sawn recoveries were maintained at levels achieved during the project. A medium sized facility processing 2,500 stems per year has an expected profit of just over $100,000 per annum. Increases in the retail price significantly increase the expected profit, however, if the retail price decreases below the break-even price of approximately $30 per m2 the project will become unviable.

A sensitivity analysis showed that fluctuations in wages costs or interest rates were less relevant. The assumptions used in the analysis can be viewed in the appended report

The demand for cocowood flooring sourced from Pacific plantations was established during the term of the project and the technical issues for processing the material have been resolved. Supply issues remain problematic with local suppliers unable to fill orders for the French flooring market or for a feature display floor in the Pacific Pavilion at the Shanghai Expo 2010.

For the project to realise its potential in regards to economic impact, solutions to the problems within the supply chain are necessary. These issues should find appropriate solutions through proper logistics investment and planning (from felled palm to the mill gate) along with trading rules in Pacific Islands context and culture.

8.3.2 Social impacts

The prospects for skills development and employment in rural areas could be improved through the actualisation of cocowood flooring as envisaged by the project partners. However it was found during the project that the concept of cutting down palms- a plant that has provided food and income for generations- is not easily translated as a benefit in many communities. The palm is considered as a food crop and is not widely accepted as a wood substitute. Other cultural implications identified during the project include that where ancestors developed traditional methods such as salt water treatments for cocowood and smoking for drying sawn boards, it is difficult to introduce replacement, modern systems such as effective chemical treatments and technologies like kiln drying. This is largely due to the preference to honour tradition and respect ancestors rather than doubting that the modern technologies are more effective.

The palm log supply issue may be compounded by land tenure complications where land ownership is shared by members of a family or tribal group with varied priorities amongst members. It is estimated that 80 % of the Fijian coconut palm resource is community or small landholding ownership.

In Samoa it is less clear whether land tenure represents a potential supply issue. The key impediment in Samoa is the lack of infrastructure for high quality processing such as kiln drying equipment required to furnish products for export markets.

8.3.3 Environmental impacts

Coconut palms are grown in plantations and agroforestry systems and can therefore provide a genuine eco-friendly resource for wood substitute products. The project team consider that chain-of-custody and standard 'green' credentials for certification readily apply to senile coconut palms harvested for processing into high value products. Options for secondary products were identified and have the potential to improve soil conditions through provision of organic matter in outer islands where fertility is low. This also minimises waste and allows for complete utilisation of harvested stems.

The use of plantation-grown senile coconut palms for wood substitute applications will reduce pressure on natural forest timbers and reliance on imported timber products from New Zealand and elsewhere.

8.4 Communication and dissemination activities

8.4.1 Website development

A project website ‘cocowood’ www.cocowood.net was launched in February 2008. It delivers information and news about the project and encourages communication between industry, research and other stakeholders.

To a large extent, it has succeeded in meeting its objective as a communication tool to provide information about the project, stimulate interest and discussion about coconut wood, collate existing information about cocowood; deliver knowledge gained from the project and provide a store for documents shared between partners.

Currently it features project news items, information sheets, technical reports, research features, information about partners, the project team, cocowood literature, useful links, an image gallery, and a discussion forum.

8.4.2 Website enquiries

The website has facilitated enquiries from growers, processors, designers and potential users. The first enquiries about the cocowood project were received within weeks of the website release. They came from North America, Papua New Guinea, Australia and the Philippines.

Since then there have been enquiries from Mozambique, Vanuatu, Tanzania, Zanzibar, Papua New Guinea, India, France, Germany, the Netherlands and Australia (Table 1).

The discussion forum has not been used extensively; most enquiries are sent directly to the project team via the feedback email, rather than provided as public posts at the forum. One cocowood processor has posted a request for sourcing coconut wood material.

8.4.3 Website registrations and web visitor statistics

Member registration allows access to more information about the research project, the image gallery, selected reports and information about training and workshops. Registration was encouraged to capture basic information about people interested in cocowood. Although registration entailed completing several required fields, it was possible to register successfully without recording a home country or their occupation or interest in cocowood.

The number of registrations increased steadily and in May 2010 there were 111 registered users of the site. Fifteen company personnel identified their businesses. The registered users come from 28 countries, while the site visitors originate from 66 different countries.

Information about website use was collected from Webstats (2008-2009) and Google Analytics (2010). There was variation in the statistics collected but an overall picture of website use is included in the appended document *Cocowood .net- a summary of site statistics.*

Overall, there was steady increase in site use, and by the third year, the website was attracting between 14 and 38 returning visitors per month, excluding the site administrators. In 2010, visitors accessed an average of 4–5 pages and spent an average of 3–5 minutes on each visit. More than 65% of all visitor traffic was directed from search engines, primarily Google, suggesting visitors were using the topics listed in the cocowood entry.

8.4.4 New information disseminated from the cocowood website

There are 60 pages of information on the website, accessible to either the public, registered members or partners. The most commonly accessed public pages were cocowood literature and cocowood properties and the most frequently viewed pages (2009–2010) were:

About cocowood – Literature (21%)

About cocowood – Properties (12 %)

Home page (10%)

Useful links (9%)

Media article – Coconut palms, the timber of the future (7%)

About cocowood – Publications (6%)

About the project (5%)

Member's area – Training and workshops (5%)

News (4%)

One important function of the website was to provide access to project information for the project partners. Annual reports, technical reports and research meeting reports are provided as downloadable files in the Partners section of the website.

Research meetings

2008 Research meeting, Brisbane, November: R&D presentations

2004 Regional workshop on coconut wood utilisation, Fiji

ACIAR reports

19/11/07 - Interim report cocowood (PDF, 95KB)

1/06/07 - 31/05/08 Annual report (PDF, 109 KB)

1/06/08 - 31/05/09 Annual report (PDF, 139 KB)

Cocowood properties

1997 Arancon, RN. (1997) Asia Pacific Forestry Sector Outlook Study working paper No: APFSOS/WP/23. FAO Rome. Copyright FAO. Asia Pacific Forestry Sector Outlook: Focus on Coconut wood. (Download PDF, 132 KB)

Cocowood properties and processing facts (2010) Technical factsheet. Agri-Science Queensland, Department of Employment, Economic Development and Innovation. (Download PDF, 253 KB)*

Cocowood research reports

First evaluation of some properties of cocowood: DGI. (2007) Karl Mahnert, Department of Primary Industries, Queensland (Download PDF, 476 KB)

Susceptibility of cocowood to damage by subterranean termites (2007) B. Peters and C. Fitzgerald, Department of Primary Industries, Queensland (Download PDF, 464 KB)

Secondary cocowood products- potting mix: Fine-ground cocowood for growing media. (2010) R. Poulter and G. Hopewell. Agri-Science Queensland, Department of Employment, Economic Development and Innovation. (Download PDF, 269 KB) *

Drying *Cocos nucifera*. A literature review (2009) A. Redman, Agri-Science Queensland, Department of Employment, Economic Development and Innovation. (Download PDF, 796 KB)

Cocowood flooring products. A financial analysis. (2010) Agri-Science Queensland, Department of Employment, Economic Development and Innovation. (Download PDF, 160 KB)

* also available to registered members.

9 Conclusions and recommendations

The ACIAR project FST/2004/054 *Improving the value and marketability of coconut wood* has enabled a detailed investigation in the material properties, leading to recommendations for optimum processing of senile palms as well as the design of a high performing and attractive flooring system. Further, utilisation options for the soft, core portion of the stem were considered.

Supply chain issues were largely outside the scope of the project which was primarily concerned with research and development. However in the course of the R&D, it was found that supply problems could prevent the establishment of a sustainable cocowood industry in the Pacific.

9.1 Conclusions

Senile coconut palms harvested from over mature plantations in Pacific Islands can be successfully processed using traditional wood machinery to produce a high value flooring product. Due to the environmental conditions (especially temperature and relative humidity) experienced in tropical coconut palm growing regions, it is necessary to plan for rapid sawmilling and drying after felling to ensure protection from degrading organisms.

Any delays between processing and drying will necessitate a dipping process to prevent staining by fungal organisms.

The wood of the coconut palm is highly variable and requires careful segregation into density grades to meet product specifications. The project trials resulted in a visual grading template to assist this grading process. It is possible to segregate the high density wood suitable for flooring products, however it is difficult to determine a density threshold for termite resistance. It was found that termite resistance is strongly correlated with density; however the conclusion was that untreated cocowood cannot be classified as termite resistant. This is not a problem for flooring products due to termite protection being fundamental to building design and would only be an issue for products used externally such as decking or poles.

In addition to the density gradients within a stem, the grain structure of the material is interlocked and formed in a spiral formation resembling a triple helix. This results in grain deviation within a board and can cause twisting during drying or in changing environmental conditions. Appropriate sawing patterns prove to effectively minimize the twisting effect. Moreover cocowood boards can be satisfactorily dried using conventional kiln equipment and prescribed schedules for cocowood, however the kiln drying process must include the application of heavy concrete weights to ensure that sawn boards retain flatness during drying. This implies that a forklift or crane with the capacity to load and unload such a weight is required as part of the kiln drying plant.

From the range of flooring profiles developed and tested during the project, the product manufactured from a thin sawn lamellae from a laminated beam adhered to a plywood substrate provides the most promising commercial flooring. This design allows for the manufacture of a wide cover width as preferred by the market and installers. It provides a unique appearance of narrow 20 mm boards but can be simply installed in panels of 133 mm cover width. The thin section of the surface layer results in the best possible recovery from the coconut palm, for example compared to solid flooring profiles.

The environments in export market destinations are usually going to be different than the conditions where the coconut palms are processed. Cocowood was shown in trials to be relatively highly absorptive in humid environments. This means that finished cocowood products will need careful and expedient attention to packaging immediately after drying and machining, prior to shipping.

There is a strong demand for quality cocowood flooring and the project, through its website, generated considerable interest from a range of potential customers around the world. One European importer liaised closely with the project team and Fijian suppliers to negotiate product specifications and prices for an ongoing supply of cocowood flooring and parquetry sourced from Pacific plantations. The importer has continued to communicate market information concerning the demand for cocowood flooring for European projects with the project team.

The fragmented nature of the senile palm resource, particularly regarding ownership, adds to the problem of ensuring continuous supply of the volumes required to sustain a small cocowood processing facility.

Chipped, low density cocowood from the inner core of the palm stem can provide organic matter to poor soils, contributing to higher vegetable productivity in the small islands and potentially to a new industry such as tropical floriculture where low density cocowood chips could be used for growing media.

9.2 Recommendations

The project has produced a considerable dataset which has informed processing methods and product designs for the harvested fibre from senile palms. Further value can be gained from the data through continuing research and development of wood substitutes derived from coconut palms to make additional gains in recovery, profitability and maximizing returns to growers and processors.

It is recommended that future research activities consider veneering processes for the high density section of the coconut palm and plant growth trials (for example vegetables and flower production, or green roof structures) with chips from the low density portion.

Supply arrangements are currently the major impediment to industry development, particularly procurement of palms from landholders. Green palm material can be shipped between islands and island nations, for example from Samoa to Fiji, and at the time of writing Fijian and Samoan stakeholders are undertaking supply chain trials in the hope of suppling finished products to Europe and Australia. Under current AQIS restrictions, all green cocowood (including DNA samples) and dried cocowood greater than 200 mm diameter are not permitted to be imported into Australia. These restrictions need to be considered in planning any further research work on coconut processing.

Veneer R&D

Cocoveneer has the potential to provide a defect free face veneer suitable for valuable applications such as formply used in concrete construction and engineered flooring.

Conventional rotary lathes aren't suitable for processing coconut palm due to their inability to secure the chuck in the low density end grain of the billet. Spindle-less lathe equipment is required to successfully peel coconut palm billets to produce cocoveneer. Trials are required to ascertain the optimum processing parameters such as billet temperature and moisture content, knife type, blade angles, power requirements, handling practices and drying protocols.

Plant industries

Cocochips could fill a need for soil conditioning in areas of poor soil structure, improving organic content. Tropical floriculture industries could make use of this product and villagers could grow vegetable crops with cocochip media. Relevant ACIAR projects include PC/2009/093 *Improving soil health in support of sustainable development in the Pacific* and PC/2008/011 *Strategies using floriculture to improve livelihoods in indigenous Australian and Pacific Island communities*.

There is emerging interest in green roof systems in architectural circles and this option should be investigated as a solution to utilising low density cocochips.

Biofuels

Ethanol production from green low density part could be another exploration path in light of recent publications demonstrating the potential benefits specifically in remote region of Pacific Island nations.

Website

The project website will continue to be managed by DEEDI for 12 months following the project and it is hoped that it can be handed over to a new manager (SPC) after this period if a follow-on project doesn't eventuate within this timeframe. This website is a capital output of the project and continuing investigations of cocowood processing and products will significantly benefit from this essential medium.

10 References

10.1 References cited in report

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10.2 List of publications produced by project

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Hopewell, G., House, S., Francis, L., Redman, A. (2010). Cocowood processing for high value products- a User Manual.

ACIAR reports

Project FST/2004/054 Annual report 2007-08

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Project FST/2004/054 Annual report 2009-10

Meeting reports

Improving the value and marketability of coconut wood. Stakeholder seminar minutes, Suva June 2010.

Improving the value and marketability of coconut wood. Final research meeting minutes, Suva June 2010.

Hopewell, G. (2008). Cocowood- industry interaction. Summary of discussions with Australian industry representatives.

11 Appendixes

The following documents are provided for more detailed information on the topics discussed in this final report:

Appendix 1 Cocowood Technical Brochure

Appendix 2 Cocowood Users Manual

Appendix 3 Cocowood secondary machining properties and appropriate flooring design development for coconut palm wood

Appendix 4 Cocowood termite susceptibility report

Appendix 5 Cocowood flooring financial analysis

Appendix 6 Cocowood potting mix