Coconut wood

Processing and use

FAO FORESTRY PAPER

57

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS

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M-32
ISBN 92-5-102253-4

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COCONUT WOOD

Processing and Use

INTRODUCTION

Coconut Wood - Processing and Use is an introduction to methods currently in use for the utilization of coconut stems for wood products and fuel.

The stems of the coconut trees become available for use when the tree ceases to yield coconuts as a result of old age, disease or hurricane damage.

Coconut Wood - Processing and Use has been produced for the information of those interested in the development of processing industries.

The information contained in this book represents the most recent findings of institutions and individuals researching the fuller use of superfluous coconut stems.

The economics and management of coconut wood industries, and the organized marketing of their products, will need increasing attention as the industries expand.

Sources of Information for Coconut Wood - Processing and Use were:

Mr. V. K. Sulc, Mr. Rodrigo Juson and colleagues, Zamboanga Research Centre, Philippines; Mr. R. N. Palomar and Mr. A. Mosteiro, Forpride, Philippines; Dr. A. McQuire and J. Kinninmonth, Forest Research Institute, New Zealand; Messrs. R. Ford, J. Turner, and J. Vaney, New Zealand Forest Service, Rotorua; Mr. N. Evans, Fe'ofa'aki Enterprises, Tonga; Mr. R. Evans and Mr. A. Afeaki, Cocostem Development Co. Ltd., New Zealand and Tonga; and Mr. K. Bergseng, Timber Training Centre, Rotorua.

Other individuals were consulted and assessments were made of a number of coconut stem processing operations in selecting material to be included.

Documents from which material has been drawn are cited in the bibliography.

The editors and the Food and Agriculture Organization wish to acknowledge the assistance given by the specialists, primarily those named above, who co-operated in the compilation of the report and from whose publications valuable information was collected.

The editors

Anthony Haas
Len Wilson

Chapter 1

The Coconut Tree

The coconut palm, *Cocos nucifera L.,* is one of the most important crops of the tropics.

It occurs in all tropical and most subtropical regions, most abundantly in Asia and the Pacific, thriving best on low-lying sites close to the sea with ground water and ample rainfall.

Nuts are produced from when trees are aged five, with highest production achieved between 15 and 50 years. Productivity declines steadily thereafter until at 60 to 70 years the tree is considered to be senile.

It is then, or when hurricanes or disease strike, that the mature coconut trees are suited for conversion to coconut wood.

Properties, Availability and Utilization

The coconut palm, *Cocos nucifera L.*, is one of the most important crops of the tropics. It occurs in all tropical and most subtropical regions, most abundantly in Asia and the Pacific, thriving best on low-lying sites close to the sea with ground water and ample rainfall. Nuts are produced from when trees are aged five, with highest production achieved between 15 and 50 years. Productivity declines steadily thereafter until at 60 to 70 years the tree is considered to be senile.

Few plants are as versatile as the coconut. The most important product is the flesh of the nut (the solid endosperm) which, dried as copra, is the source of coconut oil used in the manufacture of soaps and detergents, edible oils and fats, oilcake, plasticisers and other industrial products. Worldwide copra production amounted to over 4.9 million metric tons in 1982, and in the same year trade in coconut oil was 1.27 million metric tons with a value of about $US657 million.

Local uses of coconut palm products are many: coir, from the husk of the nut, is a fibre used in the manufacture of mats, ropes, brushes and baskets; the hard endocarp provides charcoal; coconut milk (the liquid endosperm) is used in cooking and as a beverage; sap, obtained by tapping the inflorescence of the palm, is a source of sugar, alcohol and vinegar; the leaves provide thatch and material for basket weaving; the stem is used for house construction and increasingly for other purposes to be described in the succeeding chapters.

1A The Tree of Life

The Copra Industry

The origins of the industry may be traced back to 1841 when a patent was issued for the manufacture of soap from coconut oil. During the subsequent decades copra was harvested, mainly from trees growing wild, by traders supplying the large soap-making firms. Later, in the early 1900s, demand for coconut oil for butter substitutes stimulated the establishment of plantations.

In view of the favourable investment climate at the time, much of the planting was on large estates, especially in the Philippines, but in addition many small farmers planted the coconut as a cash crop which remains to this day an important part of the economies of some island countries.

After 1918 other crops, particularly rubber, appeared to offer better opportunities for investment and large-scale coconut planting diminished, then virtually ceased with the economic depression of the 1930s.

The vast stock of trees created during the planting boom continued to produce in abundance, but wild fluctuations in the price of copra, as well as the growing acceptability of alternative vegetable oils, led to a decline in the industry with a consequent strain on those economies dependent upon it.*

The main stock of productive trees was therefore ageing until, at 60 to 70 years old, productivity began to fall steeply. In countries where trade and subsistence farming remained dependent on the coconut the need for replanting became evident and programmes were drawn up accordingly. It thus happened that, for the first time in the history of the copra industry, plantation owners were faced with the problem of cutting, extracting and disposing of overmature trees.

Not only did this involve a reversal of the traditional conservationist attitude to coconuts, but it also required the development of economic means of disposal or utilization. Stems could not be left to rot as the decaying wood provides a breeding ground for

1B Coconuts

the rhinoceros beetle *(Orystes rhinoceros)*, a pest which attacks the core of the stem, the crown and young nuts; while burning or tipping into the sea would have proved expensive and wasteful.[7] For countries with a sustained internal market for timber - especially those relying on imports - the conversion and use of coconut stems offered an attractive economic prospect and industries were developed accordingly.

The development of viable coconut wood industries required in the first place two lines of investigation: the structure and composition of the raw material, with techniques of conversion appropriate to these; and the location and availability of overmature, diseased and dead stems.

1C The Young Tongan

Effect of Stem Anatomy and Structure on Utilization

The properties and peculiarities of the coconut stem were summarised at the Zamboanga (Philippines) Coconut Wood Seminar in 1979. The following notes are derived from the proceedings of that Seminar[3]:

> Because coconut palms have no vascular cambium (lateral growing tissue) they do not increase in diameter with age. It is uncommon to find a stem over about 30 cm in diameter. Minor variations in diameter from one stem to another, or between different locations, are a reflection of the growing conditions for the individual stem during the early stages of its life. Taper is very slight (about 5 mm) and mature stem heights of tall varieties are of the order of 20m thus giving maximum wood volume per stem of about 1 m^3.
>
> To obtain optimum growth and nut production the crowns and roots must have ample space. This limits the stem density in a plantation to about 100 per hectare. Thus the wood volume in a mature or overmature plantation is about 100 m^3/ha. Stems are often curved.This limits the length of sawlog that can be prepared. Although in some favourable locations (e.g. Zamboanga) longer logs are possible, in general a log of length of about four metres is the maximum practicable. The largest sawlog will therefore not exceed about 300 kg in weight which is low compared with sawlogs from mature trees of most forest species.
>
> Most hardwoods and softwoods exhibit density gradients from the centre of the stem towards the outside and from the bottom of the trunk towards the top. This is because the later-formed wood in any cross-section is usually slower growing and is composed of cells with thicker walls. With coconut stems the gradients are much more pronounced, but for different reasons. Palm stem wood consists of a number of scattered vascular bundles (each having vessels for water conduction, phloem for elaborated food conduction, and fibres for mechanical support) set in a matrix of more or less spherical parenchyma cells. The vascular bundles are much more abundant towards the outside of the stem. A typical stem at one

1D The Young Tongan Drinks from the Coconut

1E Copra Cutting, a Traditional Source of Income

metre height would have about ten bundles/cm^2 in the central portion and about 50 bundles/cm^2 near the outside.[23]

In a young stem the cell walls are relatively thin and the basic density of wood in these two zones could be about 90 and 300 kg/m^3 respectively. These wood cells are not dead as in normal forest trees, however, and the walls continue to increase in thickness so that by the time the palm is mature the density in these same two regions can be as high as 250 and 900 kg/m^3.[29]

All tissues in the basal regions of old palms (including the ground parenchyma cells) have thicker walls. Higher up the trunk the bundles are more abundant and up to 175 bundles/cm^2 have been found near the outside of an overmature stem at a height of 19.5 metres. The cells in these zones never develop thick walls, however, and the basic density in this zone was only 250kg/m^3.[23] In the central region of this stem (at 19.5 metres) the bundle frequency was 68/cm^2. The basic density varies from stem to stem but in general the distribution of density is of the order shown in Figure 1.1.

Strength and density are very closely related[17] so the density distribution governs the sawing pattern that must be chosen if high-strength timber is to be produced. Because logs are small in diameter, and the high-density zone is fairly narrow, it follows that only a few relatively small-dimension pieces of top strength can be produced from a stem.

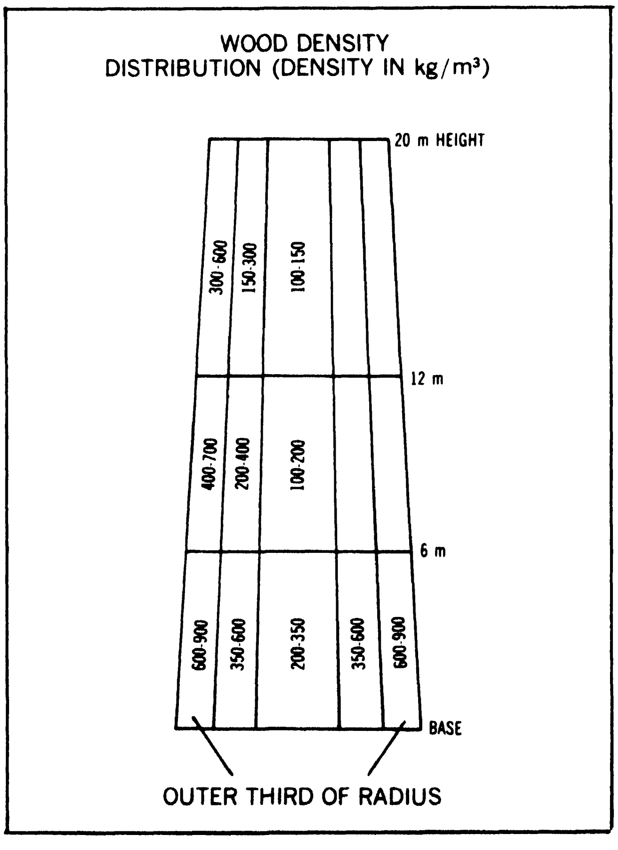
In Zamboanga the diameter average at breast height is approximately 32.5 cm - the maximum recorded is 43.6 cm.

Up to the six metre mark the high-density zone (outer one-third radius) accounts for about 20 per cent of the total stem volume but by the time allowances are made for saw kerf and other wastage, the net recoverable very high density wood falls to below ten per cent of the total. The maximum size of member that can be cut from this high density zone is 100 × 50mm. Although the quantity of this material per stem is low, the quality is uniformly high. As the palm has no branches there are no branch remains (knots) in the wood. Consequently no piece is weakened by the presence of natural defects.

Sawing

The actual operation of sawing coconut is difficult and standard steel saws will become blunted and unusable after relatively few cuts. Two factors probably contribute to this: firstly, the thick-walled fibres are extremely hard; and, secondly, the parenchyma tissues disintegrate into a fine abrasive powder which is not easily removed from the cut and which causes frictional heat increase. As the wood dries and the cell wall material becomes harder, these problems are intensified. The silical content of coconut wood is low so this is not a contributing factor as in some difficult-to-saw-hardwoods. The use of tungsten carbide tips (or Stellite–tipped or inlaid-teeth) has overcome basic sawing problems but has increased problems of saw maintenance. More costly equipment and greater operator skill are required.

Figure 1.1 Diagrammatic Section through a Coconut Stem



Seasoning

Conventional timbers have a distinct grain pattern caused by periodic radial growth. Even in species which do not show distinct growth rings the wood has different properties in the radial and the tangential directions. One of the most important of these properties is shrinkage when the wood dries from fibre saturation (about 30 per cent moisture content) to equilibrium moisture content. Shrinkage in the tangential direction is approximately double that in the radial direction so unless the wood is truly flat or quarter-sawn some distortion of shape is inevitable on drying.

With coconut wood there is no such grain differentiation so material will dry uniformly and without cross-sectional distortion. Lateral shrinkage in any direction is less than three per cent when drying from green to 12 per cent moisture content.[16]

With low density coconut wood, shrinkage is accentuated by collapse, which is not recoverable by subsequent reconditioning with high temperature steam. There is a sharp increase in this tendency to collapse as the basic density of material decreases below about 350 kg/m^3. Collapse is severe. Uses for this type of material are very limited. The volume of such unusable wood is approximately 15 per cent of the stem total.

1F Coconut Logs, Dense on the Outside, Soft Inside

Natural durability and wood preservation

The coconut palm does not form heartwood as most forest trees do. This affects its utilization in several ways. The wood is uniformly wet and approaches saturation throughout the whole trunk; variations in moisture content are dependent on variations in density and therefore the space available for water. The main consequence of having no heartwood is that the wood of the coconut stem has no natural resistance to attack by wood-boring insects and decay fungi. Freshly cut wood is very susceptible to infection by mould and stain fungi and also to attack by ambrosia beetles. Hence it is essential to dip timber in a prophylactic chemical solution immediately after sawing if a clean product is required. No part of the trunk is resistant to fungal decay but higher density material will take longer to rot completely, simply because the thick-walled cells retain some strength for a longer period. Low density wood will decay in the ground within weeks whereas very high density wood may last for two to three years.

Pressure treatment trials indicate that the wood can be treated with preservatives such as copper-chrome-arsenate. But the distribution of preservative is not as uniform as in pine sapwood where the rays are an important pathway of penetration, or in permeable hardwoods where vessels are more continuous and free of obstruction.

Transmission poles

The stems have strength properties which make them ideal for use as transmission poles. But it is difficult to dry them in a manner that will result in the preservative being concentrated in the high-strength outer zones, and without degrading.

Coconut wood is known to be more susceptible to soft-rot decay than is pine timber. So coconut wood will certainly require higher preservative loadings, but just how much more will be required to guarantee an economic service life is yet to be determined.

In the preparation of poles or posts it is first necessary to remove the bark so that the underlying wood will dry out. With most pole species this debarking operation is relatively simple, and effective machines have been developed for the purpose. With coconut stems, however, there is a gradual transition from wood to bark. The debarking region is indefinite and very fibrous. Debarking by machine is not yet possible. At present debarking must be done by hand using simple tools such as draw-knives or bush-knives. Treatment of poles by sap displacement is an alternative to normal pressure treatment but the deeply fissured nature of the bark makes it difficult to obtain an effective pressure seal on the log. Furthermore the sap-conducting elements (vessels within the vascular bundles) occupy only about four to five per cent of the total tissue volume compared with 30 to 40 per cent for the vessels in most hardwoods and 90 per cent plus for the tracheids in softwoods.

Pulp and paper

Trials in the Philippines and in New Zealand have shown that coconut stem wood can be used for making pulp and paper with qualities similar to those made from most hardwoods, although the high proportion of fines (from parenchyma tissue) greatly reduces overall yields. These small parenchyma cells also cause problems in the manufacture of particle board.

Wood fuel

The calorific value of coconut wood (heat energy released on burning, per unit weight of dry wood) is similar to other woods. But some predrying is necessary before coconut wood will burn easily. To achieve the necessary drying, the stem must be cross-cut into short lengths and then split, using suitable equipment and techniques to overcome the lack of planes of weakness in the radial direction.

1G Firewood from Coconut Logs

Summary

The coconut palm stem has a number of features that make it unique as a wood source material.

Early attempts at utilization were somewhat disheartening because results did not compare well with conventional wood from either hardwoods or soft woods. Many of the problems, however, were the result of trying to apply technology developed for one material to another that was quite different.

The development of equipment and technology specific to coconut wood has overcome many of these problems.

There is no doubt that the future will see the coconut stem being used as a conventional wood alternative in a number of applications, and in many instances doing the job equally well or even better.

Availability of the Resource

A prerequisite for the establishment of a coconut wood industry is an adequate supply of overmature or otherwise disposable stems of known volume. Estimates of the availability of raw material must be made with precision if industrial investment is contemplated.

A preliminary assessment may be made by a visual inspection of a plantation. The age of a palm can be calculated by counting the scars on the surface of the stem, while the volume of the stem is derived in the usual manner from height and diameter. A mature palm grown in the tropics will yield about one cubic metre of wood from which some 40 per cent recovery of dense and medium grades of sawnwood may be expected. In Zamboanga an average stem volume of 1.158^3 with stocking of not more than 115 stems per hectare is recorded.

Given these assumptions of maturity and yield, the potential volume of industrial wood follows from a tree count - typically 100 stems per hectare.

Resource assessment by estimation - South Pacific

Prior to the Coconut Stem Utilisation Seminar held in Tonga in 1976, all South Pacific countries attending were requested to complete a questionnaire on the extent and productivity of their coconut resources.[3] In spite of some differences in the methods of assessment and reliability of the data on which they were based, the results indicated a trend which may be significant for management policy in the future. The responses to the questionnaire showed the status of the coconut resource in the South Pacific to be as follows:

Total land area	547,989 km^2
Area under coconuts	460,000 ha
Percentage of resource considered overmature	31
Percentage of resource considered immature	23
Percentage of resource considered productive	46

Less than half the resource was considered productive in 1976, and it is possible that the rate at which this part becomes overmature will exceed the rate of replacement by immature stock. If that were the case, as much as two-thirds of the area would be available for logging and replanting. A subsequent study [3] assumed that the area of the resource available for logging in the South Pacific over the next 50 years would be of the order of 350,000 ha, and that at a felling rate of 7,000 ha per annum an annual yield of roundwood of approximately 1 million m^3 would be available (based on a high estimate of 125 trees per ha and 1.25 m^3 per tree).

On the same assumptions, it was calculated that in the Philippines 4.06 million m^3 per annum would be available from 1.6 million ha of plantations over the next fifty years.[3]

Resource assessment by survey - Tonga

In 1981, the Kingdom of Tonga completed surveys on coconut palm population, age ranges and productivity, as a result of which quantitative information was obtained on the size and distribution of the resource of overmature stems. On this basis the Government announced in 1982 a policy for controlled utilization of the resource, together with the rules to regulate the embryonic sawmilling industry to ensure its viability along with that of the copra industry.[14]

The effect was to permit the annual felling of 1.6 per cent of the total coconut palm population, with the completion of a stem utilization and replanting cycle every sixty-two years.

Resource assessment by inventory - Fiji

The usual preliminary to investment in a wood-based industry is an inventory of the source of raw material. In 1977, the Japan International Co-operation Agency undertook an inventory of coconut stems on the island of Taveuni.[3]

Aerial photography of the island was completed at a scale of 1:10,000, followed by a stratified random sample to obtain information on the number and volume of stems. Detailed photo interpretation with ground control then provided details of individual plantations including areas, number of stems per hectare, average height and total volume. Stem volume tables were prepared. Individual plantation statistics were recorded on a 1:10,000 map and overall distribution of the resource was shown on a 1:50,000 coconut location map. Reliable and detailed information of this type is needed by Governments in the preparation of plantation management plans, and by sawmillers for industrial feasibility studies.

Chapter 2

The Uses of Coconut Wood

The denser grades of coconut wood can be used as structural material while the lower grades are suitable for joinery and interior use. It has proved economic to construct dwelling houses entirely of coconut wood.

The denser material makes attractive furniture and is also widely used for utility items and curios.

The roundwood has excellent strength properties and is suitable for transmission poles and fence posts provided the problems of preservation treatment can be overcome.

The Uses of Coconut Wood

As noted in the first chapter, the over maturity of coconut plantations and the need for their replacement by higher-yielding varieties has been the foundation of all recent work on developing the use of coconut wood and of appropriate processing industries.

By the 1960s, coconut producers were expressing alarm at the problems caused by over mature palms diminishing productivity and decay and infestation of dead and dying trees. To these has often been added the destruction caused by hurricanes.

Among the institutions pioneering these studies, special mention is justified of those in the Pacific region. These include the Philippines Forest Products Research and Development Institute; the Philippines Coconut Authority's Zamboanga Research Centre, supported by the United Nations Development Programme and the Food and Agriculture Organization of the United Nations; the Fiji Forest Department, the New Zealand Forest Research Institute and the New Zealand Timber Industry Training Centre.

The range of studies covered are anatomy and wood properties, sawmilling, seasoning, preservation, mechanical properties, engineering design, charcoal manufacture, wood based panels, kraft pulping properties, machining, house construction and utilization for a variety of manufactured products. The U.K. Tropical Products Research Institute investigated the use of coconut wood in particle board manufacture and other processes.

Research and development findings were summarized at two important meetings in Tonga in 1976 and in the Philippines in 1979.[2,3]

In the meantime, small scale sawmilling industries were set up in parts of the Pacific in an attempt to market the products of the coconut wood becoming available.

By 1983 mills were being operated in Tonga by the Government, by the Catholic Church and by a commercial operator. Growers used the mills to have their own overmature stems milled. They used the sawn timber for their own projects. A commercial operator also negotiated with growers to acquire logs, processed them, and offered the sawn timber for local sale. In the Solomon Islands a commercial operator processed logs and offered the dense grade of sawn timber for export to a New Zealand company for further processing into wall panelling and flooring. In Sri Lanka a semi-government agency acquired fallen stems after a hurricane and processed sawn timber for the local market. In Kiribati a mobile sawmill began operations on an outer island to mill timber which was freighted to the Republic's capital and stockpiled pending a decision on its end use. In another Kiribati outer island a project to mill stems with chainsaws to provide timber for 30 houses was planned. Near to Los Banos in the Philippines a sawmilling project was planned to supply timber for low-cost housing. In Zamboanga, commercial and Government interests tested the use of coconut timber as a component in a low cost housing programme.

By 1983, coconut stem sawmills had operated also in Fiji, Western Samoa, French Polynesia, Vanuatu, Tuvalu, Papua New Guinea, India, Indonesia, the People's Republic of China, and Jamaica.

Some sawmilling projects have experienced difficulties arising from management, technical and economic problems which not unexpectedly had to be faced in a relatively new and widely dispersed industry. Typical of these are inadequate or irregular supplies of raw material, excessive transportation costs, insufficient attention to sawing techniques appropriate to recovery of the better grades of timber, imperfect seasoning and preservation practices, lack of quality control, incorrect assessments of markets and inability to compete with other materials.

Problems of this nature can be overcome as the public and private sectors gain experience in processing, marketing and management. Replanting programmes and incentives will ensure an adequate supply of stems; demand for the wood exists or can be developed especially in communities lacking alternative materials; and enough experience exists of production and utilization technology.

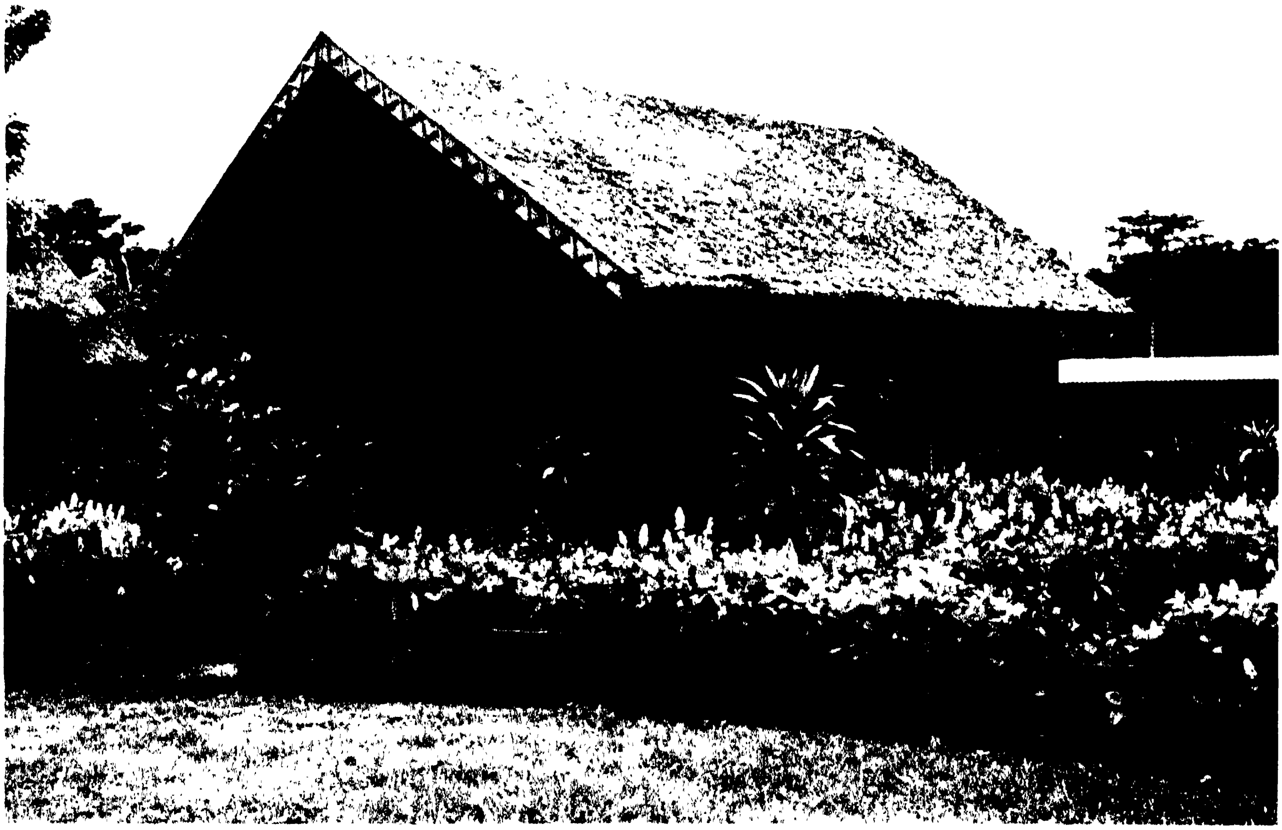
The remainder of this chapter is devoted to examples of the end-uses and products already demonstrated and in several cases marketed.

Construction

Experience has shown that almost the entire range of coconut wood can be used in appropriate functions in the construction of buildings, particularly houses.

Structural load bearing components in the house should be made from dense timber grades.

Trusses and internal members are made of medium density material and it has been possible to develop a wide range of advanced designs for the former. In addition to conventional methods of manufacture, nail plates and truss jigs facilitate the accurate prefabrication of trusses. Designs have been prepared covering a range of uses from small thatched roofs, through several house types, to school room buildings. Floors and steps are made of hard material either as machined boards or parquet. The internal linings of the walls of houses may be made of soft wood, which is quite suitable for non-load bearing surfaces, although harder wood is used when a high finish is required.



2A Coconut Wood House

2B Frame of Building

2C Cocowood in Water Contact

External cladding, also of the softer material, requires preservative treatment to prevent damage by weather, as do the hard wood window frames and any material which is in ground contact.[3]

Because of size limitations, the use of coconut wood in larger building necessitates the adoption of laminated members. This technique has proved to be successful. Some very advanced beams have been made by combining laminated coconut wood sections with plywood webbing.[3]

The hard outer layer, or high and medium density grades of coconut timber have sufficient strength for structural use in buildings.

Solid rounds used as posts placed on top of concrete foundations may be used in house construction and other parts requiring strength and durability.[24] Flooring joists, flooring, ceiling joists, trusses and framing timber can be made from dense coconut timber. The bottom and top studs, horizontal studs, top members and bracing can be made from medium density coconut timber.[38]

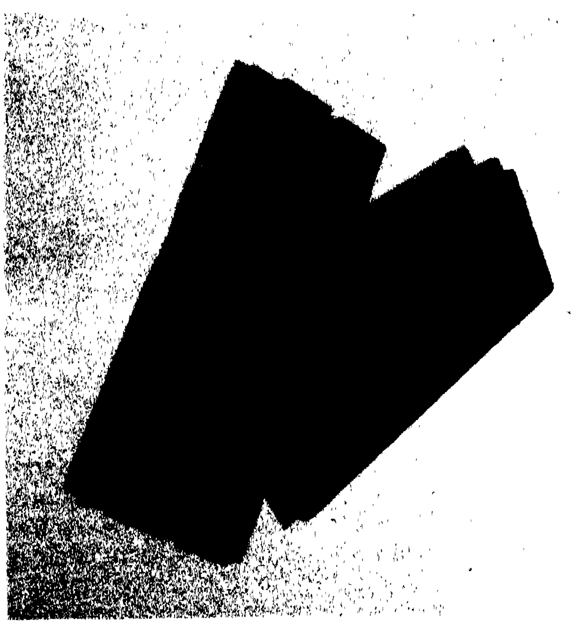
Coconut timber framing and flooring should be dried to the local equilibrium moisture content level before fixing.

Coconut wood can be used for roofing either as sawn timber or shingles. When rainwater is to be collected for drinking purposes, the roofing material may be treated with a water proof sealant rather than one of the toxic water-borne preservatives.

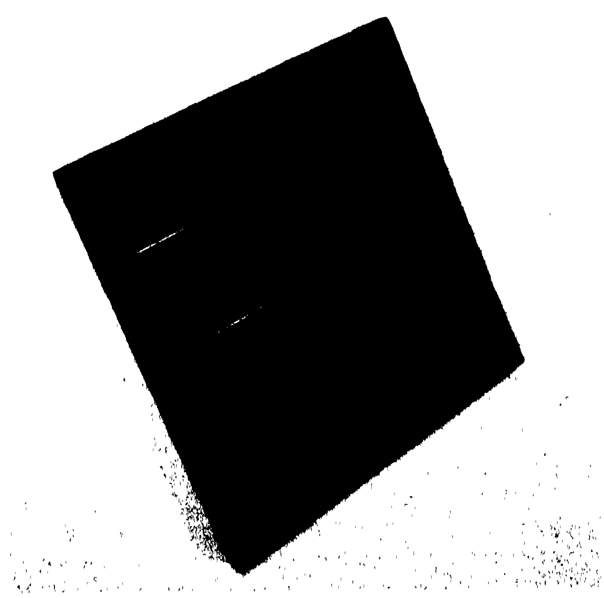
2D Shingles

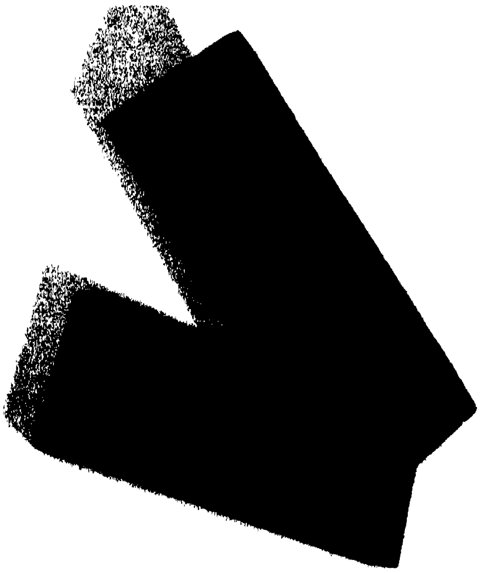
2E Feature Wall of Cocowood

2F Wall Cladding



2G Block Flooring





2I Cocowood Folding Table

2H Strip Flooring

Furniture

The harder density coconut wood, which is extremely attractive, can be used in the production of furniture, although its weight imposes some limitations on the size of pieces made entirely of this material.[5] Naturally this problem is easily overcome by utilizing coconut wood in framing and using lighter woods or laminating plywood to complete the items. Carving and fairly intricate turning is possible so attractive designs can be developed.

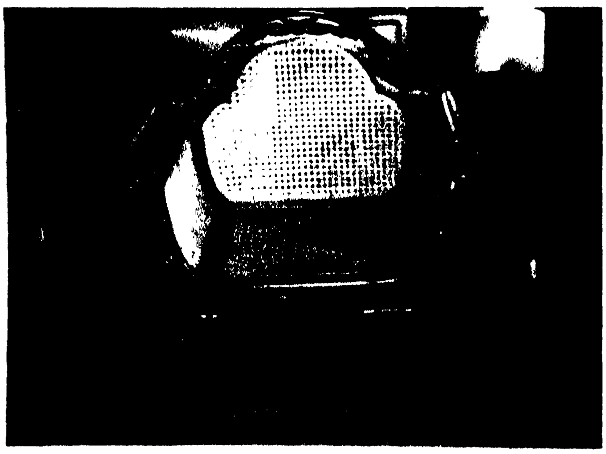
Hard density (No.1 grade) coconut timber is normally preferred for decorative furniture and is adequately strong in bending and stiffness and hard enough to resist indentation. Its colour, texture and figure enhance its suitability for this purpose.

Grade No.1 coconut timber has such a striking figure, in fact, that it can in some cases be considered overpowering if used to excess and this point should be kept in mind when designing furniture.

Selected medium density coconut timber is suitable for non-decorative and utility furniture manufacture. It is easy to screw, drill, glue and profile. Medium grade can also be used in conjunction with hard grade in decorative timber if the colour difference is allowed for or utilized in the design.

Preservative treatment for coconut wood furniture timber is usually not necessary.

For commercial furniture production it is necessary to use tungsten carbide tipped cutters on planers, spindle moulders, etc., in order to achieve a reasonable production rate.



2J Cocowood Chair

2K Cocowood Desk

Utility Items and Curios

The structure of coconut wood makes the harder material extremely suitable for a wide range of utility items with demanding specifications. The interlocking nature of the grain, which is a partial cause of the difficulties encountered in sawing, makes the wood ideal for the manufacture of tool handles with complex shapes such as axes and paint brushes where splitting along the grain is a problem. Furthermore, the resilience of coconut wood helps to absorb impact shocks in hammers and axes. By using lamination, extremely durable saw handles can be made.

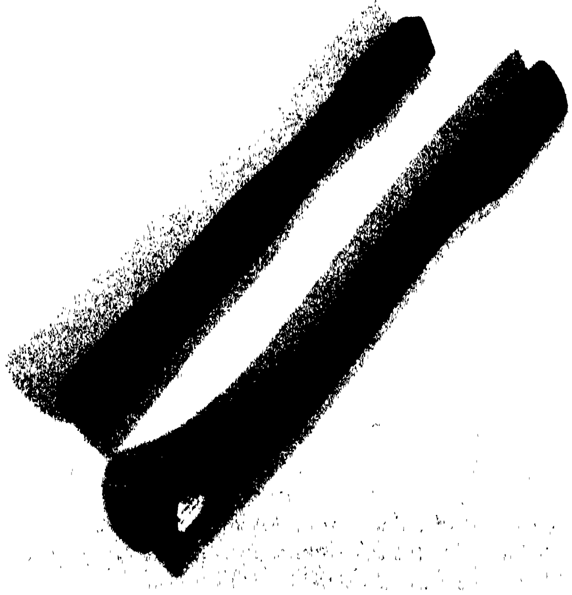
The combination of durability and attractiveness should also allow coconut wood to obtain a place in the big market of wooden bowls and boards for carving and servings. The high modulus of elasticity suggests that the material can be used in a range of rod forms, from broomsticks to surveying staffs.[3]

A wood with such attractive properties may well be utilized increasingly for the manufacture of curio items. Although this market cannot dispose of large volumes, it could be an important cottage industry giving gainful employment to many people. Items manufactured include bookends, candlestick holders, trays, bowls, mugs, chessboards, salt and pepper shakers.

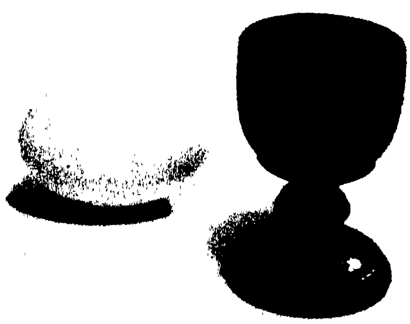
2L Walking Stick

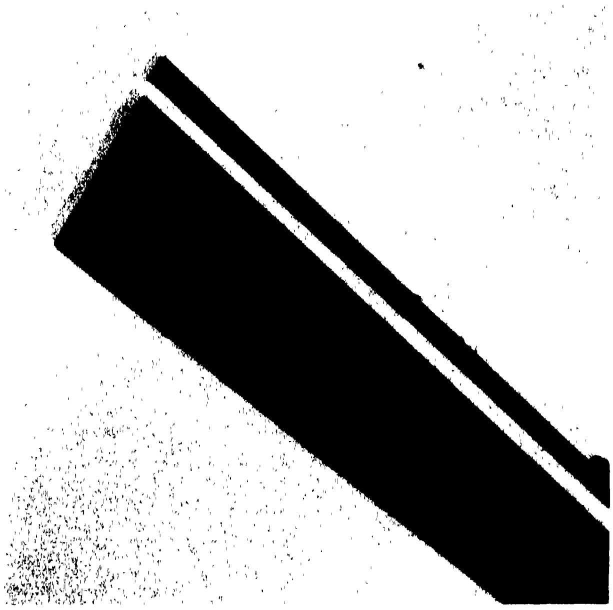
2M Bow and Arrow

2N Hammer Handles

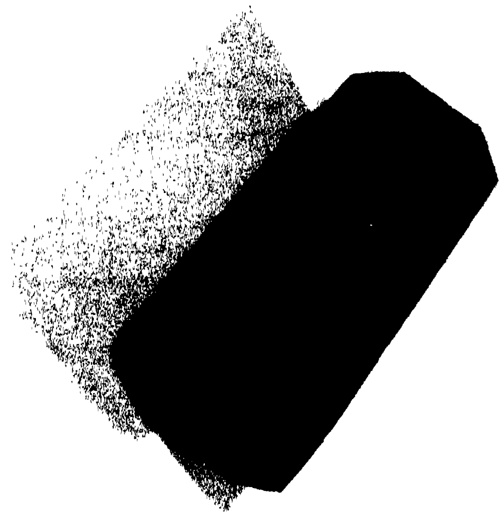


2O Eggcup





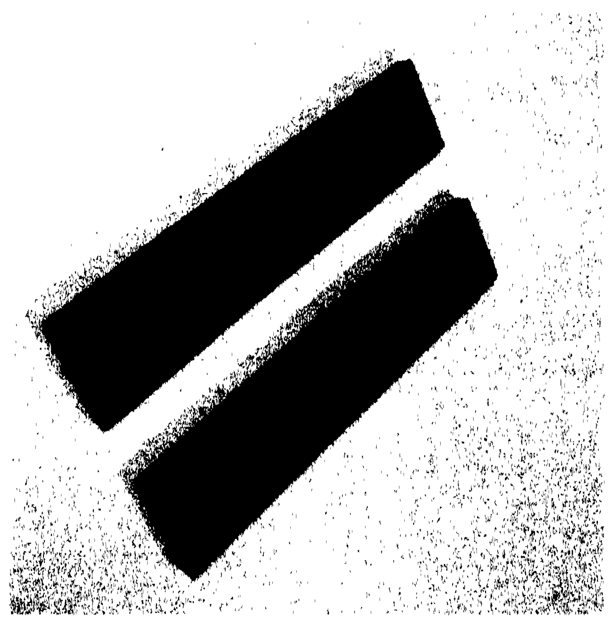
2P Sliced Veneer



2Q Laminated Cocowood

Board Products

Trials in the United Kingdom and in the Philippines [3] have been carried out on the production of particle board from coconuts.



2R Particle Board

The stem proved to be a difficult raw material for the purpose, though it was technically feasible to make boards conforming to accepted standards. An economic appraisal indicated however that board manufacture was unlikely to be viable in local conditions where competing materials exist or the market is too small.

Roundwood Products

The structure of the palm stem is ideally suited to its use as a utility pole since it has great strength and flexibility and is able to withstand high wind loads.[3] It is usually possible to select straight and defect-free stems suitable for power transmission lines.

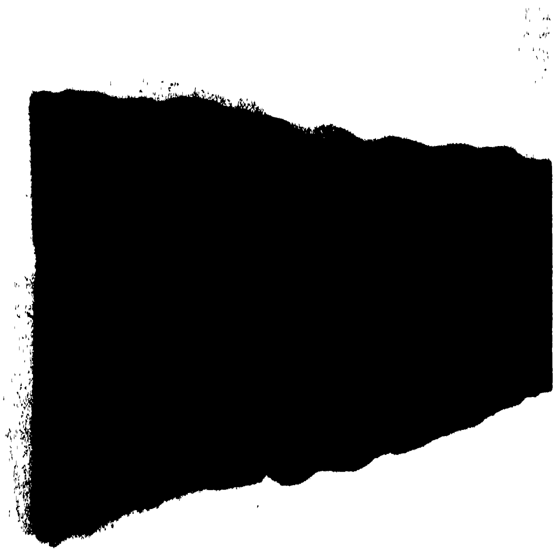
2S Power and Utility Poles

The main problem has been to dry poles sufficiently to permit pressure impregnation with a water-borne preservative, Debarking is an essential preliminary and no suitable fully-mechanized method has yet been developed. The process can be carried out manually with a spokeshave-type debarking knife.[3] The use of coconut rounds as house poles presents a similar problem.

Coconut fence posts should be prepared in semi or quarter rounds with the less dense material removed before drying and pressure treatment. This produces a post of adequate strength which can be efficiently preserved.

Fuel and Energy

The uses of coconut wood for charcoal and for the production of gas and by-products are described in Chapter 8.



2T A Slice of Cocowood from Bark to Bark roughly sanded

Chapter 3

Logging

Coconut stems can be felled and extracted in the same manner as other plantation trees.

In practical terms the felling and removal of coconut stems from plantations to a sawmill has to take into account the situation within the plantation - whether the area beneath the palms has been inter-cropped or grazed with stock, is flat or steep or rocky, whether the trees are concentrated or scattered.

The size and sophistication of the equipment is dependent, as in other forest operations, on the scale of felling and the location and capacity of the sawmill being supplied.

Logging

Coconut plantations are usually in easy and accessible terrain. The branchless and nearly straight stems, and their almost uniform and modest dimensions allow the use of comparatively simple equipment for felling, extraction and transport.

Selection and Felling

In Chapter 5 the principles of grading coconut timber are described. Quality control begins with the standing tree which may be assessed for age and potential log quality before felling.

Felling, while apparently a simple operation, is often complicated by the need to prepare the land for planting. This implies that, where the topography and absence of boulders permit mechanical cultivation, it is desirable to remove the stumps or at least reduce them to ground level.[2,3]

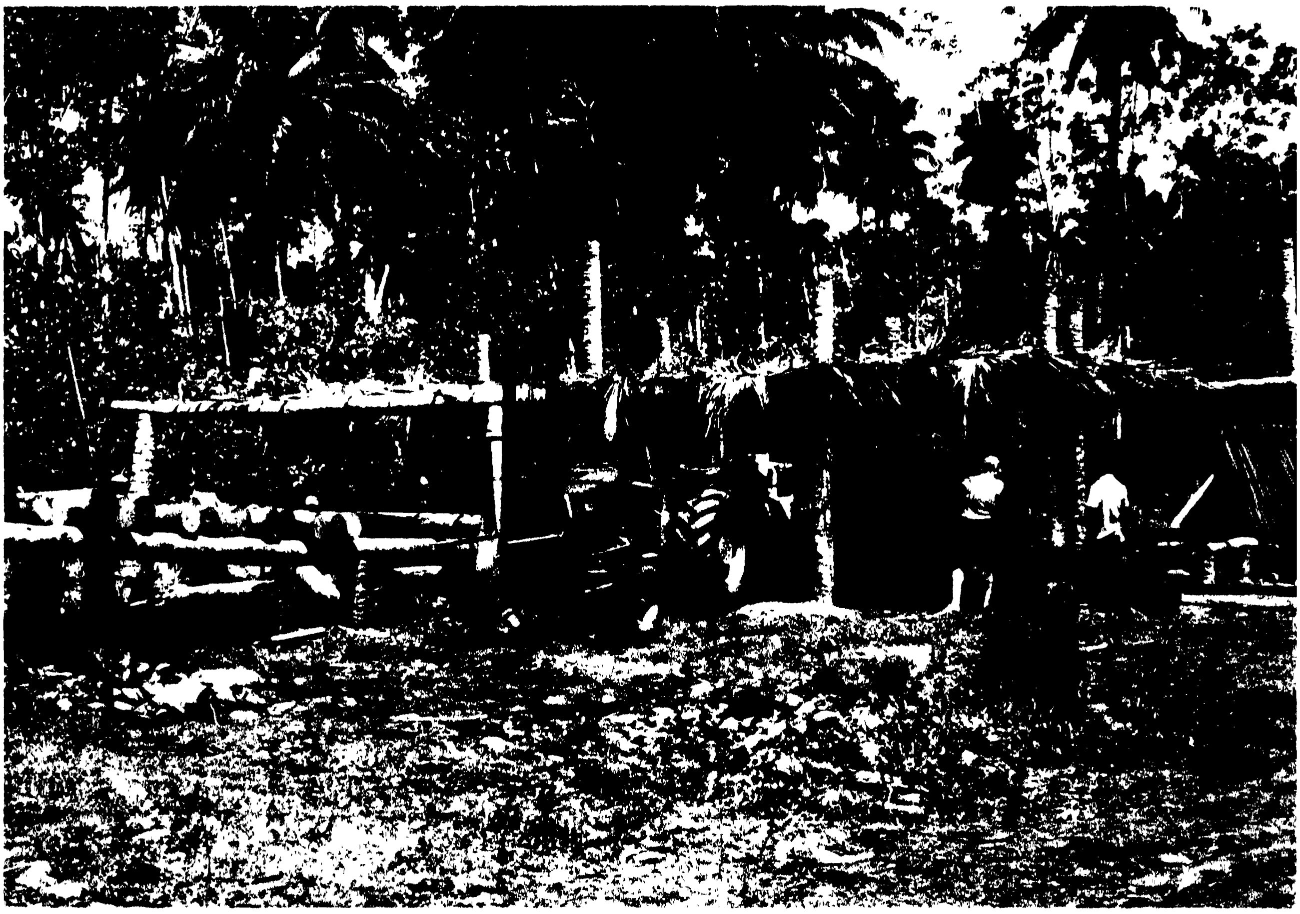
The extraction of the stump, together with the roots, is always a costly undertaking, requiring either heavy equipment or a costly input of labour, often both. If it has to be done, the roots and stump must be undercut so that the palm can be pulled or pushed to the ground by winching or bulldozing. The latter is unsatisfactory as it creates a massive problem of disposing of the stump and root system to which a massive ball of earth generally adheres. It commonly requires one man/day per stem to remove the earth and to expose the stump for burning (Figures 3.1, 3.2).

Uprooting of the stump is not, however, a standard practice, because of the cost. Stump disposal after normal felling remains a problem. One solution, already tested in the Philippines, may be the pulverising of the stump with a mechanical flail.[3]

Felling may be by axe or two-man handsaw where the number of trees to be felled is few, as in selective logging to eliminate dead, diseased or unproductive trees within a healthy plantation.

Clear felling for replanting is an operation of scale justifying the use of chainsaws. Experience in the Philippines indicates that this is the most efficient method provided that care is taken to fell the stems in a uniform direction to facilitate cross-cutting and extraction. Careful training and supervision of operators are essential, together with suitable arrangements for maintenance.

3A Tractors Used for Extraction can also Power Small sawmills



3B Log extracted by Draught Animals

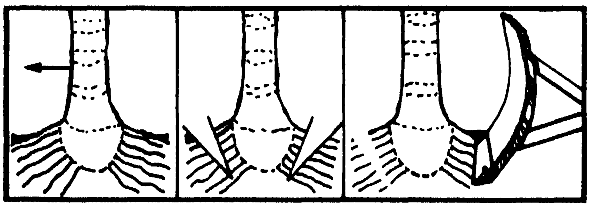
Extraction

Sawmill logs are neither large nor unduly heavy and present no problems in extraction. Depending on the scale of the operation and the nature of the terrain, extraction may be by draught animals, adapted agricultural tractors or specialised skidders.

The water buffalo, or Carabao, can play an important role in moving logs in isolated areas.

One of the most efficient and least expensive systems of log extraction is the use of an agricultural tractor with a towing bar fitted to the hydraulic lift arms.[3] This enables the butt of the log to be lifted clear of the ground for skidding . The same type of machine has proved suitable for the extraction of stems up to seventy feet long.

[Figure 3.2 Bulldozing through roots].



Transport

Loading and hauling do not require heavy or highly specialised equipment for the usual scale of plantation operation. Loading may be done manually when the logs are small; in other cases, by cross-hauling with a skidding tractor or with a hydraulic front-end loader.

Log transport, as in any forestry operation, has to be by the most economic means. In small scale plantation clearances unspecialised flat bed trucks, or four-wheel bunk trailers towed by agricultural tractors, have proved suitable.[3]

[Figure 3.1 Cutting through stem roots]

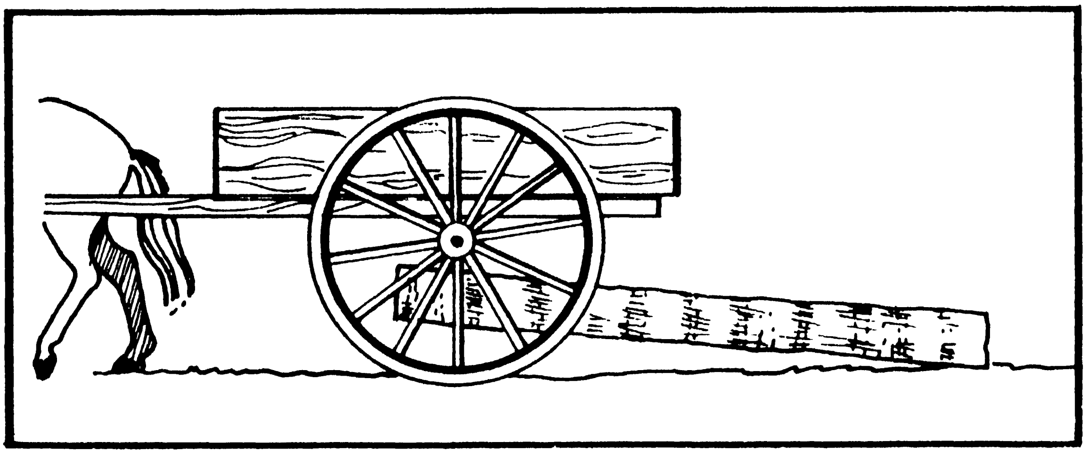
Cross-Cutting

Before the palm trunk is cut into logs, the location of each cut must be marked, the length of the log depending on the curvature of the stem and the intended end-use. High quality stems for special uses such as transmission poles, for example, must be identified and cut accordingly. Sawmill logs are usually cut into four to six metre lengths, each stem yielding one or two logs depending on the height and soundness of the tree.

Disposal of Debris

In order to minimize infestation by the rhinoceros beetle and by the palm weevil, it is of great importance to dispose of the palm fronds and the discarded top portion of the stem after logging. Utilization is in some cases possible through transport of woody material as fuel to nearby users, or by charcoaling on the spot. Otherwise all debris should be piled for drying and then burnt.

Figure 3.3 Skidding Log Behind Horse



Chapter 4

Primary Conversion

The sawing of coconut logs calls for care in selecting cutting patterns which ensure the maximum yield of the higher density outer material.

The hard and abrasive nature of the wood makes it necessary to use hardened saw teeth.

These considerations apart, primary conversion can be satisfactorily carried out with conventional sawmills, although special types, designed for portability, have been developed.

Primary Conversion

Cutting Patterns

Approximately 70 per cent of the cross-section of a coconut log is hard to medium wood, confined to the periphery, and of this slightly less than half may be recovered as sawn wood. The soft core, often extending to 100 x 100 mm sawn, must be separated and graded as inferior. It is preferable to leave bark on the higher quality outer wood rather than include any of the core. Resawing for export quality can be undertaken as required.

A typical cutting pattern for 200 to 300 mm diameter logs, designed for a centre-held log to ensure separation of hard and soft material, is shown in Figure 4.1. This gives a choice of 100 x 500 mm or 75 x 50 mm pieces plus 50 x 50 mm and 50 x 25 mm offcuts. The same pattern can be used in conventional mills as indicated in Figure 4.2.

Cutting patterns for beams and purlins are shown in Figures 4.3 and 4.4, and for grade selection in Figure 4.5.

Sawmill Systems for Coconut Timber

The most important factors in selecting milling equipment are portability and ability to be relocated if this is required; simplicity of design to avoid breakdowns which are difficult to repair in isolated situations; ease of operation as skills of operators will often be limited; and inexpensiveness as the industry is often sited in poorer, underdeveloped areas.

There are many designs of sawmill in use. In Tonga in 1983 there were in fact six mills operating, all of different design, five being manufactured in New Zealand and marketed as coconut wood sawmills, and one an old locally redesigned stationary mill. The mill layout and operation should relate to the end use at which the product is aimed. The inflow of logs should be simple, with lifting avoided and limited storage space as logs should be milled within hours of delivery if possible. Immediately after sawing, all timber should be dipped in a bath of anti-sapstain chemical and then fillet-stacked in an orderly and systematic manner for drying, carefully retaining grading marks applied in the forest.

Types of Mill Used for Sawing Coconut logs[40]

Full service tests have not been reported on all the mills used in milling coconut wood, but tests reported from the Zamboanga Research Centre in the Philippines and the Timber Industry Training Centre in New Zealand provide a guide to the selection of mills for different conditions. Other trials have been reported from field use in the Philippines, in Tonga and Kiribati.

The specifications, advantages and disadvantages of these mills are as follows:

1. Medium-size portable sawmill

A mill of this type was designed with the assistance of the TITC, specifically for the milling of coconut stems in Tonga. It is a robust machine capable of being towed over rough terrain without distortion to the frame. The main unit has jack screws at either end which can be wound down on to wooden pads to prevent movement. (The weight of the carriage travels from one end of the track to the other.) As it is on a single axle with dual pneumatic wheels it is desirable to jack and put solid packing under the central main frame to prevent movement during operation. It is desirable but not essential to have the machine set up perfectly level. All parts of the unit are tied in rigidly together (track, carriage, headsaw, power unit, rollcase) and need to be in true alignment to each other.

This machine was originally designed with a 9-gauge 1120 mm diameter saw which is adequate for most coconut logs. The companion breast bench unit can be towed by a car on roads or a tractor in rough terrain. It is self contained, of rugged construction, with trolley tracks mounting directly on to the main frame. It thus stays in true alignment with the machine regardless of the circumstances. The power pack on the main unit is mounted on a frame that can be rolled in from its operating position, making the unit more compact for transporting.

The breakdown unit requires a motor of power equivalent to a 75 h.p. electric motor and the breastbench a 30-35 h.p. motor.

Field trial

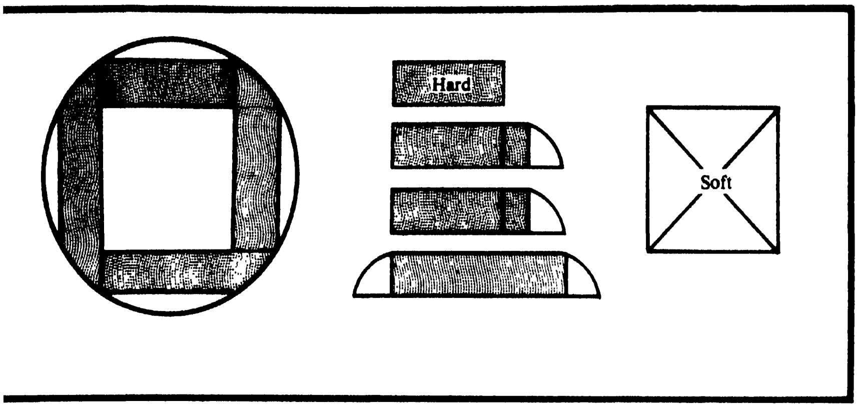
A production study of this type of mill was undertaken in the Philippines [38, 43] at the Coconut Authority Research Station.

The logs used were from 116 coconut palms felled and left on the ground in the field for about eight months, and from 241 newly felled coconut palms. The trunks, cross-cut to log lengths ranging from 10 to 16 feet from the butt to the upper portion, were piled near a fairly level site where the mill could be set up.

The portable sawmill consisted of a 1120 mm diameter breakdown saw and a 195 mm diameter saw in the breastbench. Both circular saws, equipped with 17 and 13 stellite teeth respectively, were driven by a single engine. The mill was towed to the site with an ordinary farm tractor and was set up in one day.

The mill was set to an engine speed of 2100 r/min giving an equivalent breakdown saw speed of 770

Figure 4.1 Cutting Pattern for Centre-held Log System



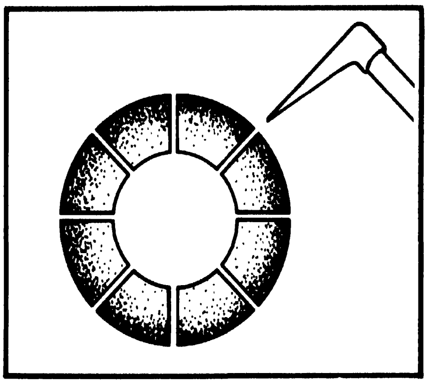


Figure 4.4 Additional Pattern for Cutting Purloins

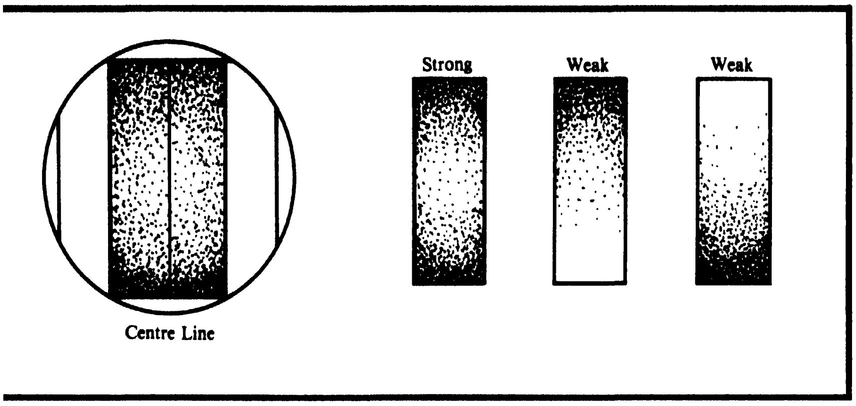


Figure 4.3 Cutting Pattern for Beams

Figure 4.5 Cutting Pattern Relative to Selection and Grading

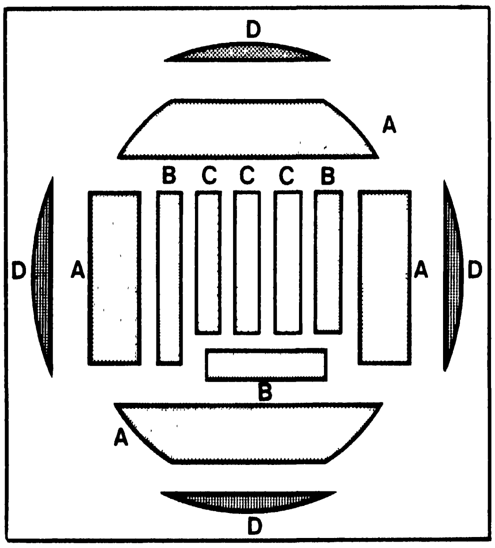
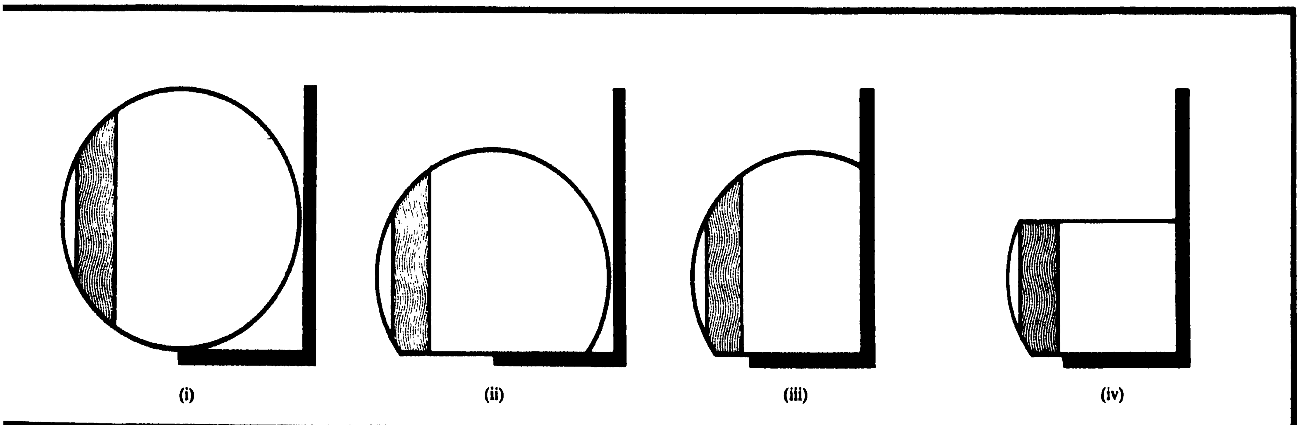


Figure 4.2 Cutting Pattern for Conventional Sawmills



r/min which in turn generated a saw speed of 1250 r/min in the breastbench. A 30-degree hook angle was maintained throughout the sawing process. A crew of seven men operated the mill in sawing the specimen with one man assisting in the gathering of data.

About 16 per cent of the logs from coconut trunks stored for eight months could not be sawn because of decay, stain or holes in the core. The average sawing time was three hours a day. About five hours were spent in conducting and fetching the crew to and from the mill, grading and stacking the sawn timber, sharpening the saw, removal of sawdust, and rolling of the logs to the deck of the mill.

The sawn timber was graded and stock-piled outdoors according to density classification. Coconut stumps 45 mm long were used as posts in stacking the sawn timber above the ground. Square 25 mm fillets placed across each layer of timber allowed the air to pass through the pile. Inspection was done once a week for the first month, and twice a month thereafter. Recovery from the old trees was 34 per cent and from the freshly felled trees 41 per cent. Approximately 14 per cent of the sawn timber was of dense grade.

The implications of harvesting steps cut in the side of coconut stems were evident in the Philippines. The steps reduced the recovery of sawn timber, particularly denser grades.

Results of the sawing tests showed that the portable sawmill can operate efficiently under field conditions. The average feeding/sawing rates varied according to the type of log sawn as follows: butt logs, 23.4 m/min; second logs, 30.6 m/min; third logs, 36.3 m/min. Loss of power was observed in the engine when sawing butt logs at an increased feeding rate. An average of 30 logs were sawn per sharpening. The stellite saw teeth with 30-degree hook angle had to be replaced after seven to eight sharpenings.

The results also revealed that ten fresh logs can be sawn at an equivalent output of 0.7 cubic metres sawn timber per hour.

Recommendations resulting from the trial:

(a) Coconut trunks should be sawn in 'green' condition to obtain better quality timber. Building up of heat in the saw blade during the sawing process is minimised as the trunks are very wet.

(b) There should be a saw doctor in the crew, an anvil for tensioning the saw blade, and a 1.5 h.p. generator for the jockey grinder used to sharpen the teeth.

(c) For commercial operations the mill should operate at least six hours daily with a crew of 12 men. Six men including the saw doctor will operate the mill and the remaining six will roll the logs to the deck of the mill, grade and stockpile the sawn timber, remove the sawdust and slabs, and supply water to the mill.

2. Larger Transportable Sawmill

A larger sawmill was designed to meet the demands of milling coconut stems in the Philippines.

In design it is almost identical to the previously mentioned mill. It is larger and has a three headblock carriage. It is transportable rather than portable, being dismantled in sections and put on a carrier rather than having its own axle and draw bar.

The unit can also be equipped with a bandsaw in place of the 1372 mm circular.

The breastbench equipment and saw are identical to those described earlier.

3. Light, General Purpose Portable Sawmills

Sawmills not designed for the cutting of coconut but rather as simple low cost mill units suitable for farms or contractors with small blocks of timber are quite widely used but have their limitations.

One variety is lightly constructed of RHS and angle iron with a steel plate sliding on the top runners as a table top carriage. It also has a lightly constructed breastbench as part of the complete mill set up. Although the main unit is on its own axle for portability, setting up is not as quick and simple as the first mill described.

4. Mini Mill

There are several mini mill designs now built in America, New Zealand and Australia. The smallest of the range is probably the most suitable for cutting coconut logs.

Differing from other designs where the log is fed to a stationary saw, this particular design has an air-cooled petrol motor mounted on a frame driving two circular saws which are mounted at right angles to each other. The saw unit travels along a track on the main framework. The saws are raised and lowered in relation to the log, and can also be moved laterally. With each pass both a horizontal and a vertical cut are made with the two cuts meeting accurately. These mills were originally designed for cutting large logs which were supported on skids on the ground, and are far less efficient in cutting small diameter logs. The unit is capable of milling coconut stems, but is not well suited to the purpose because the logs are small and must be rotated to recover the maximum high density timber.

5. Breastbench With Light Weight Carriage

Breastbench mill with an added light-weight, carriage which is merely a heavy timber plank with metal bracing. It has a steel section on its underside running in a groove in the trolleys and the feed rolls on the bench and has light dogs attached that may be hammered into the log. The feed rolls are hydraulically powered with easy control of speed and reversing. This bench is ideally suited for small logs. The log is first broken down on the carriage to manageable sections, then the carriage is removed and the unit used as a normal breastbench. Production is low but only three operators are needed.

6. Sawing with a Chainsaw and Guide Attachments

Where high production is not needed, chainsaws are useful in log conversion and have the advantages of portability and low initial cost.

Chainsaws should be of at least ten horsepower and chipper chains are recommended because of the ease of sharpening. Tension must be maintained and the bar and chain kept well oiled. A sprocket-nosed bar assists in maintaining high chain speed.[47] [48] The saw is fixed and the log fed slowly through.

Sawblades for Coconut Stem Conversion [41]

In the milling of coconut stems as with any other species it is the saw blade that is the work tool used for reducing the log to sawn timber. If there are any peculiarities in a particular species (hardness, irregular grain, abrasiveness etc), the saw blade will be changed or the cutting speed altered. Peculiarities of coconut wood are its abrasive nature and the extreme hardness of the bundles of fibres in mature stems.

Consequently it is not practical or economic to use standard plate saws, as a very limited number of cuts would be made before the saw became too dull to cut. Hard facing of the saw teeth is necessary if cocostems are to be sawn economically. There are various materials that are suitable for the hardfacing of saw teeth, each having its own method of application and maintenance requirements.

4A The Tungsten Carbide Tipped Saw

The materials that have been used to date are various grades of tungsten carbide, various grades of stellite, tunsweld, tungtech, carbitroning, high speed steel and high frequency hardened steel.

Tungsten Carbide

Tungsten carbide tipping of saw teeth is the most successful way of overcoming excessive saw teeth wear or dulling. The tungsten carbide tips are formed during manufacture to shape and dimensions suitable for fixing straight into recesses on the face of the saw teeth. Grinding to final shape and dimensions for the required use is carried out on the complete saw blade.

Although tungsten carbide has been used successfully on bandsaws and there would be no problem on frame saws (provided there was adequate clearance of the tips on the back stroke) it is mainly used on circular saws. Tungsten carbide is not an economic tipping method for bandsaws because of the number of tips required, the type of equipment to service them, and the time and skill required to maintain them.

A high degree of skill is required to maintain tungsten carbide tipped circular saws. Relatively expensive precision grinding equipment utilizing diamond grinding wheels is essential. A suitable sawshop is required which rules out servicing the saws in the field. The best known practical option in the field is a single grinder for face grinding of the carbide. The grinder would need to be a precision machine utilizing diamond wheels. The face grinding could be carried out only two to three times before the saw was sent to the sawshop for a full service.

Tungsten carbide is available in various grades. These range from softer less wear resistant but tough material, to harder more wear resistant but brittle material. Most tungsten carbides have a cobalt base. But some are also available with a nickel base. Nickel is recognised as being more corrosion resistant, tougher and easier to braze to the sawblade. The normal grade of carbide used on saw teeth is I.S.O. K20 or equivalent. But for cutting coconut the next tougher grade I.S.O. K30 may be desirable.

Preparing saws for tungsten tipping, and fixing the tips securely into the accurately ground or milled recesses in the saw tooth faces, requires skill and scrupulous attention to detail. Similarly, final grinding to produce an optimum cutting edge demands knowledge and skill, and good quality equipment. Silicon carbide grinding wheels may be used for rough grinding but diamond wheels are essential for finishing.

The essentials of carbide saw use and maintenance can be summarised as follows:

(a) Cleanliness is extremely important
(b) Carbide is brittle and must be handled with care
(c) Too large a tooth bite should not be made as the shock of overbiting can cause carbide breakages. Recommended maximum bite is approximately 1.3 mm per tooth
(d) The sharpness angle should be kept to at least 45° to ensure a strong tooth point
(e) The correct diamond grinding wheel for the job should be selected. Extreme care should be exercised while grinding
(f) Diamond wheels are expensive items and ought only be used on precision grinding machines
(g) Carbide requires great accuracy in the grinding finish. Angles on its face, back and sides and should be ground on precision grinding machines
(h) Trained personnel ought to carry out the work.

Stellite (Tungsten Cobalt Alloy)

As with tungsten carbide, stellite is available in various grades from softer, tougher grades to harder more brittle grades. The tungsten carbide manufacturing process requires that all components, including saw teeth, are formed close to their final shape early in the process and then fixed to their working place by another medium such as silver solder. In contrast, stellite is available in rod form. It can be fused directly, with heat,on to the base metal.

Consequently, stellite can be used equally as well on any type of saw, including bandsaws. It is used extensively where hardwoods with an abrasive nature are to be cut. Grade 6 stellite, which is identifiable by a red tip, is the most commonly used on saw teeth.

Cobalide 3 which is a similar material under a different trade name is also quite satisfactory. A newer material put out by Eutectic, called Eutecbor 9000, has become very popular for this use and has proven very satisfactory. The main reason for its popularity is its ease of use in applying it to the base metal, it also has very good wear and shock resistance.

Stellite is also available for saws as a preformed tip. This can be fixed to the saw using silver solder. However, these tips are more expensive than carbide.

Method of Tipping

There are three main methods of applying stellite to saw teeth.

(a) A drop of molten stellite can be applied to the swage cup

(b) A large deposit of stellite can be melted on to the end of a saw tooth which has been ground back slightly. The stellite is then formed with dies so that it looks similar to a swaged and shaped point

(c) Molten stellite can be poured into a ceramic mould around the tooth point. This gives a finished point similar to Step b.

The usual procedure in grinding stellite tipped saws is to grind the faces and backs first, then to grind the sides of the swage with an "equalising" machine. The main reason for following this procedure is that the size of the finished point can be more easily controlled if the side grinding is performed last. When grinding the faces and backs of the teeth, care must be taken to ensure that the feed finger does not push on the stellite deposit.

It is common to find sawmills using stellite tipped saws running the saws to the extent that the points become rounded and dull. In most cases it would be better to change the saw before it got to this point. This would result in less time being taken to sharpen a saw. More sharpenings would be gained from the stellite. Sharper tips also mean production of less badly cut and thus wasted timber. It would also increase the overall life of the saw.

With bandsaws, this tendency to continue sawing too long before re-sharpening (particularly with softer wood) frequently leads to gullet cracks as the saw becomes fatigued.

Details of methods of forming and grinding stellite tips have been omitted from this account. But it must be recognised that considerable skill, and the use of precision equipment are necessary for satisfactory saw performance. For these reasons most smaller mills used for cutting coconut wood have favoured the use of circular saws with inserted teeth which are rugged, easy to maintain by face grinding, and can be easily and quickly replaced when too worn for further grinding. The most satisfactory inserted tooth for cutting coconut to date has been a stellite inlaid tooth. This is a standard carbon steel tooth with a coating of stellite over the top and side surfaces, approximately one to two mm thick. Wear resistance is good. Only face grinding is necessary. Filing is not possible. Grinding is best done on a hand gulleting machine with the saw removed from the rig. A good finish must be maintained with angles accurate and face square. Portable jockey-type grinders which clamp on to the saw blade have been used in small coconut mills, but none seem to have been really satisfactory for maintaining a good cutting edge.

Tungtech

Tungtech is a powder application that can be used to harden the surface of any base metal. The alloy powder containing particles of tungsten is applied through a special oxy-acetylene torch to the surface of pre-heated base metal. The flame sweats the alloy powder into the surface of the material. This has only been used in trials so far. It has proven successful on heavier gauge circular saws. Some skill and care is required in this application as misuse of the heat will result in melting and rounding the cutting edges.

As the coating of powder is quite thin even a light grind would remove it. Therefore it must be applied to the tooth after sharpening.

A thin layer is then applied to the face of the tooth. The tooth is again ground lightly on the back to regain a sharp cutting edge without removing the hard facing from the face of the tooth.

Carbitroning

Carbitroning is the deposition of materials such as tungsten carbides and titanium carbide from an electrode of these materials by spark action on to the surface of the saw teeth. The electrode which is held in the electrical machine designed for this method of coating is vibrated against the tooth surface. The vibration makes and breaks contact causing sparks which transfer the molten carbide to the tooth. The thickness of the deposit layer will only be up to about 0.07 mm (.003 inch). For this reason the method is not entirely efficient as in some species, acids in the timber apparently will eat under the layer lifting it off. However cutting time is claimed to be increased up to five times and longer.

High speed steel

High speed steel is used in the form of inserted saw teeth. As with the stellite inlaid teeth the high speed steel teeth were designed for use in cutting species that ordinary carbon steel would not cut effectively. These bits can be used in inserted tooth saws for cutting coconut, but are not as wear resistant as the stellite inlaid teeth, nor as economical.

Waste Disposal

Waste products — or by-products — from the felling and milling of coconut trees are either a costly embarrassment to dispose of or a potential additional resource. The most important consideration with regard to removal of the trunks and other debris from coconut plantations is the phytosanitary aspect - the potential threat of pests on the newly established plantations. Rotting logs and other decaying debris provide ideal breeding places for two major coconut pests, the coconut beetle *Oryctes rhinoceros* and palm weevil *Rhynchophorus schach (Oliv).*

Disposal of the woody waste left over from milling is a problem. Burning is the cheapest and safest means. Discarded round logs, generally from the upper softer trunk, are best cut to approximately half-metre lengths, split and stacked to partially dry. They can then be burned, or used for some form of fuel (charcoal, gas, firewood). Palm fronds and the "palmit" or delicate fleshy bud in the crown of the tree become available as useful by-products if organised collection and disposal is carried out.

Chapter 5

Grading Coconut timber

Grading coconut timber according to low, medium and heavy densities is important, since the different grades have different end uses. Timber of mixed densities is more likely to twist and degrade.

Grading should begin at the commencement of logging, and be followed through the sawnwood conversion process.

The development of a uniform grading standard would help to promote local and export marketing.

Timber can be graded visually or by more elaborate techniques. A simple colour coding system is appropriate for use in recording grades.

Grading Coconut Timber

Quality Control, Particularly Relating to Export

In the course of coconut market research and product development it has been established that no importer in any of the countries surveyed is prepared to make a commitment to purchase large volumes of coconut wood unless both quality of material and reliability of supply are guaranteed. It is also desirable that uniform grading should be established within the various producing countries.

When any country considers the establishment of a coconut milling and processing industry, there should be emphasis on an overall control which is sufficient to co-ordinate quality standards. This control should not restrict efficient management but should aim to protect and foster the interests of the country, the coconut industry and its customers. An enforceable quality standard provides such a control.

System of Identification

The maintenance of quality control of coconut wood is not merely a matter of inspection and grading at the point of sale or export. Because of the widely varying densities of material within each log, and the difficulty of differentiating these by superficial inspection after sawing has taken place, it is essential that grading and identification of the wood from different parts of a log and from different logs along the length of a tree be carried out in the plantations at time of felling. Such a grading system, consisting of colour-coding the butts of logs immediately after the trees are felled and cut to length, whereby the colour markings remain on each timber piece after the logs are sawn, has been developed and tested.

The general principles of this grading system are as follows:

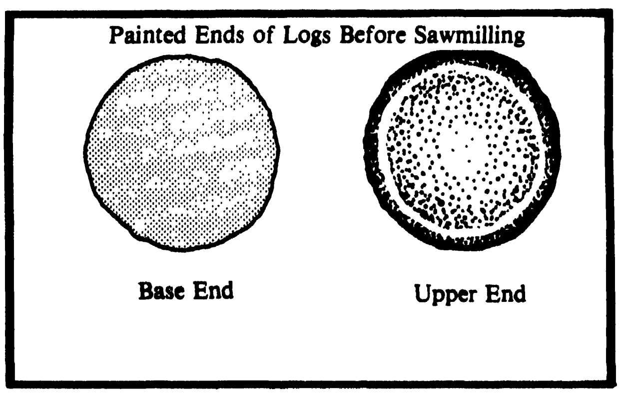
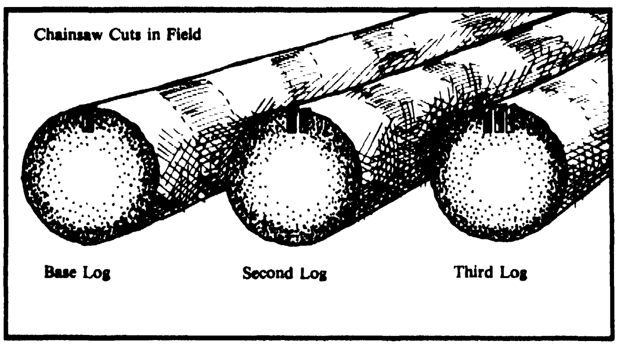


Figure 5.2 Colour Grading on Log Butt

It is first necessary to inspect standing trees so that a judgement can be made as to a tree's age, by means of length of leaf, nut production and the characteristic thinning of the stem below the crown. Suitable trees are then marked, felled and cut to length.

Before extraction, every log must be marked to establish from what part of the tree it comes. It is convenient when sawing to length to make a single chainsaw niche on the lower end of base logs, two niches for second logs and three niches for upper logs (see Figure 5.1). Then, after the logs are stockpiled butts are painted different colours on the lower end (base logs RED, second logs GREEN and third logs YELLOW). On the reverse ends they should be painted with a WHITE band extending 70mm in from the circumference (see Figure 5.2).

Figure 5.1 Chainsaw Grading Marks on Logs



Grading

After such an identification system as described above is in place, quality specifications are then necessary in relation to each end use.

In the local house-building market little further grading would be required, though general information on the characteristics and appropriate use of each grade should be available.

For other building construction, which may be subject to local government regulations or building codes, more detailed specifications are required.

Timber should be graded hard, intermediate or soft, corresponding to high, medium and low densities. The technical limits between the grades are:

High Density above 500 kg/m^3

Medium Density between 500 and 350 kg/m^3.

Low Density less than 350 kg/m^3.

As a rule only high density coconut timber is acceptable for structural purposes.

Sample Specifications

Specifications for coconut timber drawn up by a timber exporting company[46] are as follows:

-Milling tolerance minus nil plus 2.5 mm

-Minimum basic density 400 kg/m^3- for medium density and 600 kg/m^3- for high density

-Maximum moisture content E.M.C. of supplying country

-Timber must be clean and free from defects such as bark, rot, collapse, sapstain, brown spot, twist, cup, spring, checking, warp, wane or other visible imperfections

-Timber should be milled within eight hours of felling trees

-Dip all timber in approved anti-sapstain solution immediately after milling

-Protect timber from rain after dipping

-Transport timber to drying yard immediately

-Re-dip in anti-sapstain solution prior to stacking. It is preferable that this is carried out under cover to avoid any chance of chemicals being diluted by rainfall

-Fillet stack timber in proper drying racks protected from rain and direct sunlight within 24 hours of milling.

The anti-sapstain solution utilized was a proprietary mixture of captapol and chlorothalomil, maintaining a minimum concentration of 0.4 percent captapol.

Packing specifications for rough sawn timber established for export control were that all timber for shipment should be steel banded, using 75 x 25 mm fillets under all-steel banding. Packets should be banded on 100 x 50 mm gluts to facilitate forking. Packets should contain timber of like specification and be in packets of no greater than one cubic metre. After drying to E.M.C. packets must not be exposed to wet conditions.

Grading Techniques

Techniques which have been examined include visual grading, basic density determination, and grading by weight. Checks on density can be made by means of the Janka hardness test.

Visual grades may be as follows:

C-1 (clear one-face)

-Clear of step or wane on one face

-Step or wane can appear on up to half of the thickness away from the clear side of the board

-Solid spot can appear on the clear face, but in area less than two percent of the face, and individual areas of less than 0.5 cm^2

-No string spot allowable

-Lengths to a minimum of one metre accepted

C-2 (clear both faces)

-Clear of step or wane on both faces

-All sides square

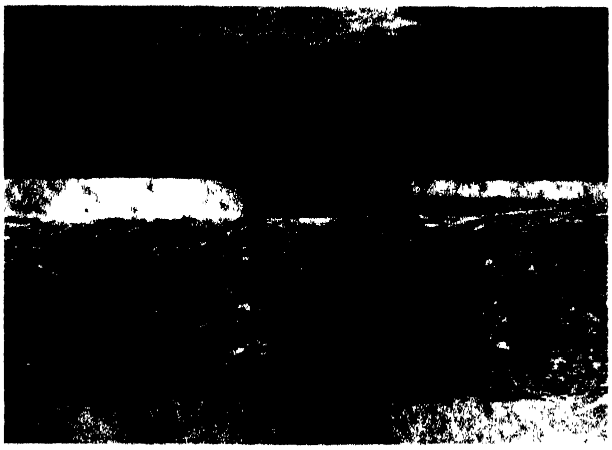
-Spot as described in C-1, for both faces

-Lengths as described in C-1

Utility

-Wane allowable up to half an edge and half one face

-Step allowable on one edge all across; but not more than one-quarter width of the face; OR one face all across but not more than one-third of the edge



5A The Low-density Grade Collapses

-Hard spot allowable in any quantity in medium and hard density, and 20 per cent area of any face in soft density

-String spot allowable up to five percent of the surface area of any face

Grading by Basic Density

The basic density of a piece of coconut timber is information of considerable value in grading and utilization of the timber. It is calculated as the oven dry weight of a sample divided by its green volume. The procedure is relatively simple and can be used within the trade to check the quality of a consignment.

Density is closely correlated with hardness which may be measured by the Janka test. This measures the pressure required to compress a metal ball of standard diameter for a measured distance into a timber sample. Tests carried out on the wood from the peripheral zone of butt logs from coconut trees from Tonga showed an average resistance of 10,950 newtons radially and 10,800 newtons tangentially at 12 percent moisture content. Comparative figures for other timbers are :[17]

European Oak	5050N - 5550N
North American Oak	5600N - 6250N
Teak	5050N - 5550N
Tawa	6300N - 7100N
Rimu	2850N - 3550N
Sapele	5600N - 6250N
Radiata Pine	2250N - 2800N
Kwila	8050N - 8900N

The figures illustrate the significantly higher hardness rating of selected coconut wood.

Appearance

The appearance of coconut wood is distinctive. The grain is strong and irregular so that the texture is variable. There is also a noticeable colour variation, sometimes related to density, the denser wood being darker. It has also been noted that there are two varieties of tree, one which produces very dark wood and the other a lighter wood. There is thus opportunity for the production of a range of colour grades in joinery or decorative features. It follows that colour classification of the wood during processing is sometimes advantageous.

5B The Densest Grades are Strong Enough for Structural Uses

Chapter 6

Seasoning Coconut Timber

Coconut sawn timber dries readily as 25 mm boards but thicker sizes dry very slowly.

Degrade is not severe apart from collapse in material below 350 kg/m^3 basic density 16.

Sawn timber should be sorted according to density before seasoning.

Seasoning Coconut Timber

Coconut sawn timber dries readily as 25 mm boards but thicker sizes dry very slowly. Degrade is not severe apart from collapse in material below 350 kg/m^3 basic density.[16] Sawn timber should accordingly be sorted according to density before seasoning.

Air Drying

The moisture content of coconut sawn timber ranges from 90 per cent to 180 per cent. The risk of stain and mould in air drying is such that appropriate chemical dip or spray treatments should be applied before stacking. For the same reason, protection from rain is desirable and air drying should be carried out in an open-sided roofed shed.

6A Correctly Stacked for Air Drying

Similar drying times have been reported from several Pacific Island countries.[2] 25 mm boards dry from green to equilibrium moisture content (17 to 20 per cent) in 9 to 10 weeks, while 50 mm material may require 6 months or more.

Kiln Drying

The New Zealand Forest Service, Forest Research Institute, has recommended kiln schedules as a result of studies on material from Tonga.[3]

25 mm Material

Moisture Content[1]	Dry Bulb Temp °C	Wet Bulb Temp °C
Green	60 (140°F)	54 (150°F)
100	60 (140°F)	51 (125°F)
60	71 (160°F)	60 (140°F)
Final conditioning	77 (170°F)	76 (168°F)4hr

[1] *Average moisture content of the two sample boards of the highest moisture content.*

Drying time is six to seven days in a commercial stack.

50 mm Material

Preliminary air drying to 25-30 per cent moisture content is recomended since 50 mm pieces cannot be satisfactorily kiln-dried from green.[3] Drying may take five to six days on the following schedule.

Moisture Content	Dry Bulb Temp °C	Wet Bulb Temp °C
30	60(140°F)	54(130°F)
25	66(150°F)	57(135°F)
20	66(150°F)	70(158°F)
Final conditioning	71(160°F)	70(158°F)8hr

The denser grades of coconut do not have a high differential shrinkage so the tendency to distort is not severe. Twist is commoner than bow or spring.[2] Collapse is the most obvious seasoning degrade, increasing progressively below about 350 kg/m^3 basic density at which level it may not be recoverable. In denser material, reconditioning after drying gives good recovery from collapse.[3]

Seasoning of poles

Because coconut wood has a high moisture content and is very prone to fungal infection it requires special care in drying in the round before preservative treatment.[13] Debarking is essential and the material should be stacked in sheds or under a rain-shedding cover in locations with good air movement.

Chapter 7

Preserving Coconut Timber

Coconut wood in contact with ground or water requires preservation if it is to last more than a few years.

Coconut wood for interior uses, such as furniture, flooring or walling, does not generally need to be treated with preservatives, although in some environments the timber (particularly low density wood) should be treated against termites and other wood borers.

Preserving Coconut Timber

Provided the timber is adequately seasoned, coconut wood can be treated by the vacuum/pressure method using copper-chrome-arsenate preservatives. It can be used in the sawn form for weatherboards and verandah decking, in either sawn or round form for house piling, in the round or quarter round form as posts, and in round-form as poles.

Material which has been treated and exposed in service trials indicates that if used clear of the ground, a life of 20 years could be anticipated, and rounds or quarter rounds used in contact with the ground should have a service life at least in the order of 15 years.[19]

Coconut wood in contact with ground or water requires preservation if it is to last more than a few years. Coconut wood for interior uses, such as furniture, flooring or walling, does not generally need to be treated with preservatives, although in some environments the timber (particularly low density wood) should be treated against termites and other wood borers.

In some environments all densities of sawn timbers will need protection against termites and other wood borers.

Some uses exposed to the weather may not justify full strength treatment. The preservation required may be necessitated by standards and local building codes, or by the length of life required. Housing from coconut timber which has been brush treated with preservative will give the house a longer life than a thatched roof house of lesser quality. Local economics can determine the preservative and length of building life desired.

It is preferable and more feasible to avoid ground contact by placing a house on foundations with a waterproof barrier between the foundation and the wood.

Health standards and public attitudes to the use of preservatives with toxic ingredients provide further cause for concern at the suitability of different types of preservation.

Load bearing poles, from fence posts to electric transmission poles, require higher standards of treatment. Coconut wood can be used inside buildings without treatment. Insects are not a major threat to dry wood.

When exposed to the weather but not in contact with the ground some protection is required. Pressure treatment with copper-chrome-arsenate to intermediate retentions (five to ten kg commercial salts/m^3) gives excellent results. Brush-coating dry wood with creosote or copper naphthenate will give good protection but retreatment will be necessary every three to four years. Surface pre-treatment with inorganic salts (e.g. 12 per cent acid copper chromate) followed by one or two coats of latex emulsion stain will give a good and durable surface.

Preservative requirements for ground-contact timber, e.g. posts and poles, are still unresolved, and more well-controlled tests are needed before a confident assessment can be made of the suitability of treated coconut wood in this situation. The most crucial factor seems to be making absolutely sure that the wood does not become infected by any fungi between felling and final treatment.[21]

Coconut stem wood is not very susceptible to attack by wood boring insects and will give good service without treatment if it is protected from the weather. If protection from insects must be ensured the wood can be readily treated with boron by diffusion.

Exposed to the weather or in ground contact coconut wood is perishable and preservative treatment is essential. Debarking round poles and posts is an extremely difficult task but is necessary if they are to be treated by conventional pressure methods or hot and cold bath. The wood must be at least partially air-dried before treatment and this must be done under cover. Provided the outer zones are well dried, good retention and distribution can be achieved with creosote by hot and cold bath, and copper-chrome-arsenate by vacuum/pressure.

Pressure sap displacement of unbarked logs has proved impracticable.[20]

Oil- and Water-based Preservative Techniques

There are two general types of wood preservatives. These are the oil-type such as creosote and pentachlorophenol, and the water-borne salt-type such as copper-chrome-arsenate.

A black or brownish oil made by distilling coal tar or coal-tar creosote, is effective for preserving wood, but its colour, and the fact that creosote-treated wood cannot be painted satisfactorily, make this preservative unsuitable for finished timber where appearance is important. In addition, the odour of the creosoted-wood is unpleasant. Nevertheless, coal-tar creosote can be satisfactorily used in treatment of fence posts and posts of low-cost houses where the materials are used externally and in ground contact.

Pentachlorophenol solution preservative generally contains five per cent solution of chlorinated phenols in a solvent of liquid petroleum gas. The heavy oil remains in the wood for a long time and does not usually provide clean or paintable surfaces. Pentachlorophenol solutions are usually applied to wood for exterior use.

Copper-chrome-arsenate preservative is highly soluble in water. This is sold in the market under trade names such as Tanalith C, Boliden K33, Celcure AP. Copper-chrome-arsenate is now preferred and more widely accepted than coal-tar creosote/pentachlorophenol because it leaves the wood clean, paintable and free from objectionable odour after treatment. Furthermore, coal-tar and pentachlorophenol have become more costly than the water-borne preservatives. However CCA is not acceptable for the treatment of roof shingles where the roof is to be used as a catchment for drinking water.

Preparing Timber Prior to Treatment

All coconut timber to be treated must be free from defects to attain satisfactory treatment and good performance thereafter. Treatment of timber by diffusion using water-borne preservatives may be done on freshly-cut sawn timber to permit movement of solution into the wood. For other methods drying before treatment is essential. Drying the material before treatment permits adequate penetration and uniform distribution and reduces risks of checking and the consequent exposure of untreated timber.

It is also of great importance that all machining should be done prior to treatment. This includes incising of wood to improve the penetration of preservative and machining operations such as planing, cutting, and boring.

For round coconut timber, debarking should be done to accelerate drying. The bark greatly retards moisture removal from the inner zone of the log thereby prolonging drying and risking decay and insect infestations to the log. Under Zamboanga conditions, it takes three to four months air drying of debarked round coconut timber to ensure good preservative treatment.

Treatment Methods

Preservative treatment of timber is undertaken by pressure or non-pressure processes. The pressure method of treatment is unlikely to be feasible in rural areas, where the relatively simple non-pressure processes can be readily adapted to local facilities.

Brush Treatment

Brush treatment is the simplest method of applying wood preservative. A minimum of five per cent pentachlorophonol or five per cent copper-chrome-arsenate can be used in treatment of dried coconut wood. One to three coatings may be applied depending on the dryness of the material. In most cases, however, wood treated by this method is recommended for internal use only.

Soaking

Cold soaking of well-seasoned coconut timber generally achieves better preservative penetration and retention than does brushing. The timber is soaked in a three to five per cent copper-chrome-arsenate solution for one to eight hours depending on the intended use. Material treated by this method can be used for construction of buildings.

7A Debarking Poles

Hot and cold bath

The hot and cold bath process involves the heating of coal-tar creosote, or pentachlorophenol in heavy petroleum oil, with the material totally immersed during the duration of treatment. The wood is heated in the preservative in an open tank for several hours, then immediately submerged in cold preservative for at least an equal number of hours. For well-seasoned coconut timber a hot bath of two or three hours followed by a cold bath of like duration or more is apparently sufficient. Longer periods are preferable, especially during heating, to ensure that the wood is properly penetrated by the preservative. During the hot bath (at about 100°C), air in the wood expands and is forced out. In the cold bath, the residual air in the wood contracts, thereby creating a partial vacuum, and the preservative solution enters the wood.

A double diffusion process, using a water-borne preservative, involves the immersion of wood in a copper sulphate solution which is then heated to about 80°C for three to six hours and cooled overnight. The material is then immersed in an equal mixture of cold sodium dichromate and arsenic pentoxide solution for one or two days. The preservative penetration and retention are satisfactory for the treatment of power electric poles and fence posts. The copper sulphate solution is highly corrosive to metal, so the treating tank should be constructed of stainless steel.

Other treatments using ammonia solutions of preservatives, and ammonia to precipitate the chemicals in the wood, have been developed at the Forest Research Institute, New Zealand, and are currently being tested at Zamboanga. The objective in these developments is to produce a safe, economical treatment for moderate decay hazards.

The plant may be a standard vacuum/pressure unit installed at a permanent location. Schedules used for this technique will give a high standard of protection.[12]

Logs should be cut to pole or post length and peeled or sawn into timber as soon as possible after the palms have been felled. Once processed into the form in which it will be dried the wood should be given a prophylactic treatment with a good fungicide. Dipping is preferable to spraying, but if spraying is the only alternative, a complete coverage should be ensured. Indications are that the best chemical mixture is Captafol (0.4 per cent a.i.) plus Chlorothalonil (0.5 per cent a.i.).

Drying stacks should be erected with care. The site should be elevated, free draining, clear of vegetation and open to sun and wind. Bearers should be of concrete or adequately treated wood, and should be at least 500 mm high. The stack should be protected with covers which should extend beyond the stack in all directions, to a distance equal to at least one quarter of the stack height. The timber should be open stacked using treated fillets or, in the case of posts, in the form of an open crib so that air can move freely. Stacks should be marked to show the date of erection, and the material should remain in stack for a period of five to 24 weeks, dependent on whether it is sawn, quarter round or full round.

Drying and preservation schedule

Use	Material	Size	Drying Period	Solution conc. (comCCA)	Initial vacuum (-85 kPA 25 in)	Pressure (1400 kPA) (200 psi)	Final vacuum (-85 kPA 25 in)	Minimum absorption (Litres/m^3
Exposed[1]	Sawn Timber	25mm thick	5 weeks	2%	20 min	45 min	10 min	250-350[2]
Exposed[1]	Sawn Timber	50 mm thick	10 weeks	2%[3]	20 min	60 min	10 min	250-350[2]
Ground contact	Posts	Quarter Round	12 weeks	6%	30 min	120 min	10 min	200
Ground contact	Poles	Round	26-24 weeks	6%	30 min	120 min	10 min	200

Notes:

1 Exposed to the weather but not in ground contact

2 Depending on density, e.g. minimum of 250 litres/m^3 for hard high-density wood

3 For structural or high value components, solution concentrations of 3 to 4 per cent are recommended

Chapter 8

Energy from Coconut Wood Residues

Coconut wood, especially of high density, will make good charcoal. Any charcoal kiln or process is suitable. But a system using old oil drums is cheap, simple and effective. Briquetting charcoal is possible with any starchy binder such as sorghum.

Coconut wood can be used in direct fired boilers although it must be well dried before it will burn.

Coconut wood if adequately dried, can be used for gasifiers.

Energy from Coconut Wood Residues

Coconut Stems as Fuel

Coconut wood is similar to other woods in its characteristics as a fuel, though the range of densities within the stem leads to variation in the energy potential.

Less than 20 per cent by volume of an average coconut stem is suitable for conversion to timber, and the remainder, together with sawmill residues, is readily usable for charcoal making and for the production of energy.

Charcoal Making

Many rural areas in the Asia-Pacific region make use of the traditional earth pit for conversion of coconut stems and shells to charcoal. The method requires only a small investment in tools and equipment but, because of the lack of control of the carbonization process, yields are low and the quality of charcoal inferior.

More modern methods, at various levels of sophistication, are now being applied. A portable metal kiln was constructed for the Philippine Coconut Authority in Zamboanga to a design similar to the kiln developed by the United Kingdom Tropical Products Institute. [3] Yields from this kiln averaged 20 per cent recovery.

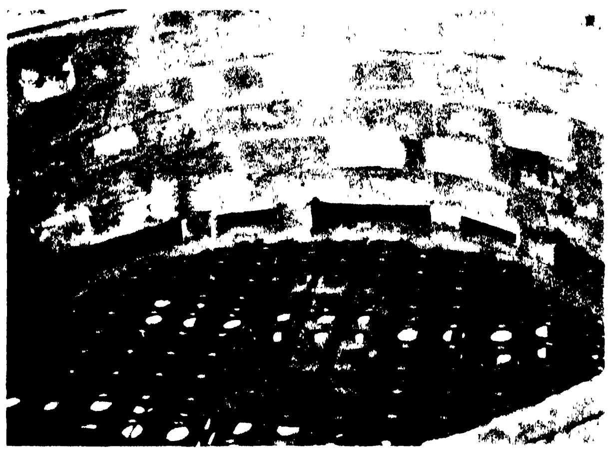
The approximate chemical analysis of the charcoal is: fixed carbon 70 per cent; volatile combustible matter 16 per cent; moisture content 12 per cent; ash 2 per cent.

Tests were undertaken on another kiln based on the TPI Mk IV design with a volume of eight m^3. The main difference in design was that instead of being of all-metal construction, the bottom cylinder was made of two layers of brick. The inside layer was firebrick lined with clay, while the outside layer was the standard building brick. This kiln had eight openings, four covered with chimneys which could be rotated from opening to opening to provide varying air flows to facilitate even burning and carbonization. The material used for charcoal was waste material from logging, and some waste slabs from sawmilling.

In Tonga, a simple kiln is constructed from a 44 gallon drum. A slot 14 cm wide and 73 cm long is cut along one side. The billets of cocowood are loaded through this slot a little at a time. The kiln is started by lighting a fire on the bottom, with the slot facing horizontal to the ground. As the billets start burning the kiln is tilted so the slot is gradually moved to a vertical position, billets being added until the kiln is full. When the billets are burning well, the cover is put on, and the kiln turned until the slot is once again facing the ground. The kiln is left sealed until cool.

8A Zamboanga Research Centre Charcoal Kiln Exterior

Several other drum designs have been used or described, differing mainly in the number and placements of air vents and therefore of operating techniques. Measurement of the efficiency of these kilns are however often imprecise since production operations do not have consistent descriptions of the nature, weight and moisture content of the initial charges. Suffice to say that the simplicity of the drum system (steel or brick) makes it appropriate where more elaborate systems cannot be justified.



8B Zamboanga Research Centre Charcoal Kiln Interior

Charcoal Retorts

Charcoal retorts differ from kilns in that the charge is sealed in a closed chamber and the heat is supplied externally, without an initial combustion stage. The efficiency of the retort lies in its recycling of effluent waste gases from the central chamber holding the wood block charge to the fire box. After an initial firing to begin the reaction, the gases become the fuel source to carry the reaction to completion. The charcoal conversion process is achieved with a low energy input, and pollution is eliminated. The design of the retort and combustion process ensure a consistent quality and higher yields. Industrial charcoal is produced, with an average fixed carbon content of 80 per cent, for a capital outlay little in excess of the traditional brick kiln method.

Charcoal retorts are capable of converting 11 metric tons of wood to four metric tons of charcoal in a 48-hour cycle including loading, firing, conversion, cooling, unloading and bagging. With the waste wood used in the initial firing of the retort, the wood to charcoal conversion ratio is between 3½ to 4:1 for air-dried wood at 20 to 25 per cent moisture content.

Charcoal Briquetting

Coconut stem charcoal has a lower fired-carbon and higher ash content than wood (and coconut shell) charcoal. Briquetting, although not necessarily increasing the fired-carbon content increases the density necessary for industrial applications, to approximate that of coke.[3]

Briquetting is the process of compressing the charcoal to form a compact, uniform mass of higher density and strength than the original material. Studies on the briquetting of charcoal from coconut stems, carried out in the Philippines using sorghum flour as a binder[3], showed that a suitable charcoal-to-binder ratio is of the order of 16:1.

Activated Carbon

Activated carbon can be made from coconut wood charcoal by the removal of hydrocarbon tars adhering to the carbon, to create a vast network of molecular capillaries to increase and improve the absorptive power of charcoal. Activated coconut-shell charcoal can be best applied ingas and vapourabsorption because of its high density. The activated low-density wood charcoal and coconut-trunk charcoal are best suited to liquid purification.

Since coconut-shell charcoal is comparable to the so-called charcoal produced from dense trees in structural strength and low-ash content, it can be a reliable source of carbon for the manufacture of various chemicals such as carbon disulfide, calcium carbide, silicon carbide, sodium cyanide, carbon monoxide; paint pigments; pharmaceuticals; moulding resins; black powder, electrodes; catalyst reactor; brake linings; and gas-cylinder absorbent.

Producer Gas - Gasifier

Gasifiers work by drying wood with heat radiating from the hearth zone at the bottom of a producer. As the wood works its way towards the hearth it turns into charcoal. The charcoal reacts with the air which is fed in through nozzles. When that takes place basic gas production starts.

The gas produced is led through a bed of charcoal which causes reduction to the main fuel gas, carbon monoxide (CO). The by-products of distillation such as tar are cracked to form hydrogen and the final moisture of producer gases is:

Combustible gas	
Carbon Monoxide	20 per cent
Hydrogen	19 per cent
Methane	1 per cent
Non Combustible gas	
Carbon dioxide	9 per cent
Nitrogen	51 per cent

Heat energy to mechanical energy:

5 kg of wood/hour yields approximately 6 hp/hour (Engine)
5 kg of wood/hour yields approximately 4 kW/hour (General)

The hearth module is the actual gas-making component of the system and is supplied as the standard stock item. All other components of a particular gasifier system are custom made or assembled from stock parts to suit the purchaser's special needs, whether they are for heat generation or for engine fuelling. Where producer gas is intended for use in process heating operations such as timber drying and gas cooling, filtration need not be employed. Where producer gas is intended for use in engine fuelling operations, cooling and greater purity of the fuel gas is essential and therefore appropriate equipment is added to the plant to obtain this result.

Ethanol from Coconut Waste Products

The production of ethanol from grains and sugar-rich crops has been practised for thousands of years. Toddy and arrack from the sap of the coconut palm are a well-known example.

The alcohol has been used mainly for drinking, for medical purposes and sometimes for chemical production. Cost of production has not been an issue. Modern techniques have however lowered costs of production and in some countries ethanol is already produced for energy use from prime agricultural products.

Considerable advances have been made in the use of cellulosic materials for ethanol production. Recent testing of coconut utilization of the softer inner core of the stem has shown promising results.[38]

Power Generation Systems

Mechanical and electrical power generation fuel led by wood, straw and similar materials has been practised commercially for over one hundred years. The earliest systems used steam and hot air external combustion engines. More recently internal combustion engines have been used in conjunction with various methods of converting the fuel to combustible gas.

Other systems incorporating closed cycle gas turbines and engines are being developed and could come into regular use in the future.

The main factors limiting the use of wood or woody material as fuel for power generation have been economic rather than technical and thus any evaluation of the potential must be concerned primarily with the economics of the systems, including saving of foreign exchange. The economics are determined by factors such as fuel costs, capital cost, plant efficiencies, labour costs etc.

The low cost of oil fuels and their simplicity of use were the major reasons why there was a move away from solid fuels at the beginning of this century.

At present there are two basic systems which can practically and economically be applied to generating power from coconut wood and other wood wastes. One system is burning with or without gasification and generation of steam to operate engines or turbines. The other system is direct gasification from wood or charcoal to produce a fuel suitable for use in internal combustion engines.

The degree of complexity, the safety hazards and capital cost are similar for both burning and gasification plants. The most significant differences are in the fuel consumption rates. Gasification direct from wood uses about half as much wood as either a direct burning system or charcoal-making followed by gasification system, to produce the same energy output. The steam engine has however advantages in simplicity of operation and reliability.

Establishment and Operation of Power System

There are many possible reasons for considering power generation based on wood. Before commencing such a project it is necessary to consider many factors in order to be sure that the project will be profitable and desirable.

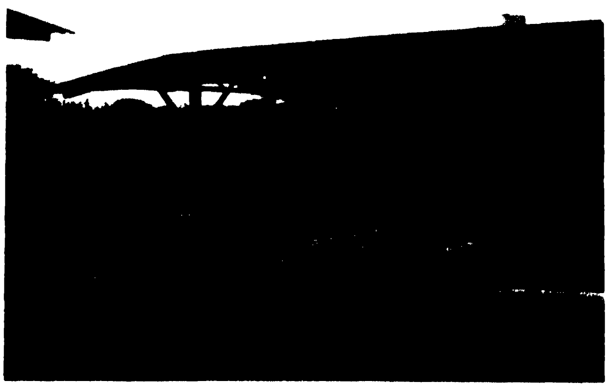
The higher capital cost of wood-fuelled systems as compared with diesel systems result in higher fixed costs. This makes it verv important to achieve high utilization. Greatest effectiveness can be achieved from a wood-fuelled system where there is a steady load without large peak demands and the plant is used to supply the base load demand of an existing system. This latter condition can be planned so that the load is shared between the wood and the diesel plants in such a way that the wood system generates at or near full output most of the time. The use of diesel is restricted to those times where the demand is high thus making maximum use of its facility for quick start-up and shut-down whilst dramatically reducing total diesel fuel consumption.

Electric power must be reliable. Many consumers need continuous supply or a very low incidence of failures if losses or hazards are to be avoided. For example, fish freezers at a base port, hospitals and large industries may be seriously jeopardised by power shut downs.

A wood-fuelled plant which is not connected to another system will usually require some duplication of equipment and some diesel engine stand by capacity, although the smallest systems such as for villages, may not need these features.

Because of the bulky nature of wood fuel, it is important, in locating a plant, to minimise roading and transportation costs. Thus power plants will generally be near the fuel source rather than close to the consumers to be supplied.

8C Firewood



Footnotes

[1] FAO Production and Trade Yearbook Vol. 36 (1982)
[2] *Coconut Stem Utilisation Seminar Proceedings held in Nuku'alofa, Kingdom of Tonga, 25-29 October 1976,* under the New Zealand Aid Programme for the South Pacific Region. Ministry of Foreign Affairs, Wellington, New Zealand 1977
[3] *Coconut Wood - 1979: The Proceedings, Manila and Zamboanga 22-27 October.* A meeting sponsored by Philippine Coconut Authority, New Zealand Ministry of Foreign Affairs, Asian and Pacific Coconut Community. Published by the Philippines Coconut Authority.
[4] Coconut Industries, 1981. *International Coir Development Newsletter,* Number 1.
[5] Cocostem Development Co. Ltd., 1978. *Coconut Wood Parquet Plant for Tonga: Feasibility Report.* Wellington
[6] Decena, A.S., Dela Cruz, R.Z. and Penid, B.J., 1976. *Forpride Digest.* Vol.V
[7] Evans, Rex D., January 1979. *Coconut Wood: The Pacific's Great Untapped Resource.* Asia Pacific Research Unit, Wellington.
[8] Evans, Rex D., 1978. *Parquet Flooring from Coconut Wood: Research Review 1 March 1978.* Cocostem Investigation Unit, Asia Pacific Research Unit and Evans(QS) Company, Wellington
[9] Ford R.J., 1982. *New Zealand Bilateral Aid -Cocostem Utilisation Project, Zamboanga City, Philippines, October 1980-December 1982.* Report to the Secretary, Ministry of Foreign Affairs, Wellington.
[10] Grimwood, Brian E., et al, 1975. *Coconut Palm Products: Their Processing in Developing Countries.* Food and Agriculture Organization of the United Nations, Rome.
[11] Groome, J.G. and Associates, January 1982. *Small Scale Power Generation: Coconut Wood and other Wood Wastes.* Prepared for Food and Agriculture Organization of the United Nations, Taupo.
[12] Hicksons Timber Impregnation Co (NZ) Ltd., April 1980. *Recommended Specifications for the treatment of Coconut Wood,* Auckland
[13] Jensen P., 1979. Skidding Bar. *Coconut Wood -1979: The Proceedings,* Zamboanga
[14] Kinninmonth, J.A. 1977. Drying sawn timber of coconut. *Coconut Stem Utilisation Proceedings, Tonga, 1976*
[15] Kinninmonth, J.A. *The Air Drying of Sawn Timber.* New Zealand Forest Service Reprint Number 42.
[16] Kinninmonth, J.A., 1979. Drying of Coconut Wood. *Coconut Wood - 1979: The Proceedings, Zamboanga*
[17] Kloot, N.H. and Bolza. E., 1977. *Properties of Timbers Imported into Australia.* CSIRO, Australia
[18] Little, E.C.S., April 1975. *Report to the Government of the Philippines on Coconut Wood Utilization.* UNDP/FAO Coconut Research and Development project
[19] McLean, Murdoch, Managing Director, Hickson Timber Impregnation Co. NZ Ltd., March 1983. Seasoning and Treatment of Coconut Posts and Poles. Cited by A. McQuire in *A Note on the Treatment of Coconut Wood With CCA Preservative.* New Zealand
[20] McQuire, A.J., 1977. The Durability and Preservative Treatment of Coconut Palm Wood. *Coconut Stem Utilisation Proceedings, Tonga, 1976*
[21] McQuire, A.J., 1979. Exposure Tests of Treated and Untreated Coconut Stem Wood in the South Pacific. *Coconut Wood - 1979: The Proceedings,* Zamboanga
[22] Meadows, D.J., 1977. The Coconut Industry - Problems and Prospects, *Coconut Stem Utilisation Seminar, Tonga, 1976*
[23] Meylan, B.A., 1978. Density variation with *Cocos nucifera* stems *New Zealand Journal of Forestry Science,* Volume 8 (3): 369-83
[24] Mosteiro, Arnaldo P., January-March 1978. *Forpride Digest,* Volume VII, Number 1
[25] Palomar, R.N., [1980a] *Preservation Techniques of Coconut (Cocos nucifera L.) Palm Timber for Electric Power/Telecommunication Poles and Fence Posts* Mimeo. Zamboanga Research Centre.
[26] Palomar, R.N., [1980b] *Charcoal Making.* Mimeo. Zamboanga Research Centre
[28] Richolson, J.M., August 1980. Coconut Stem Utilisation Programme Information Note (3): Thermal Insulation of Coconut Wood. *A Review of Utilization possibilities for Over-mature Coconut Palm Stems in Fiji.* Department of Forestry, Suva
[29] Richolson, J.M. and Swarup, R., 1977. A brief review of the anatomy and morphology of the coconut palm (Part I) with a report on its basic physical properties (Part II). *Coconut Stem Utilisation Seminar Proceedings, Tonga,* 1976
[30] San Luis, Josefina M. and Estudillo, Calvin P., 1976. Charcoal Briquetting - An Outlet for Wood and Coconut Trunk Wastes. *Forpride Digest,* Volume V, pp. 73-74
[31] South Pacific Commission, April 1957. Practical Uses for Coconut Timber. *Quarterly Bulletin,* Noumea
[32] Standards Association of Australia. *Australian Standards 1975: Use of Timbers in Structures*
[33] Tamolang, Dr. Francisco N., 1976. The Utilization of Coconut Stems and other Parts in the Philippines. *NSDB Technology Journal,* Volume I, Number 2, April-June

[34] [Tongan] Coconut Review Committee, February 1982. *A Review of the Coconut Replanting Scheme*

and Aspects of the Coconut Industry related to Coconut Production, Kingdom of Tonga. Ministry of Agriculture, Fisheries and Forests Planning Unit Technical Publication No. 1/82

[35] Turner, John, 1982. *Philippines Mini Mill Operation at San Ramon, August September 1982.* Report to [New Zealand] Ministry of Foreign Affairs Aid Assignment

[36] Walford, G.B., 1979. Structural Use of Coconut Timber. *Coconut Wood - 1979: The Proceedings,* Zamboanga

[37] Walford, G.B. and Orman, H.R., 1977. The mechanical properties of coconut timber and its design capabilities in construction. Part 1 - Basic strength properties. *Coconut Stem Utilisation Seminar Proceedings, Tonga, 1976*

[38] FAO - Kandeel S.A. 1983
FAO - Sulc V.K. 1983

[39] Bermelt C.

[40] Bergseng K. Timber Industry Training Centre, Rotorua NZ

[41] Evans N. Fe'ofa'aka Enterprises NZ

[42] Hicksons Timber Impregnation Co. (NZ) Ltd

[43] Juson R.A. Zamboanga Research Centre, Philippines

[44] McQuire A.J. Forest Research Institute, Rotorua NZ

[45] Philippine Coconut Authority, Zamboanga Research Centre

[46] Palm Pacific Hardwoods Ltd

[47] Schilling M

[48] Siers J

Bibliography

Aldamez, E.L., 1983. Cocowood utilization (at Pola Mindoro). Cocowood Training at Zamboanga Research Centre, Philippine Coconut Authority

Allison, R.W., 1976. Examination of parenchyma tissue in coconut kraft pulps. Forest Products Laboratory Report FP/PP60. Rotorua, New Zealand

Asian and Pacific Coconut Community. The Cocommunity Newsletter. Published bi-monthly. Jakarta

Asian and Pacific Coconut Community, 1977. Report of the Cocotech Meeting, Manila, Philippines, 19-23 April 1977

Asian and Pacific Coconut Community, April 1981. Coconut Statistical Yearbook. Compiled and expanded by APCCC Statistics Division, Jakarta

Astell, A.S., 1981. The primary conversion of coconut stems into sawn timber. Working Document PHI/71/523. Philippines, FAO/UNDP

Astell, A.S., and Richolson, J., 1977. Bandsaw conversion of Fiji coconut palm logs. Coconut Stem Utilisation Seminar Proceedings, Tonga, 1976: 351-60

Balzer, A.H., 1977. Chain saw trials with coconut wood. Coconut Stem Utilisation Seminar Proceedings, Tonga, 1976: 346-50

Bauza, E.B., Katigbak, S.G., Zerrudo, J.V., and Lauricio, F.M., 1983. Coconut trunks for novelty boxes. NSTA Technology Journal 3 (3): 79-83

Banzon, J.A., and Velasco, J.R., 1982. Coconut production and utilization. Philippine Coconut Research and Development Foundation Inc

Beca Carter Holdings & Ferner Ltd and Scott, G.C., 1976. Forest Industries Energy Research Summary. New Zealand Energy Research and Development Committee

Bedford, G.O., 1976. Uses of virus against the coconut rhinoceros beetles in Fiji. Pans 22 (1): 11-25

Bergseng, K., 1974. Report on trial sawing of coconut palm logs from Tonga. Rotorua, New Zealand Timber Industry Training Centre

Bergseng, K., 1977. Machining of coconut palm wood. Proceedings Coconut Stem Utilisation Seminar, Tonga, 1976: 221-26

Bergseng, K., 1977. Sawing coconut stems. Proceedings Coconut Stem Utilisation Seminar, Tonga, 1976: 111-32

Bergseng, K., 1982. Sawmilling and machinery. Development of coconut timber use. CHOGRM Working Group on Industry Seminar, Honiara, Solomon Islands

Bergseng, K., and Higgins, P. J., 1978. Coconut palm sawing trials conducted in the Philippines. Report to Ministry of Foreign Affairs, Philippines

Bergseng, K., *et al*, 1983. Sawmilling of coconut palm. Unpublished Document 2332A. Rotorua, New Zealand Timber Industry Training Centre

Bisset, J., 1945. The kiln drying of coconut palm *(Cocos nucifera)*. Division of Forest Products Report, CSIRO, Australia

Bollard, A., 1979. Coconut Wood: T-shirt and tapa cloth. A handbook for small rural business for the Pacific. Noumea, South Pacific Commission

Boyd, J.D., 1973. Notes on strength of coconut palm trees as poles. Division of Forest Products Report, CSIRO, Australia. Unpublished

Buxton, M.J., 1970. Notes on the economic feasibility of the manufacture of particle board from coconut timber in Western Samoa. Report of Tropical Products Institute, United Kingdom

Casin, R.F., Generalla, N.C., and Tamolang, F.N., 1977. Preliminary studies on the treatment of coconut lumber with vinyl monomers. Coconut Stem Utilisation Seminar Proceedings, Tonga, 1976: 413-20

Casin, R.F., and Tamolang, F.N., 1977. Seasoning characteristics of coconut lumber and poles. Coconut Stem Utilisation Seminar Proceedings, Tonga, 1976: 387-92

Casin, R.F., and Generalla, N.C., 1978. Utilisation of coconut palm timber; Its significance in some developing countries in the tropics. Philippines, FORPRIDE Digest

Centre for Technology Delivery (undated). Project Plan: Madera Imelda

Child, D., 1974. Coconuts. 2nd ed. United Kingdom, Longman Group

Child, D., 1982. Commercial aspects of sawmilling. Development of coconut timber use. CHOGRM Working Group on Industry Seminar, Honiara, Solomon Islands

Child, D., 1982. The products and the market. Development of coconut timber use. CHOGRM Working Group on Industry Seminar, Honiara, Solomon Islands

Chittenden, A.E., Flaws, J.L., and Hawkes, A.J., 1969. Particle boards from coconut palm timber. London, Tropical Products Institute Report G43:9: 1-5

Commonwealth Heads of Government (CHOGRM) Regional Meeting, December 1982. Development of Coconut Timber Use: Seminar

Report. CHOGRM Working Group on Industry, Honiara, Solomon Islands

Coconut Stem Utilisation Seminar Proceedings, held at Nuku'alofa, Kingdom of Tonga, 25-29 October 1976. Proceedings compiled and edited by A.K. Familton, A.J. McQuire, J.A. Kininmonth, A.M.L. Bowles. Wellington, Ministry of Foreign Affairs, 1977

Coconut Wood - 1979, Manila & Zamboanga 22-27 October. A Meeting sponsored by Philippine Coconut Authority, New Zealand Ministry of Foreign Affairs, Asia and Pacific Coconut Community: The Proceedings, Edited by A.K. Familton, A.J. McQuire, E.N. Balingasa, D.J. Meadows. Philippine Coconut Authority.

Contact Consult, 1982. The Australian import market for timber and timber products. Prepared for Department of Trade and Resources, Australia. Ref. AAY/TREPPO5O

Cornelius, J.A., 1973. Coconuts: A Review. London, Tropical Science 1 (1)

Cortes, T.R., 1983. Prospects of cocowood utilization in the Bicol Region 3. Cocowood Training at Zamboanga Research Center. Philippine Coconut Authority

Cousins, W.J., and Meylan, B.A., 1975. Longitudinal slicing of *Cocos nucifera* and illustrations of its anatomy. Physics and Engineering Laboratory, [New Zealand] Department of Scientific and Industrial Research 437 (19)

Cruz, I.E., 1981. Producer gas from wood: Its production and utilization in internal combustion engines. NSDB Technology Journal of Philippines 6 (1): 38-29

Cumber. R.A., 1957. The rhinoceros beetles in Western Samoa (Ecological Studies). Noumea, South Pacific Commission Technical Paper *107*

Cummins, N.H.O., 1973. Fuel value of wood: The calorific value of coconut palm wood. Forest Products Laboratory Report FP/AL 4. New Zealand Forest Research Institute. Unpublished

Dandy, A.J., and Wright, C.P., 1977. Characteristics of charcoal from coconut and mangrove. Suva, School of Natural Resources, University of the South Pacific. Unpublished

Decena, A.S., 1975. Study on the sawing characteristics of coconut (*Cocos nucifera)* trunk: Co-operative Project. College, Philippines, FORPRIDECOM Library

Decena, A.S., and Penid, B.J., 1977. The economics of three lumber conversion systems for coconut trunks. Coconut Stem Utilisation Seminar, Proceedings Tonga, 1976: *361-70*

Decena, A.S., and Penid, B.J. 1977. Production costs of coconut lumber products. 1. Treated Stone Cut. Coconut Stem Utilisation Seminar, Proceedings Tonga, 1976: *457-60*

De Coene, A., 1981. A report to the government of the Philippines on a marketing study of coconut timber products. Rome, Food and Agriculture Organization of the United Nations

De La Cruz, R.Z., *et al*, 1975. Sawing of coconut trunks into lumber. FORPRIDECOM Technical Note 156

De La Cruz, R.Z., and Sibayan, D.V., 1975. Study on sawing characteristics of coconut trunks. College, Philippines, FORPRIDECOM Library Special Report. Unpublished

Doyle, J.,1978. Coconut Tree Survey of Tongatapu, Nuku'alofa

Eala, R.C., and Tamolang, F.N, 1977. Exploratory study of machining properties of coconut timber. Coconut Stem Utilisation Seminar Proceedings, Tonga, 1976: 455-56

Eala, R.C., and Tamolang, F.N. , 1977. Face veneer from coconut trunk. Coconut Stem Utilisation Seminar Proceedings, Tonga, 1976: 470-72

Eala, R.C., and Tamolang, F.N., 1977. Special treatment of 'soft' coconut timber. Coconut Stem Utilisation Seminar Proceedings, Tonga, 1976: 393-94

Elazequi, T.A., Villanueva, E.P., and Bawagan, B.O., 1979. Dissolving pulp from coconut trunk *(Cocos nucifera)* chips in the Philippines. FORPRIDE Digest 8 (2): 40-47

Endaya, P., 1983. Prospects of cocowood utilization in Region I. Cocowood Training at Zamboanga Research Centre. Philippine Coconut Authority

Escolano, J.O., *et al*, 1970. Offset book and wrapping papers from blends of coconut coir and abaca pulps

Espiloy, E.B., Jr, 1977. Coconut trunk for power and telecommunication poles. College, Philippines, FORPRIDECOM Technical Note 182

Espiloy, E.B., Jr, and Tamolang, F.N., 1977. Bending strength of full-sized coconut trunk poles. Coconut Stem Utilisation Seminar Proceedings, Tonga, 1976: 427-32

Estudilio, C.P., and San Luis, J.M., 1969. Charcoal briquettes from coconut *(cocos nucifera* Lin.) trunk. Progress Report 744/d. College, Philippines, FORPRIDECOM Library

Estudilio, X.P., and San Luis, J.M., 1977. Charcoal production and utilization of coconut shells and trunk in the Philippines. Coconut Stem Utilisation Seminar Proceedings, Tonga, 1976: 199-220

Evans, Rex D., 1978. Parquet flooring from coconut wood: Research Review 1 March 1978.

Hamilton, New Zealand Cocostem Investigation Unit, Asia Pacific Research Unit and Evans (QS) Company

Evans, Rex D., January 1979. Coconut wood: The Pacific's great untapped resource. Wellington, Asia Pacific Research Unit

Evans (QS) Company, 1978: Coconut wood parquet plant for Tonga: Feasibility Report. Hamilton, New Zealand, Cocostem Development Co Ltd

Familton, A.K., 1977. Discussion paper on country questionnaires. Coconut Stem Utilisation Seminar, Proceedings Tonga, 1976: 299-318

Familton, A.K., 1978. What is happening among the coconuts? Wellington, Asia Pacific Forum 4 (9)

Familton, A.K., 1979. Coconut wood - 1979: The objectives. Proceedings Coconut Wood - 1979, Manila-Zamboanga:20-24

Faniel, R., 1969. Report on the feasibility of establishing a particle board factory based on coconut wood. Annex II. UNIDO Regional Tour Report

Fiji. Department of Agriculture, 1972. Record of a workshop on the coconut industry in Fiji held on 1-3 May 1972, at Fiji College of Agriculture, Koronivia

Fiji. Department of Agriculture, 1973. Commodity study paper: Coconuts. Unpublished

Fiji. Department of Forestry, 1976. Revitalisation of copra industry: The potential utilization of coconut timber. Unpublished

Fiji. Department of Forestry, 1977. Brush and dip preservatives treatment of coconut weatherboarding. Fiji Information Note (a). Coconut Stem Utilisation Seminar Proceedings, Tonga, 1976: 409-10

Fiji. Department of Forestry, 1977. Mobile pressure treatment facilities. Fiji Information Note (b). Coconut Stem Utilisation Seminar Proceedings, Tonga, 1976: 411-12

Fiji. Department of Forestry, 1977. Coconut Palm wood charcoal. Fiji Information Note (c). Coconut Stem Utilisation Seminar Proceedings, Tonga, 1976: 433-46

Fiji. Department of Forestry, 1979. Experimental coconut house. Fiji Information Note (a)

Fiji. Department of Forestry, 1979. Low density coconut weather-boarding brush and dip preservative treatment, Fiji Information Note (b)

Fiji. Department of Forestry, 1979. Thermal insulation of coconut wood. Fiji Information Note (d)

Fiji. Department of Forestry, 1979. Mechanical peeling of coconut palm logs. Fiji Information Note (e)

Fiji. Department of Forestry, 1979. Treated coconut fence post. Fiji Information Note (f)

Fiji. Department of Forestry, 1979. Mechanical splitting of coconut palm logs. Fiji Information Note (g)

Fiji. Department of Forestry, 1979. Parquet flooring service trials. Fiji Information Note (i)

Fiji. Department of Forestry, 1979. Production of coconut wood charcoal with Mark V kiln. Fiji Information Note (l)

Fiji. Department of Forestry, 1979. Production of coconut wood charcoal with Tongan kiln. Fiji Information Note (n)

Floresca, A.R., 1979. Bolt bearing properties of coconut palm*(cocos nucifera* L.) timber compared with those of some Philippine woods. Forpride Digest 8 (2): 52-61

Fluidyne R & D Ltd. Wood and crop residue fuel-gas producers. Brochure. Auckland, New Zealand

Food and Agriculture Organization of the United Nations, 1981. Jamaica coconut wood utilisation. Report prepared for the Government of Jamaica

Food and Agriculture Organization/United Nations Development Programme/United Nations Industrial Development Organization, 1983. Regional coconut wood utilization training programme RAS-81-110. Training handouts coconut wood utilization. Managerial Training Course.

Ford, R.J., 1982. New Zealand Bilateral Aid - Cocostem Utilization Project, Zamboanga City, Philippines, October 1980 to December 1982. Report to the Secretary, Ministry of Foreign Affairs, Wellington, New Zealand

FORPRIDECOM, Undated. Development of particle board on a pilot plant commercial scale using plantation and secondary wood species and agricultural fibrous waste materials v. coconut trunk and wood/coconut particle mixtures. Unpublished

FORPRIDECOM, Undated. Experiments on the utilization of coconut trees as building materials and pallets. Unpublished

FORPRIDECOM, 1975. Charcoal from coconut trunk and activation of charcoal. Unpublished

FORPRIDECOM, 1975. Strength related properties of green coconut trunk from Tiaong, Quezon. Unpublished

FORPRIDECOM, 1975. Summary of results obtained from the study of the sawing characteristics of coconut trunks. Unpublished

Francia, F.C.and Escolano, E.U. 1973. Proximate chemical composition of the various parts of the coconut stem. Philippine Lumberman 19 (7): 26-30

Francia, F.C., 1980. Utilization of coconut trunks and its waste material. Unpublished

Fremond, X., and Ziller, R., 1966. The Coconut palm. Berne, International Potash Institute

Garcia, M.L., and Reyes, A.V., 1977. Exploratory tests on the natural susceptibility of coconut wood to termites. Proceedings Coconut Stem Utilisation Seminar, Tonga, 1976: 395-402

Garcia, P.A., 1983. Prospects of coconut wood utilization in Central and Western Visayas. Cocowood Training at Zamboanga Research Centre. Philippine Coconut Authority

Goodwin, J.J., 1977. Construction of small demonstration houses using coconut timber. Forest Products Laboratory Report TE75. Rotorua, New Zealand Forest Research Institute. Unpublished

Gough, D.K., 1977. Seasoning and the seasoned recovery of timber from overmature coconut palms *(Cocos nucifera)*. Coconut Stem Utilisation Seminar Proceedings, Tonga 1976: 371-86

Grimwood, B.E., 1975. Coconut palm products. FAO Agriculture Development Paper 99: 211-19

Groome, J.G., and Associates 1982. Small-scale power generation coconut wood and other wood wastes. Prepared for Food and Agriculture Organization of the United Nations, Taupo, New Zealand

Hannam, G., 1978. Report on investigation into the North American flooring market. Wellington, Cocostem Development Co Ltd. Unpublished

Haas, Anthony, Kitson G., and Groome J.G., 1982. Vanuatu's Coconut Stem Product Export Markets. Commonwealth Secretariate. Unpublished

Haseloff, James, Mohamed, Nizar A. and Symons, Robert H., 1982.Viroid RNAs of cadang-cadang disease of coconuts. Nature 299(5881):316-21

Hawkes, A.J., and Robinson, A.P., 1979. The utilization of coconut palm timber as an aggregate with cement. Philippine Journal of Coconut Studies 4 (1) : 14-26

Herda, P.T., Carter Indonesia/South Tree Technology Ltd, 1983. Coconut wood utilisation in Indonesia. Volume 1 Technical Report; Volume 2 Financial Report; Appendices. A study prepared for the Directorate General of Estates, Ministry of Agriculture, Government of Indonesia

Hickson's Timber Impregnation Co (NZ) Ltd, 1980. Recommended specifications for the treatment of coconut wood

Hopner, T., 1957. Faserstoffe aus cocus und cycas. Das Papier II (299): 498-500

Howard, R.C., 1979. Utilization of coconut timber: Machining - Adding value and marketing. Manurewa, New Zealand, Marketing Engineers Ltd. Unpublished

Industries Assistance Commission Report, 1978. Timber and Timber Products and Plywood and Veneer, Report 168, 12 May, Canberra, Australia

Industries Assistance Commission 1978. Furniture. Report 188, 27 November. Canberra, Australia

Industries Assistance Commission, 1981. Draft Report on wood and articles of wood. Canberra, Australia

International Coir Fibre Development Association, 1980. Coconut Wood. International Coir Development Newsletter Special Issue 3 (2): 4-8

International Coconut Development Association (ICDA). Coconut Industries. Quarterly, Stockholm

International Trade Centre, 1970. The parquet market in France. Geneva

International Trade Centre, 1971. The market for parquets in Italy. Geneva

International Trade Centre, 1971. The parquet market in Austria. Geneva

International Trade Centre, 1971. The parquet market in the United Kingdom. Geneva

International Trade Centre, 1971. The parquet market in the Netherlands. Geneva

International Trade Centre, 1971. The parquet market in the Federal Republic of Germany. Geneva

International Trade Centre, 1977. The changing pattern of the market for floor coverings in the Federal Republic of Germany. Geneva

Japan. JICA, 1978. Report of an analytical survey of coconut forests in Taveuni Island of Fiji

Jansen, A.K., 1974. Experimental boron treatment of coconut timber. Unpublished notes

Jensen, P., 1979. Briefing Paper: Drying saw material. Paper presented to Meeting Coconut Wood - 1979, Manila-Zamboanga. Unpublished

Jensen, P., 1979. Briefing Paper: Sawmilling. Paper presented to Meeting Coconut Wood - 1979, Manila-Zamboanga. Unpublished

Jensen, P., 1979. Log volume and form factor of *Cocos nucifera L.* Proceedings Coconut Wood - 1979, Manila-Zamboanga:80-88

Jensen, P., 1979. Cell-wall densities for *Cocos nucifera* and *Pinus radiata*. Proceedings Coconut Wood - 1979, Manila-Zamboanga: 113-19

Jensen, P., 1979. Skidding bar. Proceedings Coconut Wood - 1979, Manila-Zamboanga: 67-75

Jensen, P., 1979. Technical information - graveyard test of *Cocos Nucifera* L. Proceedings Coconut Wood - 1979, Manila-Zamboanga: 137-38

Jensen, P., 1979. Recovery in sawn timber from *Cocos nucifera* logs. Proceedings Coconut Wood - 1979, Manila-Zamboanga: 88-90

Jensen, P., 1979. Technical information on sawmills. Proceedings Coconut Wood - 1979, Manila-Zamboanga: 90-97

Jensen, P., 1979. Machine costs for tractors, timber jacks and equipment.

Proceedings Coconut Wood - 1979, Manila-Zamboanga: 197-206

Jensen, P., and Killmann, W., 1979. Production costs of sawn coconut timber. Proceedings Coconut Wood - 1979, Manila-Zamboanga: 207-40

Jensen, P., and Killmann, W., 1979. Utilization of palm wood *(Cocos nucifera* L.). Proceedings Coconut Wood - 1979, Manila-Zamboanga: 75-79

Juson, R.A., 1983. Sawmilling tests on the Varteg sawmill under field conditions. PCA-Zamboanga Research Center Research

Juson, R.A., 1983. Sawmilling of coconut stems. Third PCARRD SMARC Co-ordinated review and evaluation of ongoing and completed research projects. Kabacan, Cotabato, Philippines

Juson, R.A., 1983. Machining of coconut wood. Third PCARRD SMARC Co-ordinated review and evaluation of ongoing and completed research projects. Kabacan, Cotabato, Philippines

Juson, R.A., and Killmann, W., 1980. Drying of coconut timber. PCA-ZRC Agricultural Annual Report. Unpublished

Kandeel, S.A., 1983. Curricula for coconut wood utilization training. PCA-Zamboanga Research Center RD-02-83

Kandeel, S.A.E., Corcuera, M., and Kherallah, I., 1983. Chemical analysis of coco-wood different density groups. PCA-Zamboanga Research Center Research Paper

Khandeel, S.A.E., Madrazo, R., Corcuera, M. and Kherallah, I., 1983. Energy from coconut *(Cocos nucifera)*stem wood. Energy generation and conservation session. Forest Products Research Society 37th Annual Meeting Conference, Virginia, U.S.A.

Katzer, G.R., and Ward, A.F., 1978. The Fore Furnace: A versatile biomass burner. New Zealand Department of Scientific and Industrial Research

Kaul, K.N., 1960. Anatomy of plants. Palm-; Bulletin 51. Lucknow, National Botanic Gardens

Killmann, W., 1979. Buildings and structures - Houses. Proceedings Coconut Wood - 1979, Manila-Zamboanga: 167-687

Killmann, W., 1983. Some physical properties of the coconut palm stem. Wood Science and Technology Journal 17: 167-85

Kinninmonth, J.A., 1974. Drying sawn timber of coconut. Timber Drying Report TDl. Forest Research Institute, New Zealand Forest Service. Unpublished

Kinninmonth, J.A., 1977. Drying sawn timber of coconut. Proceedings, Coconut Stem Utilisation Seminar, Tonga, 1976: 133-46

Kinninmonth, J.A., 1979. Current state of knowledge of drying of coconut wood. Proceedings Coconut Wood - 1979, Manila-Zamboanga: 104-13

Kinninmonth, J.A., 1979. Some physical properties of coconut wood. Proceedings Coconut Wood - 1979, Manila-Zamboanga: 141-49

Klauditz, W., 1969. Investigation of coconut palm logs: Potential suitability for the manufacture of particle boards. Braunschweig, West Germany, Institut für Holzforschung

Kloot, N.H., 1952. Mechanical and physical properties of coconut palm. Australian Journal of Applied Science 3 (4): 293-323

Kloot, N.H. , and Bolza, E., 1977. Properties of timbers imported into Australia. CSIRO, Australia

Lauricio, F.M., and Floresca, A.R., 1977. Preliminary test on the spike-holding capacity of coconut palm timber for use as rail-road sleepers. Coconut Stem Utilisation Seminar Proceedings, Tonga, 1976: 461-64

Lauricio, F.M., and Tamolang, F.N., 1977. The strength and related properties of coconut trunk *(Cocos nucifera. L.).* Coconut Stem Utilization Seminar Proceedings, Tonga, 1976: 425-26

Laxamana, N.B., 1977. Coconut trunk and shell for activated carbon. Coconut Stem Utilisation Seminar Proceedings, Tonga, 1976: 447-54

Laxamana, N.B., and Bawagan, P.V., 1973. Charcoal production at FORPRIDECOM. Forpride Digest 2 (3/4): 11-14

Laxamana, M.G., and Tamayo, G.Y., 1978. Drying characteristics of coconut lumber. Technology Journal NSDB 3 (3): 48-55

Leather, R.I., 1972. Coconut research in Fiji. Fiji Agricultural Journal 3/4 (1): 3-9

Levy, C.R., 1975. The field evaluation of perusion (HPSD) process for treatment of round timber in Papua New Guinea. Proceedings IUFRO Division S. Meeting at Abidjan

Levy, C.R., 1976. A note on insect pests of coconut wood. Unpublished

Leyland Watson and Noble/Chandler Fraser & Larsen, 1982. Feasibility study on electric power generation from wood and coconut wastes. Prepared for the Government of Western Samoa

Little, E.C.S., 1974. Coconut logs for fence post trial (end of first year report) 1973-74. Department of Agriculture, Tonga. Unpublished

Little, E.C.S., 1975. Report to the Government of the Philippines on coconut wood utilization. Unpublished

Little, E.C.S., 1978. The MINICUSAB kiln for rapid small-scale manufacture of charcoal from scrub, coconut wood and coconut shells. Appropriate Technology 5 (1): 12-14

Lockyer, Ross, 1983. Coconut Timber Utilization Manual. Prepared for the Republic of Kiribati. New Zealand Bilateral Aid Programme

Lopez, Rosemary Luna, 1983. Coconut Palace. Mabuhay, Philippine Airlines, February: 43-45

Lorenzana, L.M.C., 1981. Preservation of plantation grown species for poles and banana props. Seminar sponsored by Pacwood Inc and Hickson's Timber Preservation Pte Ltd, Philippines

McConchie, D.L., 1975. Physical properties of *Cocos nucifera.* Wood Quality Report 2. Rotorua, New Zealand Forest Research Institute

Mackie, K., Burton, R. and Whitworth, D., 1980. Coconut stem wood as a substrate for wood hydrolysis: Initial data. Forest Service Forest Research Institute. Unpublished

McLaughlan, J.M., 1974. Glue line shear tests on coconut palm timbers. File Note 51/5/2. New Zealand Forest Research Institute. Unpublished

McLean, Murdoch, Managing Director, Hickson's Timber Impregnation Co NZ Ltd, March 1983. Seasoning and treatment of coconut posts and piles. Cited by A. McQuire in A Note on the treatment of coconut wood with CCA preservative. New Zealand Forest Service Reprint 1370

McPaul, J.W., 1964. Coconut growing in Fiji. Bulletin 38. Department of Agriculture, Fiji

McQuire, A.J., 1972. Treatability of some Western Samoan timber. Forest Products Division Report 425. New Zealand Forest Research Institute. Unpublished

McQuire, A.J., 1975. Report on a visit to study coconut wood utilization in the Philippines. Travel Report 9. New Zealand Forest Research Institute. Unpublished

McQuire, A.J., 1977. The durability and preservative treatment of coconut palm wood. Coconut Stem Utilisation Seminar Proceedings, Tonga, 1976: 147-73

McQuire, A.J., 1978. Treatment and performance of coconut wood. Rotorua, New Zealand Forest Research Institute. Unpublished

McQuire, A.J., 1979. Anatomical and morphological features of the coconut palm stem in relation to its utilization as an alternative wood source. Proceedings Coconut Wood - 1979, Manila-Zamboanga: 24-28

McQuire, A.J., 1979. Exposure tests of treated and untreated coconut stem wood in the South Pacific. Proceedings Coconut Wood - 1979, Manila-Zamboanga: 125-29

McQuire, A.J., 1979. Treatment and use of coconut stem wood. PEACESAT, 1979, Forest Products Division, New Zealand Forest Research Institute. Unpublished.

McQuire, A.J., 1982. Preservation requirements. Development of coconut timber use. CHOGRM Working Group on Industry Seminar, Honiara, Solomon Islands

McQuire, A.J., 1982. An overview of coconut timber technology. Development of coconut timber use. CHOGRM Working Group on Industry Seminar, Honiara, Solomon Islands

McQuire, A.J., and Carter, L.C., 1976. Pressure treatment of coconut wood fence posts with copper-chrome-arsenate preservatives. Wood Preservation Report FP/WP 12. New Zealand Forest Research Institute. Unpublished

McQuire, A.J., and Madrazo, R., 1983. Development in coconut tree utilization. 15th Pacific Conference, New Zealand

McQuire, A.J., and Palomar, R., 1982. The treatment of coconut roof tiles or shingles with copper-chrome-arsenate preservatives. New Zealand Timber Preservation Authority

Madrazo, R., and Juson, R., 1983. Sawmilling tests on the mobile dimensional saw under field conditions. PCA-Zamboanga Research Center Research Paper RP-02-83

Madrazo, R., and Sulc, V., 1983. Coconut wood utilization research at Zamboanga Research Center RD-01-83

(The) Malaysian Timber Industry Board, 1968. The Malayan grading rules for sawn hardwood timber, 1968 edition. Kuala Lumpur, Forest Department

Malca, S., 1979. Coconut panel board and process of making. Philippines Patent Office Library

Manalo, F.D., 1983. Prospects of cocowood utilization in Western Mindanao. Cocowood Training at Zamboanga Research Center. Philippine Coconut Authority

Manas, A.E., 1974. Tannin extraction of Philippine tannin bearing material: IV. Coconut*(Cocos nucifera* L.) coir dust. Philippine Lumberman 20 (3): 26-28

Manas, A.E., and Tamolang, F.M., 1977. Tannin content of coconut tree bark, coconut trunk and coconut trunk core. Coconut Stem Utilisation Seminar Proceedings, Tonga, 1976: 503

Mangahas, A.G., Lauricio, F.M., 1977. Coconut lumber pallets. Coconut Stem Utilisation Seminar Proceedings, Tonga, 1976: 465-66

Martin, J., 1976. New insight in coconut log preservation. Marist Training Center, Tutu, Taveuni, Fiji

Martin, J.F., 1978. New insights in the preservation of coconut timber: The Tutu insertion process. Australian Forest Research 8 (3/4):227-37

Meadows, D.J., 1977. The coconut industry - problems and prospects. Coconut Stem Utilisation Seminar Proceedings, Tonga, 1976: 53-64

Meadows, D.J., 1979. The current state of coconut stem utilization from palm felling to the end-products. Proceedings Coconut Wood - 1979, Manila-Zamboanga: 15-20

Meadows, D.J., Sule, V,. Palomar, R. and Jensen, P., 1980. L'Utilization du bois de cocotier. Oleagineux 35 (7): 365-69

Medrano, R.N., 1976. Design, fabrication and operation of drum kilns for charcoaling coconut shells. NSDB Technology Journal 1 (2): 26-35

Medrano, R.N., Lauricio, F.M., 1977. Specific gravity and shrinkage of coconut palm timber *(Cocos nucifera L.)* in the Philippines. Coconut Stem Utilisation Seminar Proceedings, Tonga, 1976: 325-26

Mendoza, A.M.R., 1977. Harvesting coconut stems. Coconut Stem Utilisation Seminar Proceedings, Tonga, 1976: 103-110

Mendoza, A.M.R., 1979. The coconut replanting program and the need for coconut wood utilization. Proceedings Coconut Wood - 1979, Manila-Zamboanga: 9-15

Meniado, J.A., and Lopel, F.R., 1977. Stem anatomy of *Cocos nucifera L.* Coconut Stem Utilization Seminar Proceedings, Tonga, 1976:323-24

Meylan, B.A., 1978. Density variation in *Cocos nucifera.* New Zealand Journal of Forest Science 8: 369-83

Middleton, P., 1982. Capital requirements. Development of coconut timber use. CHOGRM Working Group on Industry Seminar, Honiara, Solomon Islands

Middleton, P., 1982. The need for feasibility studies. Development of coconut timber use. CHOGRM Working Group on Industry Seminar, Honiara, Solomon Islands

Middleton, P., 1982. Value of the resource. Development of coconut timber use. CHOGRM Working Group on Industry Seminar, Honiara, Solomon Islands

Miller, W.C., 1972. Distribution of parquet flooring during 1969. USDA Forest Service Research Paper NEZ 18

Mosteiro, A.P., 1971. Preliminary study on the treatment of coconut*(Cocos Nucifera* L.) trunks and other palm species for electric power transmission poles. Wood Preservation Report 6 (6): 11-14. College, Laguna, FORPRIDECOM.

Mosteiro , A.P., 1979. Machining properties of coconut wood. Proceedings Coconut Wood - 1979 Seminar, Manila-Zamboanga: 173-75

Mosteiro, A.P., 1981. Preservation of coconut palm wood for villagers in the tropics. NSDB Technology Journal 8 (2): 40-47

Mosteiro, A.P., 1981. Utilization of coconut lumber for furniture manufacture. Philippine Council for Agriculture and Resources Research (PCARRD)

Mosteiro, A.P., and Casin, R.F., 1973. Split coconut trunks treated by the hot and cold bath methods for use as electric transmission poles. Progress Report. FORPRIDECOM Library. Unpublished

Mosteiro, A.P., and Casin, R.F., 1975. Coconut timber preservation and utilization in the Philippines. FORPRIDE Digest: 40-52

Mosteiro, A.P., and Casin, R.F., 1976. The preservative treatment of coconut *(Cocos nucifera L.)* palm timber for electric power and telecommunication poles. NSDB Technology Journal 1 (1): 45-52

Mosteiro, A.P., and Casin, R.F., 1979. Coconut timber preservation and utilization in the Philippines. FORPRIDE Digest 5: 40-52

Mosteiro, A.P., and Siriban, R.F., 1979. Coconut wood preservation in the Philippines. Proceedings Coconut Wood - 1979, Manila-Zamboanga: 123-25

Nazma, P. Ganapathy, Sasidharan, N., Bhat, K., and Gnanahran, P., 1981. A handbook of Kerala timbers. Kerala Forest Research Institute (KFRI) Research Report 9: 59-63

New Zealand. Department of Trade and Industry [1980] Cocowood utilization in the Philippines. Reference T3/Ml 51/2/12. Unpublished

New Zealand Forest Industry Review, 1976. Research into coconut wood. Forest Industry Review 7 (2)

New Zealand Forest Research Institute, 1974. Can coconut produce wood as well as nuts? Bulletin in the Series on What is new in forest research 15

Ontalan, L.D., 1983. Prospects of cocowood utilization in Northeastern Mindanao. Cocowood Training at Zamboanga Research Center. Philippine Coconut Authority

Orman, H.R., 1974. The strength properties of coconut palm timber. Timber Engineering Report. New Zealand Forest Research Institute. Unpublished

Pablo, A.A., and Tamolang, F.N., 1977. Panel products from coconut palm. Coconut Stem Utilisation Seminar Proceedings, Tonga, 1976: 479-83

Paddon, A.R., 1978. Report of a visit to Fiji, 13 June to 9 July 1978. London, Tropical Products Institute Report R763

Paddon, A.R., and Harker, A.P., 1980. Charcoal production using a transportable metal kiln. Rural Technology Guide 12. London, Tropical Products Institute

Palm Pacific Hardwood, P.O. Box 2951, Auckland, January 1982. Brochure on Decorative timber flooring

Palm Pacific Hardwood, Undated. The world's newest building products step right out of history ... brochure

Palm Pacific Hardwood, Undated. Specifications and fixing instructions for panelling brochure

Palmer, E.R., 1972. The production of activated carbon from coconut palm timber. New Zealand Department of Scientific and Industrial Research Report CD2150

Palmer, E.R., and Gibbs, J.A., 1979. Pulping trials on the wood from the trunk coconut *(Cocos nucifera)*. London, Tropical Products Institute Report L52

Palomar, R.N., 1979. Pressure impregnation of coconut sawn lumber for building construction material. Proceedings Coconut Wood - 1979, Manila-Zamboanga: 129-36

Palomar, R.N., 1979. Technical information: Charcoal making. Proceedings Coconut Wood - 1979, Manila-Zamboanga: 176-77

Palomar, R.N., 1979. Technical information on preservation. Proceedings Coconut Wood-1979, Manila-Zamboanga: 120-23

Palomar, R.N. [1980] Charcoal making. PCA-Zamboanga Research Center. Unpublished

Palomar, R.N., 1980. Coconut wood preservation for the rural areas. PCA-Zamboanga Research Center

Palomar, R.N., [1980] Preservation techniques of coconut *(Cocos nucifera L.)* Palm timber for electric power/telecommunications poles and fence posts. PCA-Zamboanga Research Center. Unpublished

Palomar, R.N., 1980. Training on wood preservation. PCA-Zamboanga Research Center

Palomar, R.N., 1982. The role of coconut timber utilization in national development. PCA Workshop, Tagaytay City, Philippines: 106-110

Palomar, R.N., and Sulc, V.K., 1981. Preservative treatment and performance of coconut palm timber. Seminar Pacwood and Hickson's Timber Preservation Ltd, Philippines

Palomar, R.N., and Sulc, V.K., 1983. Exposure test of surface treated sawn coconut timber. PCA-Zamboanga Research Center ZRC-RP-04-83

Pande, J.N., 1957. A note on the preservative treatment of palmyra *(Borassus flabellifera)* and coconut *(Cocos nucifera)* palms. Journal of Timber Dryers and Preservers Association of India 11 (3): 2-9

Papua New Guinea. Copra Marketing Board, January 1972. Coconuts and copra. Konedobu, Department of Information and Extension Services

Parthasarathy, M.V., and Klotz, L.H., 1976. Palm wood anatomical aspects. Wood Science and Technology 10 (3): 215-29

Parthasarhty, M.V., and Tomlinson, P.B.T., 1967. Anatomical features of metaploem in stems of *Sabul, Cocos* and two other palms. American Journal of Botany 54(1): 1144-55

Patel, J.S., 1938. The coconut: A monograph. Madras, Government Press

Peat, N., 1982. Coconut winning as a new timber source. New Zealand Forest Industries

Penid, B.J., *et al*, 1975. Report on the manual sawing of coconut trunk. College, Philippines, FORPRIDECOM

Philippine Coconut Authority, 1976. The Philippine Coconut Industry. Market Promotions Division

Philippine Coconut Authority, 1977. Preparation and treatment of coconut stem for fencing. Coconut Wood Utilization Division, Zamboanga Research Center Report

Philippine Coconut Authority, 1979. Research into the utilization of coconut wood

Philippine Coconut Authority, 1980. The uses of coco timber. Philippine Council for Agriculture and Resources Research and Development Technology 2 (7): 1-16

Philippine Coconut Authority, 1981. Philippine Coconut Authority 1981 Annual Report. Quezon City

Philippine Coconut Authority, Undated. Spectrum of coconut products. Quezon City, Public Information Office

Philippine Council for Agriculture and Resources Research and Development (PCARRD), 1982. Charcoal as supplementary fuel for cement production. Technology 4 (5): 1-12

Pieries, W.V.D., 1936. An essay on the uses of the coconut palm. Ceylon, Coconut Research Scheme

Pieries, W.V.D., 1938.Rhinoceros beetle breeding in split coconut logs. Tropical Agriculture 90:297

Piggot, C.J., 1964. Coconut growing. Oxford University Press

Pomier, M., 1967. Coconut research at Rangiroa. South Pacific Commission Technical Paper 153

Powell, R. 1957. Practical uses of coconut timbers. South Pacific Commission Quarterly Bulletin

Powter, A., 1976. Papua New Guinea shake and shingle manual. Port Moresby, Department of Primary Industry, Office of Forests, Forest Products Research Centre

Purey-Cust. J.R., 1983. Regional coconut wood utilization training programme managerial course. Report of the Tongan representative

Purseglove, J.W., 1968. Tropical crops, monocotyledons. London, Longman Group. (Volumes 1 and 2 combined 1975)

Ramos, A.N. and Miciano, R.J., 1966. The mechanical properties of coconut palm *(Cocos nucifera L.)*

Ramos, A.N., and Sasondoncillo, R.W., 1971. Mechanical properties of coconut palm *(Cocos nucifera L.)*from Los Banos, Laguna. Co-operative Progress Report. College, Philippines, FORPRIDECOM Library

Reyes, E.P., *et al,* 1958. Coconut charcoal briquettes. Philippines Journal of Science 87 (1): 33-36

Reyes, G.P., Jr., 1982. The Asian and Pacific Coconut Community. Development of coconut timber use. CHOGRM Working group on Industry Seminar, Honiara, Solomon Islands

Rich, Stuart U., 1970. The marketing of timber and wood products. McGraw Hill

Richardson, Dennis, 1981. Coconut charcoal could fuel ships. Pacific Islands Monthly May:14

Richolson, J.M., 1979. The unique properties of coconut palm wood. South Pacific Bulletin fourth quarter

Richolson, J.M., 1980. A review of utilisation possibilities for over-mature coconut palm stems in Fiji. Suva, Department of Forestry

Richolson, J., 1982. Charcoal from coconut timber. Development of coconut timber use. CHOGRM Working Group on Industry Seminar, Honiara, Solomon Islands

Richolson, J.M., and Alston, A.S., 1977. Coconut palm wood charcoal, a potential source of heat energy for rural and semi-rural areas of Fiji. Part I. Production with simple steel drum kiln. Part II. Cooking with cast concrete charcoal stove. UNESCAP Regional Workshop on Biogas and other rural energy resources, University of the South Pacific, Fiji, 20 June to 8 July

Richolson, J.M., and Swarup, R., 1977. A brief review of the anatomy and morphology of the over-mature stem of the coconut palm*(Cocos nucifera L.)* (Part 1). Proceedings Coconut Stem Utilisation Seminar, Tonga, 1976: 65-102

Salita, A.A., 1973. An exploratory rotary veneer cutting of coconut trunks. A special project. College, Philippines, FORPRIDECOM

Salita, A.A., and Tamolang, F.N., 1977. Utilization of coconut timber residues for parquet flooring. Coconut Stem Utilisation Seminar Proceedings, Tonga, 1976: 467-69

Sampson, H.C., 1923. The coconut palm. London, John Balesons, Daniela Sons Ltd

San Luis, J.M., and Banzuela, A.Y., 1976. A preliminary study on the production of coconut shell charcoal briquettes. FORPRIDECOM Library Project ID-76/ITD-CP-D-1

San Luis, Josefina, M., and Estudillo, Calvin P., 1976. Charcoal briquetting - An outlet for wood and coconut trunk wastes. Forpride Digest V: 73-74

Santiago, C.A., 1983. Cultivation of"Tainga ng Daga" (*Auricularia*spp.) on coconut trunks. NSTA Technology Journal 8 (2): 24-27

Sasondoncilio, R.S., 1975. Mechanical properties of coconut palm (*Cocos nucifera*L.) from Los Banos, Laguna. Forpridecom Library. Unpublished

Segaar, C.F., Undated. The tropical timber and timber products market in the Netherlands. Rotterdam, The Centre for the Promotion of Imports from Developing Countries (CBI)

Semana, J.A., and Ballon, C.H., 1977. Hardboard from coconut trunk. Coconut Stem Utilisation Seminar Proceedings, Tonga, 1976: 473-77

Seneviratne, Gamani, 1981. Cracking the coconut market. United Nations Development Forum Business Edition, 16 February

Sibayan, D.V., and Decena, A.S., 1976. Study of the sawmilling characteristics and recovery of coconut *(Cocos nucifera L.)* trunk. Philippine Lumberman 22 (4): 15-17

Siriban, F.R., and Tamolang, F.N., 1977. Preliminary treatment of green coconut (*Cocos nucifera*L.) lumber by non-pressure methods. Coconut Stem Utilisation Seminar Proceedings, Tonga, 1976: 403-408

Siriban, F.R., and Mata, P.G., 1977. Stake tests of treated and untreated coconut *(Cocos nucifera L.)* Coconut Stem Utilisation Seminar Proceedings, Tonga, 1976: 421-26

Smart, D.W., 1974. Coconut palm timber for particle board. Fletcher Timber Co Ltd, New Zealand. Unpublished.

South Pacific Commission, 1957. Practical uses for coconut timber. Noumea, Quarterly Bulletin, April.

South Pacific Commission, 1982. Presentation of the 190 kW gas-generators feeding the public network of the commune of Bora-Bora - Operation results, produced by S.A. Electricite de Tahiti. rev. ed. Noumea

Stacey, D.L., 1970. Report on particle board manufacture as it affects Western Samoa. Bangkok, FAO Report

Sudborough, J.J.,*et al,* 1920. Wood distillation. Parts 3 and 4. Journal of Indian Institute of Science 3 (9): 285-89,293

Sudo, S., 1977. Anatomical properties in relation to variations in density in coconut wood. Anatomy and identification. Tokyo, Wood Technology Division, Government Forestry Experimental Station. Unpublished

Sudo, S., 1979. Variations in some important anatomical properties and density in the stems of coconut (*Cocos nucifera*) in relation to suitability for pulp making. Ibaraki, Forestry and Forest Products Research Institute. Unpublished

Sudo, S., 1980. Variations and density in the stem of coconut palm *(Cocos nucifera L.)* Forestry and Forest Products Research Institute Bulletin 312: 81-101

Sulc, V.K., 1977. Coconut stem utilization at the Philippine Coconut Authority Research Center. Coconut Stem Utilisation Seminar Proceedings, Tonga, 1976: 327-45

Sulc, V.K., 1979. Briefing paper: Design of different structures in PCA Timber Utilization Division. Paper presented to Meeting Coconut Wood - 1979, Manila-Zamboanga. Unpublished

Sulc, V.K., 1979. Briefing paper: Grading coconut wood. Paper presented to Meeting Coconut Wood - 1979, Manila-Zamboanga. Unpublished

Sulc, V.K., 1979. Briefing paper: Design and mechanical properties of coconut wood as used in PCA. Paper presented to Meeting Coconut Wood - 1979, Manila-Zamboanga. Unpublished

Sulc, V.K., 1979. Glossary of defects. Proceedings Coconut Wood - 1979, Manila-Zamboanga: 98-100

Sulc, V.K., 1979. Grading coconut wood. Proceedings Coconut Wood - 1979, Manila-Zamboanga: 100-101

Sulc, V.K., 1979. Coconut wood lamination. Proceedings Coconut Wood 1979, Manila-Zamboanga: 156-66

Sulc, V.K., 1979. Technical information: Possibility to use low density coconut wood for thermal insulation.Proceedings Coconut Wood - 1979, Manila-Zamboanga: 167

Sulc, V.K., 1979. Design and mechanical property of coconut wood as used in PCA Zamboanga Research Center, Timber Utilization Division. Proceedings Coconut Wood - 1979, Manila-Zamboang

Sulc, V.K., 1980. A report on the 1980 inspection of CCA-treated coconut electric poles and pole stubs. PCA-Zamboanga Research Center, Philippines. Unpublished

Sulc, V.K., 1982. Tonga report on coconut wood utilization. Rome, Food and Agriculture Organiz - ation of the United Nations

Standards Association of Australia [1975]. Australian Standards 1975: Use of timbers in structures

Standards Association of New Zealand, 1979. Limited relaxation of ban on wood shingles. News Release: 10 December

Tamolang, F.N., 1976. Studies on the potential uses of coconut trunk in the Philippines Chemical Society of the Philippines/National Science Development Board Seminar

Tamolang, F.N., 1976. The utilization of coconut trunk and other parts in the Philippines. NSDB Technology Journal 1 (2): 36-48

Tamolang, F.N., 1976. Studies on the utilization of coconut trunk and other parts in the Philippines. Proceedings of Seminar Workshop on Coconut Industrial Research: 144-58. Tagaytay City, Philippine Coconut Authority

Tamolang, F.N., 1979. Utilization of coconut trunk: An economic conservation approach and a business opportunity. Paper read in the Second World Recycling Congress, 20-22 March 1978 in Manila

Tamolang, F.N., *et al*,1958. Fiber dimensions of certain Philippine broadleaved and coniferous woods, palms and bamboos II. TAPPI 41 (10: 614T-620T)

Tamolang, F.N., and Valbuena, R.R., 1960. Fiber dimensions of certain Philippine woods, bamboos, agriculture crops, wastes and grasses III. TAPPI 43 (6): 527-34

Tansinsin, L.G., 1981. Availability and process of indigenous materials. NSDB Technology Journal 6 (1): 39-47

Technology Resource Centre, 1983. Technical information on cocowood (or coco-lumber). Manila. Unpublished

Thampan, P.K., 1982. Handbook on coconut palm. 2nd ed. New Delhi, Mohan Primlani, Oxford & IBH Publishing Co

Timber Promotion Council, Australia, 1980. Specifying and ordering structural timber. Blackburn, Technical Advisory Brochure 1

Tomlinson, P.B., 1961. Anatomy of monocotyledons: II. Palmae. London, Oxford University Press

Tomlinson, P.B., and -Zimmermann, M.H., 1967. The wood of monocotyledons. Zurich, Bulletin of the International Association of Wood Anatomists 2: 4-24

[Tongan] Coconut Review Committee, February 1982. A review of the coconut replanting scheme and aspects of the coconut industry related to coconut production, Kingdom of Tonga. Ministry of Agriculture, Fisheries and Forests Planning Unit Technical Publication 1/82

Tropical Products Institute, 1969. Postulated cost structure for particle board plant in Western Samoa using coconut palm timber. London

Tropical Products Institute, 1978. Interim report on the utilization of coconut palm timber (*Cocos nucifera L.)* as an aggregate with cement. London. Unpublished

Tropical Products Institute, 1979. Laboratory production of charcoal and charcoal briquettes from Fijian coconut palm timber. London. Unpublished

Turner, John, Undated. Philippines mini mill operation at San Ramon, August-September 1982. Report to [New Zealand] Ministry of Foreign Affairs Aid Assignment.

Turner, J.C.P., 1983. Report to the Ministry of Foreign Affairs on two years Bilateral Aid Assignment, Philippines

Uprichard, J.M., 1977. Kraft pulps from coconut stem wood *(Cocos nucifera L.)* the blending of coconut stem wood pulps with those from Pinus species. Coconut Stem Utilisation Seminar Proceedings, Tonga, 1976: 249-97

Vaney, J.C., 1982. Report to the Secretary, Ministry of Foreign Affairs, Wellington, on assessment of the New Zealand Bilateral Aid coconut sawmill project in Kiribati, 13-14 September 1982. Unpublished

Vergara, J., 1983. Prospects of cocowood utilization in Southern Tagalog Region. Cocowood Training at Zamboanga Research Center. Philippine Coconut Authority

Villegas, B.M., and Buencamino, J.A., 1982. The threshold family income of a coconut farmer (or why it is urgent that we think short-term for the coconut farmer. In the long run he may be dead), Part 1. Economics and Society Series B. Manila, Center for Research and Communication

Walford, G.B., 1974. The strength of coconut palm poles. Forest Products Division Report 488. Forest Research Institute of New Zealand. Unpublished

Walford, G.B., 1979. Coconut wood in structures. Overseas Travel Report. Forest Products Division, New Zealand Forest Service. Unpublished

Walford, G.B., 1979. Structural use of coconut timber. Proceedings Coconut Wood - 1979, Manila-Zamboanga: 150-56

Walford, G.B., and Goodwin K.J., 1976. Structural properties of green coconut timber from Fiji. Forest Products Laboratory Report FP/TE76. Forest Research Institute of New Zealand

Walford, G.B., and Orman, H.R., 1977. The mechanical properties of coconut timber and its design capabilities in construction. Coconut Stem Utilisation Seminar Proceedings, Tonga, 1976: 174-98

Watanabe, H., 1978. Report of an analytical survey of coconut forest in Taveuni Island of Fiji (Addendum). Japan Forest Technical Association

Western Samoa. Western Samoa Trust Estate Corporation, 1976. WSTEC crop debris utilization 1976-1980

Yudodibroto, H., 1979. The potential use of impregnated coconut wood for power line poles in rural areas of Java. International Research Group on Wood Preservation Working Group III, Preservatives and Methods of Treatment. Document Number IRG/WP/3130

Zerrudo, J.V., and Escolano, J.O., 1976. Coconut for paper pulp. Coconut Stem Utilisation Seminar Proceedings, Tonga, 1976: 493-502

Zimmermann, Martin H., and Tomlinson, P.B., 1974. Vascular patterns in palm stems: Variations of the Rhapis principle. Journal of the Arnold Arboretum 55 (3): 402-24

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