PROCEEDINGS OF CONFERENCE ON IMPROVED UTILIZATION OF TROPICAL FORESTS

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Summary Sections

RESOURCE

Since time immemorial man has had ambivalent feelings about trees. They provided him with food, fuel, and feed for his animals and with shelter. The forest also hid the enemy, housed fearsome ghosts, and occupied land on which, from time to time, other crops should be grown. In Europe man sorted out his ambivalent feelings some time ago and concluded that at least 25 percent of his land should grow trees. In Sweden the forest has been increased in size over the last 400 years, Finland is draining marshes in the North at enormous cost to grow new forests, the area of German forests has been increasing for 200 years, and that in France for 150 years.

In developing countries, demands on the forest to improve the quality of life are much greater than they have ever been in Europe or North America. More than 2 billion rural people depend on fuelwood to cook their meals; fruit, pods, and leaves of trees are a major part of their diet, and they hunt the game that lives among the trees; poles and branches are used to build the homes; and they sell some big logs to obtain foreign exchange for their most urgent imports. More recently people have looked to the forest as a source of paper. There is general agreement that the forests of the moist tropics do not contribute an adequate share to human welfare and great concern that they are damaged and often destroyed in spite of their meager contribution.

Forest

Area

Half of the world's forests, some 2.3 billion hectares, lie within the tropics; furthermore, almost half of this is closed forest. About 60 percent of the tropical forest is in Latin America, 25 percent in the Asia-Pacific areas, and 15 percent in Africa. The largest block is located in the Amazon basin, where it makes up 40 percent of the land area of Brazil. Inventories are generally inadequate to provide accurate estimates of the forested areas in most tropical countries.

The forest regions of the tropics are usually populated by isolated families--dedicated mostly to subsistence agriculture. The population of the region is increasing at rates in excess of 2 percent, with a life expectancy of less than 55 years. Incomes are low and amenities are few.

Types

A large number of forest types characterize the tropics, ranging from dry-deciduous to rain forests. Almost 90 percent is of mixed broadleaf trees and only 2 percent is coniferous. The natural forest of the moist tropics contains a great diversity of trees. The wood of these trees varies widely in density, color, contents of extractives and silica, and in many other respects. Not only do the physical, mechanical, and chemical characteristics of the woods differ among species, but large variations also exist within species, depending on site, rainfall, age, and other influences. This is true in the natural forest and in plantation species, whether native or exotic.

Values

Tropical forests possess a broad spectrum of values which, in the context of this Conference, were seen as of two types: Those primarily of a social nature and those primarily economic for the production of commodities.

A. Social

1. As sources of useful information on organic evolution and ecosystem dynamics.
2. As habitats for numerous species of plants and animals, including indigenous human cultures.
3. As a stabilizing influence on climate, soil, and water behavior.
4. As sources of recreational enjoyment.

B. Economic

1. As regulators of the quality of useful water.
2. As sources of plant and animal products, including wood-based materials.

The wealth of species is reflected in forest tree inventories. One such inventory in the Amazon Valley shows 438 tree species on less than 60,000 hectares of land. Many additional plant species are potential sources of medicine, foods, pesticides, and other industrial raw materials. The animals present pollinate the plants, disperse seeds, control pests, and assist in nutrient recycling.

World-wide, the timber volume in tropical forests is on the order of 200 billion cubic meters. Paradoxically, the present utilization of the trees of these forests is inadequate to supply the needs of tropical countries. Part of this problem stems from the fact that, because of topography, climate, or accessibility, large forest areas are not considered "economically operable" for harvesting. A large proportion of the wood volume cannot be disposed of in any other way but for fuel in populated areas and not at all otherwise.

These two factors exclude more than 80 percent of the forest biomass from industrial consideration in Latin America. In the Asia-Pacific region the figure is near 55 percent, and for Africa it is about 90 percent.

The number of timbers utilized for industrial purposes varies widely with accessibility, forest composition, and efficiency of operations; in some cases only one species is extracted, while in other situations, 50 or more species may be used. Notwithstanding these limitations, there are many little-used woods that can be expected to be accepted on the market for a variety of products.

Trends in Forest Area

The fact that the area of tropical forests is shrinking is common knowledge. One estimate is that they now cover only 60 percent of their former area. Of the former dry forest area, some 20 percent apparently has been converted to desert, with the remainder considered under threat. The richness of the tropical forest in terms of species has been reduced by breaking up its integrity, to the detriment of the flora as well as fauna.

The annual removal of industrial and fuel wood is on the order of 900 million cubic meters per year, or about 1/200 of the standing volume. Some 85 percent of this is used as fuel. In most countries, the more accessible tropical forest has already been cut over once or more. These observations have led to predictions of the disappearance of the tropical forests, as we now know them, in 25-50 years. There are no systematic inventories or other data to support an accurate prediction but dangers may well exist in some localities.

In a world where population pressures keep on increasing and land is becoming more and more valuable, it is reassuring to realize that only small areas of plantations are required to produce a very large volume of wood. Tropical tree plantations now occupy less than 1 percent of the tropical forest land and it is unlikely that more than 2 percent will be used for tree plantations by the turn of the century. Concerns that establishment of plantations are an imminent threat to the genetic diversity of trees growing in the tropics appear exaggerated.

Environmental Considerations

Impacts of More Complete Utilization

The environmental impacts resulting from more complete tropical forest utilization are largely a matter of conjecture. They undoubtedly would vary from place to place. Probable impacts would be accelerated soil erosion, at least some temporary reduction in nutrients, reduction in soil microorganisms, decline in the quality and uniformity in flow of runoff water, and a decline in genetic quality and diversity.

The magnitude of these impacts may vary with the degree of modification of the natural ecosystem. Where important rainwater catchments or where growing populations need hydroelectric energy, these impacts could be severe.

The decline in nutrient levels caused by increased removal of trees and tree products may give rise to vegetation unsuitable for future timber crops. Removal of stemwood from tropical forests reduces key element (N, P, K, Ca, and Mg) residuals at almost five times the rate characteristic of the temperate zone.

Possible favorable environmental impacts are also foreseen from intensified forest utilization. Silviculturally, more options are available. Higher yields would require less land, and mixed ecosystems with their ecological stability would become more practical to manage. Quantity of unused material would decline and the combination of wood and food production in close harmony with traditional tropical agriculture become more attractive.

Hazards

Because it is apparent that substantial areas of tropical forests will be harvested, reasonable rather than extreme policies must be established to guide these efforts. The fate of the forests should not be left solely to either the forces of narrow preservationism or those of short-term exploitation. The proper policies lie between these two extremes. Forests that need not be developed or modified preserve a maximum number of optional uses and are cheaper to maintain in this condition than in any other. Thus, those who propose change must document the need. Natural forests, whenever slightly modified, lose forever attributes which, when more fully studied, may prove to be of great value.

The very complexity of the humid tropical forests presents a unique challenge for ecological management. Pressures on the forest will increase, with an estimated tripling of the rate of timber harvest in the foreseeable future. Fuelwood shortages will become locally more acute. The thousands of species, many endemic to small areas, deserve our concern.

To face these hazards, neither the forestry profession nor any other is adequately versed in tropical ecology. Any intervention into the forest causes change. In what ways? How seriously? For how long a period? Will sites be maintained? Will a second crop appear and prosper? Will it be useful? All of these questions lead to a single watchword--caution.

Guidelines

Underlying proper care of the environment are three prerequisite techniques:

1. Good planning for the use and alteration of the land based on use capability.
2. High standards in the conversion from one land use to another.
3. Good management of all land uses.

Enough knowledge and experience is available in the world to implement a majority of the measures to ensure satisfactory development of tropical forest lands. However, the approach must not be: "Here is a resource--we must use it," but rather "How can it be used to the greatest benefit, local and world-wide?"

Resource inventories must be accelerated and expanded not only to find new resources, but to protect them where necessary to secure their full value. Instead of recording stemwood volume only, biomass inventory should be substituted and gradually extended to include information on soils, animals, birds, and fish population, etc.

Areas needed for protective uses should be allocated before land is designated for transformation. Reserves of tropical ecosystems must not be limited only to the least productive lands but should represent some of the best as well. The well-being of indigenous peoples should be primary in those forested areas upon which they depend. Areas of forest allocated for agricultural use must only be those suitable on a continuing or rotational basis.

Full use must be made of timber and other produce from the forests. Extraction must protect site values and assure continual productivity in any subsequent use of the land. Bench marks sensitive to environmental quality changes must be established, used, and monitored to guide future practice.

Silvicultural Considerations

Site Potential

The net industrial wood increment in the natural tropical forest ranges from 1-7 cubic meters per hectare per year depending upon a variety of factors, some a response to silvicultural practice. Increased utilization of the forest should increase the yield, particularly in secondary stands. As a result, the protection and culture of such stands could become much more attractive.

Not only could the area of land required for a given level of production be reduced but hauling distances to processing plants could be reduced as well. Timber production as an adjunct to farming should become more attractive. The more complete removal of native forests could also facilitate the conversion to plantations where technically desirable. This change alone could increase site productivity tenfold in terms of volume, and thus further reduce the necessary production area.

Trees need not be killed to contribute wood for pulp and fuel. One speaker mentioned that leaving two coppices of Leucaena instead of one nearly doubles the annual increment. In India and Nepal, lopping of tree branches is the customary way of obtaining firewood. We may find that, without destroying the tree, more wood in dimensions suitable for pulp and firewood can be harvested.

Natural Regeneration

Except for parts of the dipterocarp region, natural regeneration of selected timber species has been disappointing. Harvesting has generally resulted in a less productive second crop. The prospect of more fully utilizing the native species could reduce selectivity to a point that natural regeneration becomes more acceptable. Under favorable conditions in the Asia-Pacific region, satisfactory natural regeneration is not rare, with only open areas being planted after logging. Immature dipterocarps remaining after the harvest are protected and released, thus providing a continuous cover to the soil and assuring an early second crop. This practice is applied not only to natural stands but also to plantations of Albizia.

If improved utilization of tropical forests is to arise from the production of fiber, the mixtures resulting from natural regeneration of native forests retain some handicaps when compared to plantation crops. Not only must the production area be larger for natural regeneration, but the lack of forest uniformity presents processing problems and higher costs.

Artificial Regeneration

Experience with timber plantations has been sufficiently successful as a potential source of pulpwood and other forest products so that this technique is favored over natural regeneration in many places. The advantages are in yields, which range from 4-10 or more times those of native forests; greater control and uniformity of product; smaller productive area required; and shorter average haul to processing plants. It is also more compatible with the more complete removal of native forests which will result from improved utilization.

The selection of tree species is still under study at most locations, hundreds having already been considered and tested. Most popular are: Gmelina arborea, Pinus caribaea, P. kasiya, Eucalyptus spp., Albizia falcataria, and Anthocephalus chinensis.

Procedure for plantation development requires a fairly complete clearing of the land by harvesting all merchantable material, followed by burning. Nursery stock, either bare root or containerized, is produced from seed either purchased or produced locally. Planting is followed by a period of weeding, sometimes accomplished by inter-cultivation of food crops or establishment of grasses compatible with the young trees.

Plantation yields range from 10-30 or more cubic meters per hectare. But uncertainties remain as to the capacity of most sites to sustain production under a system of such heavy removals. Likewise, the optimum rotation length for quality pulpwood from some tree species is still to be determined.

Several speakers expressed preference for the use of indigenous over exotic species for plantations. There are several well-documented cases where exotics, away from home, have done much better than expected. Monterey pine in New Zealand is a classic case. Indications are that industrial wood from the natural forest will be more expensive than from plantations, in the long run at least, because the supply is more scattered and has to be transported over greater distances.

Culture of Established Forests and Plantations

The culture of naturally regenerated secondary forests is not yet a widespread practice. Where natural regeneration is adequate, it generally is left to grow with a minimum of attention. An exception is in the dipterocarp forests of the Asia-Pacific region where release cuttings and thinning are practiced. The objective is to eliminate what appear to be worthless trees. Little is known as to the benefits, if any, from such practices.

Timber plantations, particularly where large-diameter material is desired as well as pulpwood, may be pruned once or twice and thinned twice or more during the rotation. Again, the benefits are not yet fully appraised.

UTILIZATION RESEARCH

Anatomy of Wood

The large number of tree species in tropical forests gives rise to a wide range in anatomical features, many of which are significant to utilization. Fiber lengths range from 0.4 to 3.2 mm, with the average almost 1.5 mm. Fiber wall thickness ranges from 2 to 14µ with the average about 5.6µ--somewhat thicker than for North American hardwoods.

Runkel ratios, considered by some as indicative of papermaking quality, showed an average for the species listed at 1.4, or generally poor quality. However, by eliminating the 10 worst of 130 species, the average ratio was lowered to 0.85 or quite good.

Silica levels found in 21 of 130 species tested present a utilization problem unique to tropical woods. This factor results in rapid dulling of chipper knives and machining tools, and creates problems in the kraft cooking liquor preparation system.

Extractives can cause problems but a general knowledge of their kind and character permits adoption of alleviating techniques. This factor relates primarily to pulp and paper processing systems.

In summary, the special anatomical characteristics of tropical woods are both favorable and unfavorable. They must be understood for these woods to fully utilized.

Wood Fiber and Reconstituted Product Research

The Forest Products Laboratory, in cooperation with USAID, has over the last 3 years conducted systematic research to explore how woods from the humid tropical forest could be used for the manufacture of pulp, paper, and reconstituted board to fill the needs of the quickly growing and ever more literate and sophisticated population. Other national and international organizations are also hard at work to wrest a larger contribution from the moist tropical forest.

Even more important is the fact that many research agencies in such countries as Philippines, Colombia, Brazil, and Mexico are doing excellent and successful research as well. Several pulp and paper plants have been established during the last few years in developing countries, which conclusively confirms research findings that pulp and paper can be produced satisfactorily from mixed tropical woods.

All speakers have reported that, by excluding small percentages of the very light and very dense woods, pulp can be manufactured at good yield for various uses comparing favorably with hardwood pulp produced in Scandinavia and Canada.

Some speakers suggested that the mix of pulpwood going into the digester should be kept the same while the mix from the forest changes. This is admittedly a difficult task and costly to achieve. Several others said that pulp quality will be sufficiently consistent to satisfy market requirements if the chip mix comes from a large variety of trees.

Mixtures of tropical woods were also used for manufacturing board products, both high- and medium-density. No major problems were encountered when using the wet or dry processes or when adding the usual amount of bonding agents.

The quality of these boards compared favorably with that of North America products. The test, conducted at the U.S. Forest Products Laboratory and similar tests at CSIRO in Melbourne, P & P Research Institute in Montreal, CTFT in Paris and elsewhere, confirmed that there are no insurmountable problems to using random mixtures of mixed tropical hardwoods to make good paper, hardboard or fiberboard. From the inventory figures and indications of productivity of the second-growth natural forest and the plantation, indications are that availability of raw material is not a major concern even if plentiful secondary sources of fiber available in the tropics are neglected. Palm trees or vegetable fibers have not even been considered.

The discussions and the comprehensive research that preceeded them indicate no insurmountable technical constraints to produce pulp and paper from a random mix of tropical woods from which a small percentage of unsuitable wood may need to be eliminated. Even fewer problems are apparent in manufacturing good-quality reconstituted board from mixed tropical woods. Obviously, there is a long way to go until the findings of laboratory-scale experiments are translated into the operating papermills that developing countries can afford, can satisfactorily operate, and which will produce the lion's-share of their requirements at an acceptable cost.

Most tests reported were conducted in the laboratory, and only tests conducted over periods in a factory setting can assure that no serious problems have been overlooked. One speaker reported that factory-scale tests cost about $500,000, so securing this reassurance is not a cheap or simple matter.

At least three important characteristics in the natural tropical forest differ widely from those of the temperature zone. The "second-growth" forest contains less dense wood, a larger proportion of the biomass is in leaves and green shoots, and the juvenile wood matures more rapidly. A 5-year-old tree may make very good pulp; by harvesting the trees at an early age, we can be actually increasing the amount of nutrients returned to the soil.

INDUSTRIAL PRACTICE

Logging

A wide variety of logging methods is used in the tropical forests, and improved utilization of standing timber can be expected to open more options. The increased yield anticipated per unit of area should reduce logging costs, particularly in the range of 5-50 cubic meters per hectare. A reduction in the average size of material removed may have an opposite effect.

The degree of mechanization of logging is a matter for continuing study. Even with more complete utilization, labor-intensive methods or a combination of both labor-intensive and mechanized logging may prove most desirable economically and socially. Highly sophisticated systems can be expected to have disadvantages in many areas.

Transportation

Improved utilization of tropical forests will make it feasible to haul materials further but also require much better and more permanent transportation systems between the landing and processing plants. Of major importance will be an all-weather primary system, eliminating seasonal work stoppages. Equally important will be the location of the processing plant near the wood source. The result should be lower unit costs and increased feasibility to utilize wood types now left in the forest.

Human Factors

The potential of forestry and forest industries for alleviating unemployment, for transferring technical skills to local inhabitants, and in assisting equitable distribution of economic activity within each country and among the various social strata of their populations remain virtually unrealized.

Prospects for improved utilization of tropical forests are increasing the horizon of forestry operations. Integrated utilization of various products, larger plant investments, and more employment all involve operators in more social concerns. The development of planned communities of forest workers is taking place, a relatively new phenomenon in tropical forestry. Accompanying this is a greater concern for personnel training and safety.

Notwithstanding progress in this direction, work-science in this field is in its infancy. Ergonomics has not yet found a strong base in tropical forestry within either national or international agencies.

Storage of Wood Chips

The prospect of greatly increasing utilization of tropical wood in the form of chips has focused attention on storing wood in this form. Lengthy storage of pulpwood either in the round or as chips can be a major problem. It was mentioned that in some instances pulp yield may drop by 30 percent after 3 months' storage.

In any case, prompt use of chips is desirable, especially for the lighter colored woods. It has been shown that storage of dipterocarp woods for as long as 9 months in a humid climate need not cause serious deterioration in the strength properties, burst, tear, and tensile value of sulfate pulp. Research on this practice has not proceeded to a point where broad generalizations can be made.

Mill Operations

It is hard to predict what the future holds but we can be encouraged if we look back at what has been achieved in the last 20 years. Short-fibered pulp, the type which can be produced from tropical hardwoods, now constitutes 60 percent of the furnish for paper in Japan and Europe; this value used to be less than 25 percent only 10 years ago. One of the world's large manufacturers is now producing newsprint and good paper from Philippines wood. Operations based on Colombian wood have been successful for the last 17 years, Peru makes particleboard from a mixture of 45 different local woods, and so on. Many other smaller operations are successful and several more are on the drawing board.

Silica content in many tropical woods creates a severe problem in chipping, may create one in the black liquor, and has an unknown effect in the pulp. No one seems to know why silica is so readily absorbed into the tissue of tropical wood, and whether tree breeding may produce logs with a low silica content. Nor is it known why silica is present at times as amorphous globules in the wood, at other times as coating of the cell wall.

Machine barking of several species was also identified as a major problem, but not too serious a one.

A high percentage of solubles may affect pulp yield and cause foaming problems. Species with high soluble content may have to be used for fuel, the same way as very dense wood.

Some tropical woods contain a high percentage of nonfibrous elements that make them uneconomic for pulp. Others may require excessive amounts of bleaching; but these woods can be easily separated and used for unbleached pulp only. The same is true for a type of wood with exceptionally high lignin content.

Depending on the end use, tropical wood can be pulped by the kraft processing or by the neutral sulfite semichemical process. Some lower density, light colored woods will yield fiber suitable for newsprint when ground by the thermomechanical process.

INDUSTRIAL PLANS AND INVESTMENT CONSIDERATIONS

Salient Features of Industrial Development

With half of the world's forests situated in the tropics, the last quarter of the century has seen the development of some technologies for their full utilization. But benefits derived from the industrial processing of wood from these forests are still modest compared to their potential. Industrial development based on tropical forests is even more unsatisfactory from the viewpoint of the tropical timber-producing countries; some 80 percent of the industrial wood harvested in those countries is now processed in other countries.

Even if the tremendous potential of forests and afforestable areas in the tropics is underutilized as a base for industrialization, important progress has been achieved in the development and utilization of tropical forests.

Removals of tropical saw and veneer logs have multiplied during the last 2 or 3 decades and have created substantial export earnings and employment to many tropical countries. Moreover, infrastructure for wood harvesting and transport has been improved. A great number of new species have been successfully introduced to international markets.

The growth of the sawmilling industry in the tropics has not matched optimistic expectations because industrialized countries have dominated the markets. Yet significant new inroads have been realized in exports of sawn wood. Furthermore, the use of secondary species for domestic consumption has made gradual progress.

In spite of the high export volume of veneer logs, the plywood industry has grown rapidly in such tropical timber-producing countries as Indonesia, Malaysia, the Philippines, several West African countries, and Brazil. Furthermore, several developing countries (Singapore, South Korea, and Taiwan) have developed significant plywood exports based on imported logs ("in-transit industries").

While only two small-scale industrial trials were carried out in the early 1950's to use mixed tropical hardwoods for pulp and paper, commercial pulping of tropical hardwoods is now taking place in a number of countries including the Philippines, India, Bangladesh, Brazil, and Colombia. Practical experience and research have proven that most grades of paper and paperboard can be made from fiber furnishes comprising mainly fiber from mixed tropical hardwoods.

Possible production of pulp from mixed tropical hardwoods for international markets has received attention for a long time. It now appears this dream is going to be realized despite the currently depressed markets for short-fibered pulp. Market pulp projects in Cameroon and Gabon are under implementation and other projects in such countries as Ivory Coast, Guyanas, and Indonesia are under serious investigation.

The specific case study prepared for this conference concluded that under the present conditions a 500-ton-per-day market pulpmill based on mixed tropical hardwoods in the Philippines would not be viable if the mill is considered exclusively on its own financial merits. At the same time, the study pointed out substantial social and economic benefits to be derived from such a project. Current low prices of market pulp do not attract major investments to expand capacity anywhere in the world. The demand/supply balance of market pulp is gradually improving, however, and the climate for new investments appears more favorable in the early 1980's.

Integrated planning of forestry and forest industries development will become more and more important to make full use of the resources. The goal should be to develop forest-integrated forest industries able to make optimum use of available raw materials. Considerations should be given to the use of low-value roundwood and residues to generate energy, both for captive needs and for sale. More attention needs to be paid to the vertical integration of several stages of production.

Development of short-rotation timber crop plantations during the last couple of decades has dramatically changed the potential role of the tropics in the global wood supply picture. The present focus of quick-growing plantations is directed toward pulpwood supplies. Perhaps more consideration should be given to catering to the raw material needs of the utility plywood industry supplying them from fast-growing tropical plantations.

As the techniques of managing plantations improve, the cost of producing wood will decrease. Furthermore it is likely that some plantation land can sooner or later be sold for more valuable uses. Plantation-based forest industries in the tropics are now taking their first steps to participate in the world supplies of wood products. Two striking projects are being developed in Brazil--the Aracruz and Jari market pulp projects. Plantation activity for the Aracruz project was started as late as 1967, but this 400,000 ton/annum eucalyptus pulp plant will start commercial operation toward the end of 1978. The first stage of the Jari forest industries project will be a 250,000 ton/annum gmelina pulp mill. Most of the plant has been built on two barges, which has cut down the construction time on the spot and facilitated the maximum use of foreign finance.

The past development of forest industries in the tropics has been based on conventional processes which can be applied to utilize tropical timbers. Such technological breakthroughs as particleboard manufacturing, dry-process fiberboard manufacturing, and thermomechanical pulping, developed for the needs of the industrial countries, have found limited application in the tropics. The challenge to develop appropriate technologies for the utilization of tropical forests is now becoming acknowledged.

Economy of scale has led to the design of commercial pulp mills and papermills that produce many times the requirements of most developing countries; such mills might require capital investment in the range of the annual budget of many of these countries. They require a huge water supply in regions where clean water is often scarce, they create major pollution problems, and the country's economic health may depend on the ability to market a major proportion of the production in the notoriously unreliable export markets.

Attempts to solve these problems have come from several directions. The Chinese, for example, are operating some very small mills in which they produce the requirements of a region from regional lignocellulosic materials, usually by-products of agriculture. These mills are reported to be inefficient by North American standards and pollution control is none too strict, but they save the cost of moving raw material and products over great distances. When the savings in social cost of keeping people at home are considered, these mills appear highly desirable. Another alternative is to redesign the North American-type mill for smaller production. This has been investigated before, with the introduction of thermomechanical pulping once expected to solve this problem, but so far nothing dramatic has happened. It is likely that the solution will be found by making small changes in processes, equipment design, and product specification.

Problems in Industrial Utilization

Industrial use of timber, as compared with the volume of growing stock in the tropics, is still very small in relation to the industrial countries. A number of obstacles slow forest industry development in the tropical countries. The most important problem is the underdeveloped industrial infrastructure in such aspects as:

-- Lack of good roads, ports, storage facilities, and efficient shipping.

-- Poor communication facilities.

-- Lack of chemical, engineering, construction, and service industries.

-- Nonavailability of public power supply.

-- Poor community services.

-- Shortage of experienced management and skilled labor.

-- Slow and bureaucratic procedures by authorities.

-- Underdeveloped domestic capital markets.

The size of the markets is often too small to support required economies of scale in the capital-intensive industries. Market outlets for wood residues may not be available, as compared to the industrialized countries.

The natural resource base may present specific problems such as: Heterogeneous forests with problem species of high silica content or extractives, sensitive soils, climatic disadvantages to human labor, or lack of domestic energy resources.

Sustained forestry and investments may be hindered by population pressures and underdeveloped land-use policies, frequently coupled with shifting cultivation.

Time and effort may have to be spent to obtain necessary resource data through forest inventories, species trials, studies of wood properties on different species, and so on.

Appropriate technology by modern standards may not be available to meet the requirements set up by small markets, less skilled labor, deficient service industries, and heterogeneous, less-known raw material bases.

Various means should be adopted to obtain higher value added in the exports of tropical timber products. Attention should be directed to promote favorable trade policies and product development.

In striving for optimal development of their land and forest resources, the tropical countries should note that development of short-rotation timber crops and the full utilization of natural tropical forests are competing as the raw material for short-fibered pulp production. While maximum production of biomass should be given consideration, demand for long-fiber pulp, high-quality solid wood, and decorative wood products should have equal attention.

In the strategy of forest industries development, attention must be paid to the whole production and distribution chain, from the seedling to the delivery of products to the consumer. Export shipping of bulky forest products always comprises a substantial part of the total cost of delivered products. That is strikingly the case in shipping forest products from the tropics to industrialized countries. Shipping systems must be improved through concentration of trade flows, building of forest product terminals, and use of specified vessels. A clear distinction must also be made between domestic industries and export industries.

In general, domestic industries can operate on a smaller scale and use lower grade raw materials than export industries. Appropriate technology should be developed for the domestic forest product industries with full consideration of the size of the market (often small), availability of skills and services, and the quality of raw materials.

Export industries have to be internationally competitive with regard to price, quality of product, terms of payment, reliability of delivery, etc. In capital-intensive industries such as pulp and paper, international competition requires large investments because of the pronounced economies of scale. Investment requirements for an export pulp mill, considering infrastructure and forest development, are in the order of 300 to 600 million U.S. dollars. Because of liquidity problems, these types of projects need a high share of equity--say 30-40 percent of the total investment unless acceptable guarantees can be given. Availability of adequate amounts of risk capital is a major problem for most of the tropical countries aiming to establish export pulp and paper industries. Perhaps some fresh thinking is needed as to how the international aid programs could help in the formation of the necessary equity capital.

Establishment and operation of forest industries requires inputs from the engineering, construction, chemical service, power, shipping, and communication industries as well as improvements of roads and ports. In the traditional forest product-exporting countries, the above-mentioned linkages have led to the establishment of major supplier industries. Thus the tropical timber-producing countries should establish a suitable economic climate for the development of these linkage industries.

COMMENTS FROM ATTENDEES

The discussions and comments from the floor after the summations were primarily directed at the resource and its maintenance or even expansion for the benefit of the people. Because the conference centered on pulp, paper, and reconstituted products, it was accused of being myoptic. While this was the orientation, the flood of opinion, thoughts, and experiences in other areas resulted in recommendations that this type of conference should be continued. Diversity of backgrounds and full exchange of ideas should help with full realization of the problems ahead.

FAO conferences, which are held every 3 years or so, pretty well cover specific areas of immediate concern in forestry and forest products development. The Eighth World Forestry Conference will speak about forests and people. That man is included in plans for tropical forest utilization is recognized, but the manner in which the planning will achieve a common good is not generally agreed upon.

The need for characterization of more species was expressed, as well as that some natural forest should be set apart for research to understand the total function and use of tropical forests. A comprehensive view must be established.

Since the technical problems of utilization are not the most critical for development, conferences which consider the political, social, and economic factors would do much to focus on problems that hinder development.

The question of plantations versus natural generation was presented from diverse viewpoints. Some deplored the accent on plantations, while others indicated this was the only way to proceed to assure the availability of suitable wood at economic prices for a variety of forest products and reduce excessive exploitation of the natural forests.

The soil of mixed tropical forests is not fertile and thus the forester must work with the people of the forest in learning how to handle this complex ecological system.

The conference was reminded that 85 percent of all tropical wood goes into fuelwood and thus needs exist for more efficient use of this wood by the natives in better stoves and new types of cooking utensils, as well as change in dietary habits to foods requiring less heat to prepare.

Finally the attendees from the developing countries were urged to look carefully at the development of forest product enterprises in the industrial nations. It is important to accept the appropriate technology advancements, while rejecting techniques which have little bearing on the functional use of the product but significantly increase the cost of production.

CONCLUSIONS

1. The tropical forest resource covers one half of the world forested area.

2. Forest types range from dry-decidious to rain forests and contain a great diversity of trees and other biomass.

3. Tropical forests have social, economic, and environmental values of world-wide as well as local significance.

4. The tropical forest area is shrinking, at a rate which appears irrational.

5. Inventories are inadequate to provide accurate estimates in most tropical countries.

6. Areas needed for protective uses should be allocated before forest lands are designated for wood production.

7. Enough knowledge and experience is available to support technically satisfactory development of tropical forest lands.

8. Forestry and forest industries have great potential for alleviating unemployment and for development of technical skills by local inhabitants.

9. Prospects for improved utilization of tropical forests are increasing the horizon of forestry operations, although work-science in this direction is in its infancy.

10. Anatomical characteristics of tropical woods can be both favorable and unfavorable to utilization and must be fully understood.

11. Laboratory research has demonstrated the feasibility of using mixed tropical hardwoods in pulp, paper, and reconstituted building products.

12. The establishment and successful operation of commercial plants has generally confirmed laboratory research results and provided solutions to problems arising from the varied character of the wood.

13. Environmental impacts of more complete utilization are a matter of conjecture and need further study.

14. Natural regeneration with selected timber species has not been predictable and therefore is disappointing.

15. Experience with timber plantations has been sufficiently successful for pulpwood and other forest products to make this technique preferable to natural regeneration.

16. The concern about plantation effects on genetic diversity appears exaggerated.

17. Development of short-rotation timber crop plantations in the tropics has dramatically changed the potential role of tropical forests in the global wood supply picture.

18. Long-time storage of tropical woods, especially in the form of chips, has economic hazards.

19. Problems for industrial utilization are many but the most important is the underdeveloped industrial infrastructure.

20. Market considerations will restrict the number of large plants. Developing countries in the tropics need procedures and guidance for stepwise development of forest industry complexes in scales suitable for local markets.

21. There is recognition that, with cautious and enlightened development, major environmental concerns can be met.

22. Developments by the year 2000 will be slow and thus permit organized and systematic approaches to the sound and wise utilization of the vast but diminishing tropical forest resource.

RECOMMENDATIONS FOR ACTIONS

1. USAID, in conjunction with other large technical assistance agencies, should develop common, environmentally sound guidelines for assistance in achieving long-term benefits from tropical forest lands, including their distinction from those more properly put to other uses. To the extent possible, timber operations should be concentrated on lands which would be cleared of forests in any event.

2. USAID should coordinate research on an international basis, preferably through technical assistance agencies, in the following areas:

(a) The need for natural forest reserves.

(b) Impacts of existing tropical forest uses and their significance to future environmental values.

(c) Studies of typical mixtures of woods from primary and secondary forests for all types of forest products.

(d) Site productivity potentials and the effectiveness of silvicultural practices in plantations and naturally generated forests.

(e) The potentials of agroforestry.

(f) Strategies adaptable to areas of weak infrastructure: harvesting and export of logs; manufacture of sawnwood, veneer, and plywood; export of chips; production of energy; manufacture of pulp; manufacture of paper; and production of finished lumber.

(g) Intermediate technology for harvesting that has social and economic balance.

(h) Forest product manufacturing technology suitable to produce the bulk of domestic needs of the medium-size developing countries.

3. FAO should lead in promoting world-wide inventory of areas and trends for both commercial and noncommercial forests; savanna areas appropriate for reforestation should be included.

4. FAO should monitor global markets for forest products to assist industries in planning the timing of new capacity development.

SUMMATORS

Three prominent scientists and experts in the field of tropical forestry and the utilization of these forests consented to summarize segments of the conference. The summators' experience in the respective areas added a significant dimension to the results. In their summations they reviewed the highlights of the papers and presented the main points of the discussion. Finally, they were charged to provide recommendations for future study: (a) those areas vital for short-term needs and (b) those more of a long-term nature.

Frank H. Wadsworth summarized the papers related to resources, environment, silviculture, harvesting, transportation, and storage. Dr. Wadsworth is Project Leader at the Institute of Tropical Forestry in Puerto Rico. He received his BSF, MF, and PhD in forestry from the University of Michigan. He has been involved in silvicultural research for 40 years, most of this time in Puerto Rico. He is forestry consultant in Latin America on forest management and silviculture. His projects at the Institute include (1) tropical timber plantation culture, (2) ecology of tropical ecosystems, and (3) management of tropical forest wildlife.

John G. Bene summarized the research results for wood fiber and reconstituted products. Mr. Bene is Senior Advisor to the President of the International Research Centre of Ottawa. In this capacity he led a team of experts in identifying research priorities in tropical forestry that would significantly contribute to the enhancement of the social, economic, and environmental welfare of the people in tropical forest areas. This effort resulted in a report entitled "Trees, Food, and People--Land Management in the Tropics." He is now active in implementing the report's recommendation via the International Council for Research in Agroforestry. Mr. Bene received degrees in mechanical and electrical engineering from Jossif University at Budapest in 1932. His career in forest operations and the forest products industry spans the five continents and 45 years. He was founder, director, and president of Western Plywood Co. Ltd., later renamed Weldwood of Canada Ltd. Since 1968 in various assignments for CIDA and IRDC, he has travelled extensively in the developing countries, leading task forces and advising on forestry, land management, and forest products-oriented projects. He has been discussion leader at several FAO World Consultations. He also has made himself available for service to the Children's Foundation in Vancouver, to UNICEF of Canada, and other organizations whose efforts are aimed at social and economic improvement of people.

Risto Eklund summarized the papers on industrial plans and practice, investment considerations, and discussion. Mr. Eklund is chairman and chief executive officer of Jaakko Pöyry Consulting in Finland. He has a Master of Forestry degree from the University of Helsinki and the University of Washington, as well as a Master of Science in Engineering from the Technical University of Helsinki. He received an honorary Doctor of Science degree in agriculture and forestry from the University of Helsinki in 1977 and is a member of the Finnish Academy of Technical Sciences. Mr. Eklund has held various positions in industry and government from 1949-1959. From 1959 until 1966 he was with FAO as Chief of Forest Industries Section and Regional Forestry Officer for Eastern Africa. He joined Jaakko Pöyry and Company in 1966 as Director of Forestry and Forest Industries Development Division. In 1971 he was appointed a Senior Vice-President, which position he held until he undertook his present assignment.

R. J. Auchter, now a consultant, was the Tropical Hardwoods Program Manager at the Forest Products Laboratory until his retirement in July 1977.

TECHNICAL PROGRAM
of the 1978 Conference on Improved Utilization of Tropical Forests
May 21-26, at Madison, Wis.

May 22. Welcome and Opening Remarks:

Robert L. Youngs, Director, U.S. Forest Products Laboratory

Henry Arnold, Director, Office of Science and Technology,
U.S. Agency for International Development, Washington, D.C.

Keynote Address:

Kenneth F.S. King, Assistant Director General, Forestry Department,
Food and Agriculture Organization of the United Nations, Rome

I. The Tropical Forest Resource
Moderator: Richard J. Auchter, Consultant, Madison, Wis.

S. L. Pringle, Forestry Department, FAO
"Quantity and Quality of the Tropical Forests."

Robert C. Koeppen, U.S. Forest Products Laboratory
"Some Anatomical Characteristics of Tropical Woods."

II. Environment and Silviculture
Moderator: Frank H. Wadsworth, Institute of Tropical Forestry,
U.S. Forest Service, Rio Piedras, Puerto Rico

Duncan Poore, Evenlode, Stonesfield, Oxon, U.K.
"Values of Tropical Moist Forests."

John J. Ewel and Louis Conde, University of Florida, Gainesville
"Environmental Implication of Any-Species Utilization in Moist Tropics."

Charles B. Briscoe, Jari Florestal e Agropecuaria, Belem, Para, Brazil
"Silviculture in Plantation Development."

Felipe B. Abraham, Jr., Nasipit Lumber Co., Inc. and Affiliates, Manila, Philippines
"Practices and Experience of Nasipit Lumber Co., Inc., and Affiliates in its Natural and Artificial Regeneration of Forests and Plantations."

S. D. Richardson, Asian Development Bank, Manila, Philippines
"Forests and the Faustian Bargain."

P. F. Stager Carvajal, Manasa da Amazonia S.A., Manaus, Amazonas, Brazil
"Little-Known Woods of the Brazilian Bargain."

E. R. Palmer, Tropical Products Institute, London, England
"Factors Affecting Pulpwood from Plantations and Natural Forests in the Tropica."

May 23

III. Harvesting, Transportation, and Storage
Moderator: Edward P. Cliff, Consultant, Alexandria, Va.

Jack R. Schoening, Weyerhaeuser Co., Longview, Wash.
"Forest Industry Development in Southeast Asia."

Ulf Sundberg, Royal College of Forestry, Garpenberg, Sweden
"Implications of Improved Utilization of Tropical Forests on Harvesting and Transport."

Alfeo E. Minato, H. C. Mason & Associates, Portland, Oreg.
"Implications of Logging Systems for More Complete Utilization."

Pancracio V. Bawagan and Jose A. Semana, Forest Products Research and Industries, Development Commission, College, Laguna, Philippines
"Outside Chip Storage in the Philippines."

IV. Wood Fiber and Reconstituted Products Research
Moderator: Von L. Byrd, U.S. Forest Products Laboratory

F. H. Phillips, A. F. Logan, and V. Balodis, Div. of Chemical Tech., Commonwealth Scientific and Industrial Research Organization, South Melbourne, Victoria, Australia
"Suitability of Tropical Forests for Pulpwood: Mixed Hardwoods, Residues, and Reforestation Species."

G. J. Kubes, Barry C. Garner, and Henry I. Bolker, Pulp and Paper Research Institute of Canada, Pointe Claire, Quebec, Canada
"Bleached Kraft Pulp From Mixed Hardwoods From Ivory Coast Forests."

Celso B. Lantican, Univ. of Philippines, College, Laguna, Philippines
"Suitability of Some Fast-Growing Hardwoods and Long-Fibered Species for Various Products."

Borje Kyrklund, Forest Industries Div., Forestry Department,
Food and Agriculture Organization of the United Nations
"Use of Mixed Tropical Hardwoods for Pulp Manufacture."

Jose A. Semana, Forest Products Research and Industries
Development Commission, College, Laguna, Philippines
"Fast-Growing Plantation Hardwoods for Pulp and Paper
Production."

May 24

V. Wood Fiber and Reconstituted Products Research
Moderator: Harold E. Wahlgren, U.S. Forest Service,
Washington, D.C.

James F. Laundrie, U.S. Forest Products Laboratory
"Kraft and Neutral Sulfite Semichemical Pulping of Mixed
Tropical Hardwoods."

Donald J. Fahey and James F. Laundrie, U.S. Forest Products
Laboratory
"Market Pulp and White Papers from Mixed Tropical Hardwoods."

John W. Koning, Jr., James F. Laundrie, Donald J. Fahey, and
David Bormett, U.S. Forest Products Laboratory
"Linerboard, Corrugating Medium, and Corrugated Containers
from Mixtures of Tropical Hardwoods."

Gary C. Myers, U.S. Forest Products Laboratory
"Hardboards from Mixed Tropical Hardwoods."

Roland O. Gertjejansen, D. W. Haavik, H. F. Carino, S.P.A. Okoro,
H. J. Hall, College of Forestry, University of Minnesota,
St. Paul, Minn.
"Properties of Particleboards from Mixtures of Philippine
Hardwoods."

E. R. Palmer, Tropical Products Institute, London, England
"Investigations at the Tropical Products Institute
of Fibrous Materials for Use in Pulp and Paper."

TOUR of the Forest Products Laboratory

CONFERENCE DINNER

Speaker: David L. Luke, III, Westvaco Corporation,
New York, N.Y.

May 25

VI. Industrial Plans and Practice
Moderator: John N. McGovern, Univ. of Wisconsin, Madison, Wis.

Georg Petroff, Centre Technique Forestier Tropical, Nogent-sur-Marne, France
"Tropical Hardwood Pulps."

R. L. Stapelaere, Parsons and Wittemore and Arbocel, and P. F. Ginsburger, Arbocel
"Utilization of Bleached Sulfate Tropical Hardwood Pulp."

Pedro M. Picornell, Paper Industries Corp. of Philippines, Makati, Rizal, Philippines
"Some Points to Consider in Improving the Utilization of Tropical Forests."

J. Cubillos, Carton de Colombia, Cali, Colombia
"Practical Experiences in Pulping Mixed Tropical Hardwoods."

Y. K. Sharma and A.R.K. Rao, Hindustan Paper Corp., New Delhi, India and J. Fellegi, Food and Agriculture Organization of the United Nations.
"Increased Utilization of Tropical Hardwoods by the Indian Pulp and Paper Industry."

VII. Investment Considerations
Moderator: Thomas H. Ellis, U.S. Forest Products Laboratory

Haydn H. Murray, Indiana Univ., Bloomington, Ind.
"Problems in Process Chemical Production in Developing Countries."

J.E.M. Arnold, Forestry Dept., FAO, Rome, Italy
"Economic and Political Environment for Investment in Natural Tropical Forest Development."

Robert N. Zabe and Richard J. Albert, Charles T. Main, Inc., Boston, Mass.
"Utilization of Tropical Hardwoods for Manufacture of Pulp, Generation of Steam, and Electrical Energy-- A Preliminary Industrial Survey."

May 26

VIII. Summations

Moderator: Richard J. Auchter, Consultant, Madison, Wis.

Frank H. Wadsworth, Institute of Tropical Forestry, Rio Piedras, Puerto Rico
Sessions I, II, and III

John G. Bene, International Development Research Centre,
Ottawa, Ontario, Canada
Sessions IV and V

Risto Eklund, Jaakko Pöyry and Company Oy, Helsinki, Finland
Sessions VI and VII

CONFERENCE OBJECTIVES

The purpose of this conference was to familiarize those attending with the most up-to-date information about utilization of tropical forests.

Major issues discussed included:

- The resource
- Environmental concerns
- Silviculture
- Harvesting and transportation
- Wood fiber and reconstituted products research
- Industrial practices and plans
- Investment considerations

While some emphasis was placed on research that the Forest Products Laboratory recently completed in cooperation with the Agency for International Development, other research conducted worldwide was also included.

This conference thus provided anyone interested in improved utilization of the tropical forest a good background in its problems and promises.

INTRODUCTORY REMARKS

By

R. L. YOUNGS

Director
Forest Products Laboratory

This Conference on "Improved Utilization of Tropical Forests" culminates an effort that began 3 years ago. At that time, we joined forces with the Agency for International Development to determine and demonstrate opportunities for effective utilization of the "secondary" or underutilized tropical timber species. This was designed to broaden management options for such forests, help make more informed management decisions, and strengthen economic development of the nations in which those forests grow.

Forest Service involvement in this effort, primarily through the Forest Products Laboratory, stems from our basic mission. The Forest Service has primary Federal responsibility for the management and condition of our Nation's forests. We must do what we can to see that our forest lands produce as much timber, as much forage and wildlife habitat, as much recreational opportunity, and as much water--as much of all forest resources--as possible.

The role of the Forest Products Laboratory is to conduct research that increases productivity of the Nation's forests by finding ways to get more product from each harvested tree, to use tree species not now considered commercially valuable, to use residues left after harvesting or processing, and to do all of these within sound forest management systems.

A logical extension to the concept of using wood wisely here at home is the development of technology that permits wise use of all the world's wood. We are a global society, interdependent as to most resources, and waste on any continent ultimately affects us all. Consequently, it was a proper part of our mission to be involved in this cooperative project with AID to improve the utilization of tropical forests. In undertaking this work, we built on many years of research on properties and utilization of wood from many parts of the world.

Our specific function was to find out if the commonly underutilized tropical species could be used for reconstituted paper and panel products. Lowland humid tropical forests typically include large timber volumes in hundreds of tree species. But commercial production is usually limited to a small volume from a few species. The "secondary" or underutilized species make up the great bulk of the tropical forests, but are essentially unused. They are often burned to create room for a shifting agriculture and then abandoned to produce new growth of poor quality.

In our research, we tested a wide range of tree species from three tropical areas--the Philippines, Ghana, and Colombia. We designed experiments to see if all tropical species, regardless of source, could be blended in various proportions and used to produce paper, fiberboard, and particleboard. We examined processing variables and their effect on the finished product.

Our research demonstrates that mixtures of tropical woods will be a good raw material for a wide range of papers from tissue to linerboard for corrugated boxes. Fiberboard and particleboard panel products of high quality can be produced as well. The heavy woods in the species mixes can be sorted out for processing energy. These species-independent processing systems allow a complete nonwasteful harvest of the forest resource. It offers resource managers silvicultural and economic options heretofore hardly attainable.

Together with the Agency for International Development of the U.S. Department of State, we have organized this Conference. Some emphasis will be given to the research we have recently completed at the Forest Products Laboratory. However, our research does not stand alone in solving these important forest resource problems. We have therefore solicited, and received, valuable contributions from others working in this area of research. I commend the planning group for assembling such an outstanding array of scientific and technical contributions.

One of the participants on the program has stated: "In the hands of the greedy, the technical capability to utilize any and all species could lead to unprecedented destruction of tropical forests. Used wisely, it could provide us with ecologically beneficial tools to maintain highly productive, diverse, and renewable ecosystems."

This Conference is unique in that it brings together a worldwide array of talent concerned not only with the technology and economics of a tropical timber harvest, but also those who are well aware of the potential for havoc if utilization systems are not carefully planned and controlled. Their voice of concern will be heard during these proceedings, and indeed it is our concern as well.

However, the major emphasis in this Conference is on opportunities for effective utilization. This is by design, because that has been the essential impetus behind our research and much of the other research that will be reported and discussed.

But it does need to be considered in perspective. The Forest Service, in many cases working directly with the Agency for International Development, is also involved in many other activities designed to help solve critical forest and range resource problems on the ground. The Forest Service is working with AID under several Participating Agency Service Agreements (PASA's) to assist developing nations in dealing with conservation problems--an example is the work in Kenya on range and water conservation. The Forest Service is working with AID, the World Bank, and the Peace Corps in introducing forestry into the deliberations on the Sahel--working with the Club du Sahel on reforestation, sand dune stabilization, planning wells and water holes and assisting wildlife and human communities. The Forest Service, also working with AID, is strongly involved in the Man in the Biosphere (MAB) program, particularly those parts dealing with tropical forestry, the temperate forest, and biosphere reserves, and to a lesser extent those dealing with grasslands and mountains and tundra ecosystems.

The efforts to come to grips with the critical issues of how to deal effectively with forest and rangeland resources of the tropics are worthy of the best work all of us can do. It has been our privilege to contribute to some of those efforts. I look forward to the opportunity to do more.

It is also our privilege to share the results of that work with you of the broader research community and to have many of you bring to this assembly the results of the related work you have done.

I look forward with great anticipation to what we will discuss this week. I look forward with even greater anticipation to what may come from these discussions in terms of better lives for the many peoples of this world whose productive development--whose very existence is tied to the forest resource with which they have been endowed.

I'm sure there will be questions and honest differences of opinion about some of the points raised and discussed, and about some of the conclusions reached. I have yet to see the Conference worthy of its salt in which such differences were not aired. I hope that we can deal with those differences in the attitude of objective inquiry that leads to more complete insights among all concerned. And I hope that, at the end of this week, we can agree it has been a week well spent.

WELCOMING REMARKS

By

HENRY ARNOLD, Director
Office of Science and Technology
Agency for International Development

On behalf of the U.S. Agency for International Development, it is my pleasure to greet all of you. I am especially pleased to see representatives from so many parts of the world. Your contributions to this program will, I hope, provide all of us with deeper and broader insights into the world of moist tropical forests and reveal some ways in which this natural resource can be sustained and yet wisely used in a world of expanding population.

The Agency for International Development (AID) is the part of the U.S. Government responsible for carrying out development assistance programs aimed at the needs of the world's developing countries, particularly those of the rural poor. AID's major efforts are related to the basic needs of people--food and nutrition, population planning, health, and education. But AID is active in other important sectors, one of which is natural resources. We are placing special priority on moist tropical forests, an important natural resource of some 30 countries receiving U.S. development assistance.

Before I discuss the role of forests in development, it may be useful to mention the salient characteristics and common problems of the poorest countries.

> They have population increases greater than 2 percent per year, which means that their populations will double in 35 years or less. In a few countries, the population will double in 20 years!
>
> Their average per capita income is less than $150 per year.
>
> Life expectancy at birth is less than 55 years. (In the United States, it is in the high 70's.)
>
> They face high infant mortality. In some of the poorest countries, half of the children die before they reach 5 years of age.

> The majority of their population is involved in agriculture and much of this is subsistence agriculture.
>
> They have inadequate housing, medical care, nutrition, education -- they struggle for basic human needs.

But we all know the deceptiveness of averages. When we talk of an "average per capita income of less than $150 per year," we sometimes forget that in almost every poor country a few wealthy city dwellers raise the average considerably. What of the poor majority? They are outside of the country's real economy--with yearly incomes of perhaps only $50.

Industries based on forest resources tend to be located in rural areas, and thus could provide employment opportunities for some of these rural poor. In the early 1970's, AID began studies to understand better the nature of moist tropical forests and how the use of this natural resource might be improved for the benefit of the developing countries. Many developing countries and most tropical forests are located between 10° north and 10° south latitude. This audience is well aware that these tropical forests are composed of a multitude of unknown or barely known species. Only a few of these are being harvested and exported to developing countries, mostly as logs. The "secondary" species left behind are subjected to considerable damage during logging operations. Once inroads are made into the forests, those rural people who practice shifting cultivation or "slash-and-burn" agriculture follow close behind. With burgeoning populations, the need to clear new land to grow food and the growing demand for firewood and charcoal has exacerbated the damage. The consequences can be erosion and loss of arable land, shortage of fuel, desertification, and even climate change.

Ironically, those same developing countries whose hardwood logs are exported often use significant amounts of scarce foreign exchange to import paper products and some of their wood-based building materials, which could provide employment if manufactured locally from nonexportable secondary species.

In 1975, with the cooperation of the U.S. Forest Products Laboratory, AID began research to determine whether natural mixtures of hardwood species from moist tropical forests could be used as raw materials for the production of pulp and paper products and wood-based building materials. A steering committee was organized with members from Government, industry, and universities to oversee the research and to provide advice. Specialists in forestry, silviculture, paper products manufacture, wood and paper products research, tropical ecology and botany, chemical engineering, and geology were included to insure a multidisciplinary view.

I will not talk about the details of the research findings--these you will hear from the scientists and engineers of the Forest Products Laboratory during the Conference. But I will note that their research results show that there are no major technical problems in using an "any-species" mix of hardwoods from moist tropical forests for the manufacture of common paper products and wood-based building materials. This is significant new knowledge for the improved utilization of these forests, and I am glad to have this opportunity to compliment Dr. Youngs and the staff of the Forest Products Laboratory for the thorough and careful work which has helped to fill important gaps in our knowledge of such forests. We in AID were fortunate to have such expert and broad-visioned partners.

The Madison International Conference now brings together from all over the world scientists, technologists, industrialists, and representatives of development agencies to discuss the research findings and to give them even broader perspective. This is convincing evidence that the subject is both timely and important.

Finding long-term solutions to problems of economic development of less developed countries is not simple. Well-meaning actions taken to improve a given situation may provide unexpected, counter-productive consequences. We all know the horror stories of rich as well as poor nations where seemingly beneficial actions have opened a Pandora's Box of environmental problems. But we are beginning to grow wiser. At a recent meeting of the governing council of UNEP in Nairobi, Charles Warren, Chairman of the President's Council on Environmental Quality, stated two tenets of U.S. policy: "Intelligent stewardship of the environment is a prime responsibility of government" and "Sustainable economic growth depends upon a healthy sound environment." AID is following these tenets.

We do not have the luxury of waiting until all the answers are in if we are to halt or reverse the array of growing problems affecting the world's poor. In fact, Mr. Warren also noted that "efforts to meet human needs between now and the year 2000 have the potential for damaging the environment to such an extent that the earth's productive capacity to meet even basic human needs early in the 21st century may be jeopardized."

Thus, AID is committed to providing developing countries with assistance for protecting and managing their environment and natural resources. In 1976, we developed regulations which require an Initial Environmental Examination of each new AID project. Where there is the likelihood that there will be significant environmental impact from the project, a more detailed Environmental Assessment, developed in a collaborative style by AID and the host country, is required before we and they decide whether to proceed. Where the activity will have impact on the United States or the global commons, an Environmental Impact Statement must be prepared. From the start of this research project, we have recognized the possible adverse environmental impact of increased utilization of moist tropical forests. This is why we asked leading specialists in forestry, silviculture, tropical ecology, and botany to review the design and progress of the research every 6 months.

All of you know that forests and forest problems of development countries are receiving increasing attention in many places, but you may not be aware of some significant events in the U.S. Government sector.

First, the National Academy of Sciences under sponsorship of AID's Office of Science and Technology has completed three new studies on tropical forest vegetation which are important to developing countries. The first, entitled Leucaena: Promising Forage and Tree Crop for the Tropics, was published earlier this year. The others, one on tropical legumes, and one on tropical species of vegetation suitable for firewood and charcoal, are in preparation for publication.

Second, AID has mobilized three other U.S. Governmental units having major expertise in environmental matters and in the natural resources field to provide training and expert advice to developing countries. For this purpose, the Environmental Protection Agency, the Department of Interior, and the U.S. Forest Service are coordinated through the U.S. "Man and the Biosphere" program.

Third, the Foreign Assistance Act under which AID operates was amended in 1977 to include a new section, Section 118, on Environment and Natural Resources. This section specifically directs AID to assist developing countries develop and strengthen their capacity to protect and manage their environment and natural resources. Further, it directs that special efforts shall be made to maintain and where possible restore the land, vegetation, water, wildlife, and other resources upon which depend economic growth and human well-being, especially that of the poor.

Fourth, a new AID Energy Office was established last month. Major emphasis is being placed on renewable energy resources such as solar converters, biogas generators, biomass conversion, and mini-hydro plants.

Fifth, a year ago the President requested a study on the probable environmental and natural resource problems which the world will face by the year 2000 as a consequence of its expanding population. The report will be released in about 3 weeks and will highlight the critical status of tropical forests.

Sixth, AID and the Department of State will cosponsor a U.S. strategy meeting in Washington in mid-June on tropical deforestation to discuss what additional knowledge is needed and what scientific and technical resources the United States can marshall to attack the problem.

Seventh, AID has some $25 million programmed for FY 1979 for research and specific country activities related to the preservation and prudent use of forests.

The Steering Committee of this AID/Forest Products Laboratory research project recommended in March of this year that AID should continue to support research on tropical forestry and tropical ecology at a level equal to or greater than the level of this current utilization project. AID is now involved in program planning for FY 1980, and we hope to be able to follow the Steering Committee's recommendations.

In closing, let me remind you that AID is concerned with countries where most of the people exist in desperate need of food, water, fuel, and shelter. They must, and they will, make use in one way or another of whatever resources they can put their hands on. We and they need guidance which will encourage them to use their forest resources to help fill their basic needs--but simultaneously to manage and conserve these resources wisely. To provide such guidance is my challenge to you.

Thank you.

KEYNOTE ADDRESS:

IMPROVED UTILIZATION OF TROPICAL FORESTS

By

K.F.S. KING

Assistant Director General
Forestry Department
Food and Agricultural Organization of the United Nations
Rome, Italy

More than half of the world's forests are situated in the tropics, yet the material benefits which these forests yield to the inhabitants of the developing countries, which lie mainly in the tropical zones, are minimal and derisory. The developing countries are net importers of wood and wood products. Despite the presence in their territories of what appears to be a very valuable resource, they expend scarce foreign exchange on products made from raw materials similar to those they have in abundance. Moreover, the number of industries based on wood in the tropical world is disappointingly low. Most wood that is produced in the developing countries is exported in the form of logs, and processed in the developed, already industrialized world. As a consequence, the value added through processing and conversion of tropical woods into secondary and tertiary products accrues mainly in the rich countries of the world. What is perhaps more important, the potential of the forestry and forest industries sector for alleviating the high rates of unemployment which are endemic in developing countries, the potential of the sector for importing and transferring technological skills to the inhabitants of the non-industrialized world, and the potential of the sector for assisting in the equitable distribution of economic activity within a country, and the equitable distribution of income among the various social strata of their populations, remain virtually unrealized.

The tropical high forests are either wholly unutilized, or are significantly under-utilized. In addition, they are either unmanaged, or in many instances, palpably mismanaged. Where attempts have been made to manage these forests under systems of natural regeneration, the management systems that have been adopted have generally lacked precision, been costly and uneconomic, unreliable, wasteful, and in many countries, been somewhat dysgenic.

Because the tropical high forest contains a great number of species, many of which are found only infrequently; because only a small proportion of these species has been traditionally considered to be marketable; because silvicultural specialists and forest management experts consequently have tended to concentrate their regenerative efforts on species considered by them to be "desirable"; because of these factors, they have ruthlessly eliminated, consciously and deliberately, numerous other species that are defined by them to be "weeds."

These natural regeneration systems which have been practiced in the tropical forests, and which are still being pursued in many developing regions, are inefficient and wasteful, and a drain on their already beseiged economies. These are their internal problems. What may be internationally significant, however, is the possibility, that in removing weed species, foresters might be unwittingly endangering the future existence of many tree species, might be reducing the number of species in the forest gene pool. Their practices, as I have said, might be dysgenic.

Where natural regeneration systems have been wholly or partially replaced by systems of artificial regeneration, and where there have been significant programmes of afforestation and reforestation, the situation is not much brighter. There is evidence that the best provenances of forest tree species are not being selected for these new schemes; plantations, once having been established, are not being scientifically maintained and managed. In short, there is evidence that many plantations of exotic and native forest species being established in the tropics are not of optimum quality. One does not have to be too imaginative to suspect that we are creating for ourselves, and for succeeding generations, problems difficult to solve.

We still are by no means certain of the effects of these plantations, both of exotic and of native species, on the soils of the wet tropics. Even more in the realms of fancy and conjecture, is the effect of short-rotation plantations, which have been established for pulp, and even for fuelwood, on these tropical soils.

Now, I do not wish to give the impression that I am against establishing forest plantations in the wet tropics. Plantations have many economic and commercial advantages which natural tropical high forests do not seem to possess. Moreover, they are, in many cases, the only means of establishing forests where none exists. I merely wish to point to the need for research in their establishment, and, most important, to link the biological aspects of research with utilization practices.

Another area of tropical forests in which knowledge is most rudimentary, lies in the fields of harvesting, transport, and storage. The practices of the world as a whole, with respect to the harvesting, transportation, and storage of forest products are not very commendable. But the practices in tropical countries are even more reprehensible. There is great wastage of the raw material when felling; transportation systems generally are primitive, inefficient, and costly; there is little seasoning, little preservation, and few effective storage facilities in the developing countries.

This list of the ills of tropical forestry is by no means exhaustive. But it is sufficiently long to demonstrate the parlous state of our knowledge of the tropical forestry sector, and to point to the need for research in various fields, in different areas. The list is sufficiently varied also to stress the importance of looking at problems of tropical forestry from many angles. I was especially pleased with the organizers of this conference when I received their programme. It became evident to me that, although the main purpose of our meeting is to examine the possibility of the improved <u>utilization</u> of tropical forests, the conference organizers had recognized and appreciated the systemic nature of the problem, had understood the inter-connections and the linkages, and had arranged our work in such a way that the gamut of our activities, and their relevance, one to another, would be considered.

The basic problems of the natural tropical high forests stem from their heterogeneity, from the mixed nature of their species composition. This simple factor has bedeviled and stultified the development of these forests. Silviculturalists and forest management specialists, accustomed to temperate conditions, attempted to transfer and adapt the silvicultural and management systems of forests that were relatively uniform in structure and in composition, to the polyspecific and complex physiognomy of tropical forests. It is not surprising that they failed.

It is not my intention to apportion blame. Much of what I am saying is the result of hindsight. But the consequences of the research during the last 20 years in utilization of tropical woods suggest that approaches, in the management and silviculture practices be adapted to tropical forests. I believe there is room for plantation forestry, and there should be intensive research work in this field; but there will still be a place for some highly priced high-quality species in the natural forests, and a significant proportion of tropical forests will continue to be managed for the production of these species. What is needed is the refinement of research activities already underway. I am positive that much of the demand for wood from tropical forests will, in the years ahead, be in the form of cellulose; the consumer, except in rare circumstances, will not require individual, particular species, but will be more interested in wood as wood. If I am right, silviculture and management research devoted to most of the natural tropical forests should be concentrated on how best to improve the total yields of cellulose in the tropical forest ecosystem. The approach should be one of biomass, cellulose production--not individual species production. This new emphasis, is directly tied to the research achievements in the field of tropical wood utilization, which I should now like to discuss briefly. I wish to emphasize, however, the essential linkage, which ought to exist between silvicultural and utilization research. Indeed, Mr. Chairman, this linkage ought to be established among research activities in all fields of the forestry and forest industries section.

It has been said, and I think with some justification, that the process of pulverization (of chipping, pulping, producing fibres, rather than merely producing logs, boards, and planks from tropical forests) is inevitable.

You will hear, during this conference, of the progress being made in the pulping of mixed tropical hardwoods for the production of pulp and paper. You will learn of the valuable research work being undertaken in many parts of the world, for example as Dr. Youngs has already indicated at the U.S. Forest Products Laboratory in Madison, and at the Centre Technique Forestier Tropical in France. You will be informed of the investigations on pulping tropical wood species in mixtures, from the Philippines in Asia, from Ghana in Africa, and from Colombia in Latin America. It appears that in general, the quality of tropical hardwood bleached krafts would be at least equal to hardwood pulps now produced in the United States and in Scandinavia. You will hear of the research efforts being directed, in the neutral sulfite semi-chemical process, through cooking to lower yields, in using higher alkali concentrations, to the use of mixtures of tropical woods at densities above 0.66. You will discuss other successes, and a range of other problems connected with the utilization of mixed tropical hardwoods for the production of pulp. You will perhaps be surprised to learn that researchers in the U.S.A., in France, and in the Philippines have found that many species of the tropical forests have fibre lengths of well over 3 mm. I venture to suggest that you will leave this conference with the conviction that this hoary and what had been considered intractable problem has had its back broken, and all that remains is for us to refine the various processes and continue research to improve their efficiency.

In recent years there have been considerable advances in the technology of particleboard and fibreboard manufacture. As a result, almost any size and shape of forest and mill residues, and an extremely wide range of wood species, can now be utilized in these processes. One particleboard mill in Peru utilizes up to 45 species. The use of heterogeneous mixtures in this industry is possible because of the diverse types of flaking machines that can be used for conversion into particles--drum flakers, ring flakers, screen ring refiners, pressure refiners, etc.

The fibreboard industry is even less sensitive to mixed raw material input than the particleboard industry. The trend throughout the world in this industry is to use more mill residues, a higher proportion of unbarked round wood, more mixed hardwoods, and more tropical hardwoods.

The plywood industry has traditionally been the most demanding--in terms of raw material and quality--of the wood-based panel industries. However, even in this industry tropical hardwoods of many species, and of varying qualities and sizes, are being utilized more and more. One way of getting around the problems of tropical wood species which are prone to mechanical damage, which have a high sugar content, and which have unattractive colors, for example, is to use the veneer of such species as cores. The thicker the core, the greater the volume of "lesser-used" wood species that may be used in the plywood industry. Moreover, in certain cases, veneers with unattractive appearance can be coated or laminated, thus making it possible to use them as top veneers in plywood. Lamination may also permit the use of sugar-rich wood in surface layers on concrete forms by providing barriers that are impenetrable to organisms seeking sugar.

Wood species which are peelable, but which occur in small quantities, should be used either as plywood cores or as surface veneers, provided that a final product such as flush doors is made in the same factory. This possibility is, of course, very important, in view of the characteristic heterogeneous species composition of the tropical high forests.

So far, I have spoken only of the traditional wood-based panel products. Yet there have been developed, in recent years, a range of products which might provide an outlet for the mixed wood species of the tropical forests, and for low-grade wood which is often found in them. I refer to such new products as composite plywood or particle-core plywood; "press-lam" which has been developed here in Madison; "wafer board" which has been pioneered in Canada; structural flakeboards with oriented flakes or strands; and a whole range of other panel products, based on low-quality wood and on the orientation of particles or fibres--hardboards with oriented fibres, cement-bonded particleboards, and so on.

So much for the sophisticated process and products.

I feel, Mr. Chairman, that a considerable amount of the wood in tropical high forests may be utilized if greater attention were paid to seasoning, preservation, and building techniques. Much research has been conducted in these areas, and more attention should be devoted to them. They require relatively little capital but can be of considerable importance in the utilization of tropical forests.

Let us consider that the millenium has come; let us imagine that, through research, we have understood how to convert the many species of the tropical forests to usable end products, that we have the ability to market these products, and that they are acceptable in both local and external markets. Let us further assume that we have evolved adequate natural and artificial regeneration systems, and that we are able to replace these forests with vegetation types, the products of which we know will be marketable. Should we therefore advocate the complete utilization of these forests, without giving serious attention to the ecological consequences of such utilization?

No gathering of foresters would countenance ignoring the effects of other aspects of their work on the forest ecosystem. It appears, however, that there is often a conflict. On one hand are the "developers," who wish to utilize the forests so that the proceeds from them may help to remove the hunger and malnutrition and misery which exist in many parts of the tropical world or who wish the forests to be exploited so that the returns gained from them may be used for the erection of schools, houses, and hospitals. On the other side are the "conservationists" or "preservationists" who urge either that the tropical forests be left untouched, or that they be disturbed only minimally.

The fate of the forests of the wet tropics should not be left to the narrow conservationists--to uniformed but vocal pressure groups. Nor should the tropical forests be utilized before careful ecological studies are made. The countries of the Third World need the money which may be gleaned from the exploitation of these forests for their direct material development. This is clear. They also need these forests for the services which they provide: the minimizing of floods and droughts, the control of erosion, the amelioration of the micro-climate. This also is clear.

The way to reconcile these apparently conflicting demands for forest land is to base tropical forest land development on soundly conceived land-use plans. More research is, of course, needed in this field, but we know enough already to prevent us from making serious mistakes, and for us to know where to proceed with caution. There is a promising and potentially rewarding field of research in the application and use of simulation models for forecasting the effects of various forest management and silvicultural methods on the forest ecosystems. The developmental possibilities of forestry should not be ignored because of vague conservationist premonitions. Sound land use and sound research should provide the basis for our decisions.

The categories of land-use are not closed. Often, in the tropics, the correct land-use is not necessarily agriculture, or forestry, or animal husbandry. Often, the optimum land-use, from both the socio-economic and bio-physical points of view, is a combination of the traditionally separated land-use systems--and all land-use planners and decision-makers should take cognizance of this.

If we are successfully to harness shifting cultivation, if we are to ensure that wood and food are provided from forest land to the landless, to the rural poor, these agro-forestry systems must be thoroughly researched.

My concept of the forests is holistic. My philosophy regarding the practice of forestry draws upon this concept. We should see the various forests as ecosystems, and we should aim at the comprehensive utilization of these ecosystems. The timber, the wildlife, the leaves, the resins, the waters of the swamps and the mangroves--all the bounty of the forests--should be utilized. We should not see ourselves only as producers and managers of wood, of timber, of cellulose. There should be a blend of technologies, an adaptation of various systems of production and exploitation to suit the demands of the products and the needs of the societies. In the tropics, the system of agro-silviculture, in which agriculture is combined with forestry to maintain the fertility of the soils and the quality of the habitat, and at the same time produce wood and food, should be perfected and extended. It should not be considered an aberrant system, or merely a way of getting cheap labor for the establishment of forest plantations.

Mr. Chairman, it has been said that the tropical high forests are in danger; that they will disappear in 25, 30, 40, or 50 years--the shortness of the period having a direct relationship with the pessimism of the guesser. There are no global data which would permit anyone, or any organization, to say with any degree of accuracy whether the tropical high forests will disappear, and when. The figures of the economists have no basis in fact. The evidence suggests that in some countries there is such a danger, but there are still vast tracks of tropical forests that are untouched in this world.

There is much poverty, much misery, much malnutrition, much want, much ignorance, much death, in tropical countries that are blessed with forests. Should we not develop these forests? Should we preserve them while men starve and die?

I wish to suggest that the strategy to be adopted, at the national and international levels should be:

--Inventorying the forests of the world as rapidly as possible, using the most modern techniques and technologies that are available.

--Preparing sound land-use plans that are based on scientifically conceived land-capability classifications. Here again speed is of the essence, and here again the most modern techniques should be employed.

--Intensifying research in all aspects of land-use, particularly in fields traditionally encompassed by forestry and in the relatively new field of agro-forestry. This research should be planned, systematically pursued, and coordinated by an international agency.

I hope that at this conference we all make one step toward the attainment of these objectives, toward the implementation of this strategy. I wish you all success in your work, both here and in your various organizations. Thank you.

SPEAKER, CONFERENCE DINNER:

WESTVACO: CORPORATE CITIZEN/BRAZIL

By

DAVID L. LUKE III

Westvaco Corporation
New York, New York

I am pleased to have this opportunity to tell you about a rewarding experience Westvaco has had in forestry resource development in a semi-tropical environment. This month marks the twenty-fifth anniversary of our decision to begin operations in Brazil, where we have been operating successfully and profitably since June of 1953.

I would like to divide my remarks into three sections:

1. Why we went to Brazil in the early fifties, a good twenty years before the latest surge of interest by forest products companies in this sector of the world.

2. How we got started, the actual steps we took to build a sound base for growth, and where we are today in Brazil.

3. What we have learned through successful experience that might be of value to others considering the utilization of raw material resources in one of the relatively less developed areas of the world.

In covering why we went to Brazil, the logical point to begin is the period immediately after World War II. In the late forties, our company was concerned about the availability of future timber supply in the United States. Because of our concern, we began to survey all the major forestry-producing areas outside of the United States, and to consider all the fibrous materials.

For example, we looked at all potential sources of fiber ranging from wood to bamboo and ramie. Geographically, we went from Southern Alaska to South Africa, from Newfoundland to New Guinea.

After examining many areas, we began to concentrate on Brazil. Brazil appeared to have great forestry opportunities. We were very impressed with the potentials of both the softwoods and hardwoods in the semi-tropical areas of southern Brazil. Here the climate is ideal for tree farming. Soils are rich and deep.. Mean temperatures range between 60 and 90 degrees. Rainfall is ideal to support extensive agricultural programs, and specifically we liked what we saw in our first view of the Parana pine and some of the hardwoods which seemed to do so well in the area.

But we were also impressed with another quality of the country. Within its borders Brazil seemed to contain an intriguing and growing market potential for our products. In fact, Brazil was almost unique among all the areas we covered--it appeared to combine a great tree-growing potential with a promising market potential within the same country. In our view this major market potential existed because of the country's fundamental strengths.

Twenty-five years ago, Brazil had a population of nearly 100 million people, of whom about 60 million were involved in one way or another in the economy of the country. These factors meant that the available labor force and pool of potential consumers could grow, both through population growth and also by attracting people within the country who were not yet a part of the cash economy into the cash economy.

Secondly, the government had traditionally shown a positive attitude toward private industry and also toward the values of foreign capital investment.

It seemed very clear to us that, while we would not receive any special subsidies or assistance, at least we would be considered welcome and would be given treatment equal to that of purely locally owned firms. We could own any percentages that we wanted in a Brazilian company, up to and including 100% if we chose to do so.

Third, and very important, the people of Brazil appeared to be energetic and hard working. Brazil is a melting pot, much like the United States. This and other factors seemed to be giving the nation a spirit of accomplishment, and less of the inhibition of culture and tradition which we saw in other countries.

Fourth, although Brazil's economy seemed destined for considerable growth, its paper industry was small, and the country depended on imports for much of its need for wood pulp and paper products.

As of 1951 or so, we satisfied ourselves that we had found a raw material supply potential that was attractive and matched by a very positive market potential. That meant the only remaining question was how should we proceed to approach this opportunity?

This leads then to my second topic--how we got started, the actual steps we took to build a business, and where we are today.

As we thought about how to capitalize on Westvaco's strengths and our interest in applying these strengths in Brazil, our first reaction was, "Let's start right away and build a paper mill. Let's bring to Brazil a sort of mini-version of one of our integrated operations in the United States."

But we didn't have to think about this for very long before recognizing that, while this opportunity might be a logical way to expand in the United States, it would probably be totally inappropriate for us in Brazil.

We felt instead that we needed to study Brazil's economy, its laws, its customs, and how specifically to relate our ambitions to the country. We felt very strongly that, in particular, we needed to understand the local markets; we came to believe that before making major investments we should develop market outlets and start to build a strong organizational nucleus which could successfully carry out significant investments.

In short, we decided that it was wise to start small, start with focus on the markets, and build gradually to a U.S.-type operation.

I'd like to describe briefly the way we carried this out. In the Spring of 1953, 25 years ago, we bought a very small corrugated box-making business, which was supported by an extremely small papermill whose local fiber base consisted of waste paper and straw. At the time of purchase, this little company held no forest reserves and depended partially on the import of pulp to supply its paper mill. When we bought it, the business was in financial difficulty.

You might say, what a funny way to begin a business if your basic interest is wood! But I can say now, with the benefit of hindsight, that this approach of doing our homework, starting small, focusing on markets, and carefully building a strong foundation for the future, proved a magic key to a later success.

For a couple of years after buying the business, we did nothing but work at improving it within its existing scale of activity. We trained people. We worked to develop our own marketing organization and cultivate new customers. We improved the standards of quality of our products and began to add new product designs. We established some of the foundations of business success, and we spent a good bit of time studying how to take the first step to develop the forestry potentials on which we were originally focused.

In 1956, after 3 years of careful study, we had selected the specific location around which we would accumulate our forest lands. We acquired our first piece of property at a site which was well suited for experimental forestry activity and which was equally suitable as a site for an eventual fully integrated and modern papermill.

With the acquisition of this site at Tres Barras on the south side of the Rio Negro, which represents the border between the State of Parana and the State of Santa Catarina, we could now begin to make really intensive experiments in support of our commercial forestry objectives.

Because of Parana pine's unusually long fiber length and its consequent and obvious potentials in papermaking, and because it was indigenous to the area, we looked first at the Parana pine. We evaluated its aptitudes in natural regeneration, and its suitability for plantation regeneration. As we looked, we found that its characteristics did not make natural regeneration as promising as we had first hoped; as a candidate for plantation establishment, the costs were high because of its limited ability to outstrip competing vegetation in the early years after planting.

However, while we were evaluating the Parana pine, we were also evaluating some 62 other softwood and 53 hardwood species from both temperate and tropical climates all around the world. After about 5 years of intensive evaluation, we came to believe that loblolly pine and slash pine were the most promising of all of the potentials we had considered. When this decision was reached, we began to increase the size of our nursery and to accelerate our purchase of land so that we could start a vigorous campaign of plantation establishment.

Some of the land which we purchased combined well-stocked and mature stands of Parana pine and hardwoods. These we retained in natural form, to provide the first fiber resources for use in the papermill which we hoped to build. When we acquired lands which were inadequately stocked, we cleared them completely and began the establishment of slash and loblolly plantations.

With good fortune and with the benefit of exceptionally fine work of our increasingly skillful local organization, our efforts began to show real success. We have continued to the point where we now own a little less than 100,000 acres, of which something more than 50,000 acres is planted with very high productivity plantations.

We operate an excellent and modern nursery which has the capacity to produce in excess of a million prime seedlings annually, enough to establish about 5,000 acres of plantations annually. At the present, all of the seed planted in our nursery is now being harvested from our first plantations of Brazilian loblolly pine. Our forestry practices and the favorable local condition have enabled us to achieve growth which has been most gratifying.

By the time our plantations have completed their eighth growing season, they are ready for the first thinning. A 9-year-old loblolly pine at Tres Barras attains a height of 49 feet and a stem diameter of 8.5 inches, while the same tree grown on the best sites of South Carolina attains a height of only 27 feet and a stem diameter of 5.3 inches.

In South Carolina, the fastest growing loblolly pine at age 9 has not yet reached merchantable pulpwood size. At Tres Barras we are thinning an average of 11 cords per acre at that age.

In South Carolina, the best stands are ready for their first thinning in 15 years. They will yield 11 cords per acre at that age.

At Tres Barras 14-year-old stands will undergo their second thinning, with removal of an additional 21 cords per acre. Total harvest volume from Tres Barras stands at this point will equal 32 cords per acre, or three times the volume produced by their South Carolina counterpart.

Until we clear-cut more of our tracts we cannot give you really reliable figures on our yields per acre, but we think they will be several times the yields we realize on our best sites in the United States.

One reason for fast tree growth in southern Brazil is the deep and fertile soils that have good structure and no characteristics adverse to the development and growth of pine roots. The soil profile with 10 feet of topsoil and about 2½ feet of dark soil, high in organic matter at the surface, is typical of much of the area near Tres Barras.

The area is also blessed with rainfall which ranges between 50 and 60 inches per year with remarkably even distribution throughout the year.

We have authority from the Brazilian government to increase our holdings to about 120,000 acres. While this appears small by U.S. standards, we believe that it is an adequate base to supply a papermill producing between 500 and 600 tons per day.

During the 20 years during which we've been forestland owners, a number of things have occurred in southern Brazil:

First, we have shared our experience fully with other groups, both public and private, and it can be fairly said that we have made a major contribution to the forest economy of the area. Others have followed our achievements and have developed very large plantation acreages based on the knowledge derived from our pioneering experience with slash and loblolly.

Secondly, the potential represented by excellent soils and good rainfall has also made the area attractive for agricultural investment. As we buy land now, we find ourselves competing with farmers who want to produce soybeans, corn, and other crops.

From an economic standpoint, an area which 20 years ago had almost no cash economy is now beginning to develop very solid economic potentials. The impacts are visible in a great many gratifying ways.

During the decade of the 1960's, while we were growing our trees and building the business and the market outlets which we had acquired in 1953, we carried out studies of how to construct a first-rate and modern papermill to utilize the trees we were growing.

In 1970, we authorized such a facility; in 1974 we placed in operation the facility which had been part of our plan since 1953.

At present, we have a business in Brazil which supplies about 20 percent of that country's requirement for corrugated boxes and other packaging material. It is fully integrated, from our pine plantations, through several papermills and through our own box-making facilities, all the way to the ultimate customers for packaging through a good portion of Brazil.

Our products are sold solely in Brazil, but our quality levels and product designs are fully as good as similar products produced anywhere else in the world. It is also true that with the increase in exports of manufacturing and food products from Brazil, our packaging is helping to transport such Brazilian-made products throughout the world.

An early and sharp focus on forestry has taken us into a business which has been continuously profitable over its 25 year history, and has contributed importantly and in a great many ways to the country in which it is located.

Brazil has been good to us and we've tried consistently to take the long-run view and be equally good to Brazil.

Our organization is made up almost completely of Brazilian nationals whom we have trained in Brazil. We have brought, and shared within the country, forestry know-how, technological know-how, marketing know-how, financial know-how with the assistance of Americans who have been able to impart these skills. We have always re-invested the majority of our profits within the country.

With experience, we have also learned a great deal about our plantations. Initially, we decided to plant both slash and loblolly pine, because we weren't sure each would do equally well, and because we wanted to diversify our risks of failure. By the early 1970's it became apparent that the actual growth of loblolly was appreciably better than that of slash. Our calculation was that any problem which would affect one would be equally damaging to the other, and so now we are planting only loblolly pine.

This brings me to the third section of my talk, where I would like to be of value to others who become interested in the tropical or semi-tropical forestry resources in one of the relatively underdeveloped areas of the world.

Because this conference deals with forestry, I will say that good forestry decisions, and thorough and rigorous applications of good forest technology, are very important. However, good forestry management is only one of a handful of ingredients which are absolutely essential to commercial success.

Commercial ventures do not become successful without a sound base of market strategy and careful development of promising and healthy markets. On a scale of priorities, our experience would say that this is number one.

Next, I would say that the adequate availability of a range of other general management skills is extremely important. On a scale of priorities, our experience would say that this probably would be priority number two.

Finally, our experience would suggest that another vital ingredient is the factor of time.

Thus, if sound marketing strategy is number one, adequate availability of a range of general management skills is number two, then sound forestry is number three, and the fourth ingredient is the factor of time. The four ingredients together have, in one case at least, produced success.

SECTION I

TROPICAL FOREST RESOURCE

QUANTITY AND QUALITY OF THE TROPICAL FORESTS

By

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QUANTITY AND QUALITY
OF THE TROPICAL FORESTS

By

S. L. Pringle

INTRODUCTION

The vegetation of the Tropics, the belt between the Tropic of Cancer and the Tropic of Capricorn (23.5° N and 23.5° S) is extremely varied, and frequently complex. It ranges from sparse desert vegetations to the rich evergreen rain forests. The variety reflects differences in climate--especially temperature and moisture and their seasonal variations. These, in turn, are greatly influenced by latitude, altitude, and continental position. In some cases transitions are gradual. In others, often because of past history, the changes are abrupt. With this diverse structure, the development of a uniform vegetation classification has been difficult despite the excellent efforts of many researchers. The recent UNESCO classification recognizes within the tropics, at least 31 subcategories of closed forests,[1] 11 of woodland,[2] 6 of scrub,[3] and 12 of treed savannahs,[4] as well as many more with the occurrence of widely scattered trees. All of these subcategories may provide some form of wood products, other tree crop, or some service from the environmental effects of trees.

Indeed, the treed savannahs and the woodlands supply a very substantial portion of the large amounts of fuelwood consumed in the tropical region, as well as a number of commercial woods for local industry or even export. They may even have a good potential for conversion to forest plantations. It is, however, the first category, "closed forests," to which this paper will direct primary attention. These fall largely into two major groups:

(a) the moist forests including evergreen rain forests (with considerable differentation with altitude or edaphic conditions), mangroves, the evergreen seasonal forests, semideciduous forests, moist deciduous forests, the evergreen needle-leaved forests, and bamboo.

(b) the dry forests of predominantly deciduous drought-resistant species.

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[1] Formed by trees at least 5 m. tall with their crowns interlocking.

[2] Composed of trees at least 5 m. tall but with crowns not usually touching but with ground coverage of at least 40%.

[3] Woody shrubs 0.5 to 5 m. tall, either open shrub land or closed thickets.

[4] Grasslands with 10-40% cover of trees.

There are in addition some closed forests with extremely xeromorphic trees although these often grade into woodlands or scrub. The important tropical evergreen needle-leaved forests--the pine forest of Central America and South East Asia--are from the utilization point of view much like some temperate pine forests and may not be of specific interest to this Conference.

DISTRIBUTION OF TROPICAL FORESTS

The accompanying maps[5] show the forest climax areas for major forest type groups in the tropics. The present existing forest areas are considerably less than those indicated for climax areas.[6]

This information is also summarized in Annex I. The moist evergreen forest shows great diversity with varying elevation drainage and soil as well as over the broad range of the five continents where it is found. Some indication of these differences are shown in this Annex. Because of their special situation--coastal accessibility and good utilization possibilities--mangroves have been given individual attention on the maps and Annex I.

QUANTITATIVE APPRAISAL

Information is far from adequate for even a general overall quantitative appraisal of the tropical forests. Although quite a few countries[7] have undertaken, or are conducting, some form of national (or nearly national) forest inventory, there are striking gaps in the data for the region as a whole.

Good data are often available but are in many cases only partial--for parts of countries, limited species or size classes--and are seldom comparable with respect to definition and classification of forest types and organization. Three major forested countries (Brazil, Indonesia, and Zaire), one in each continental area, which account for more than two-thirds of the tropical closed forest area, have not yet been able to assess with any appreciable accuracy their forest resources. This is in

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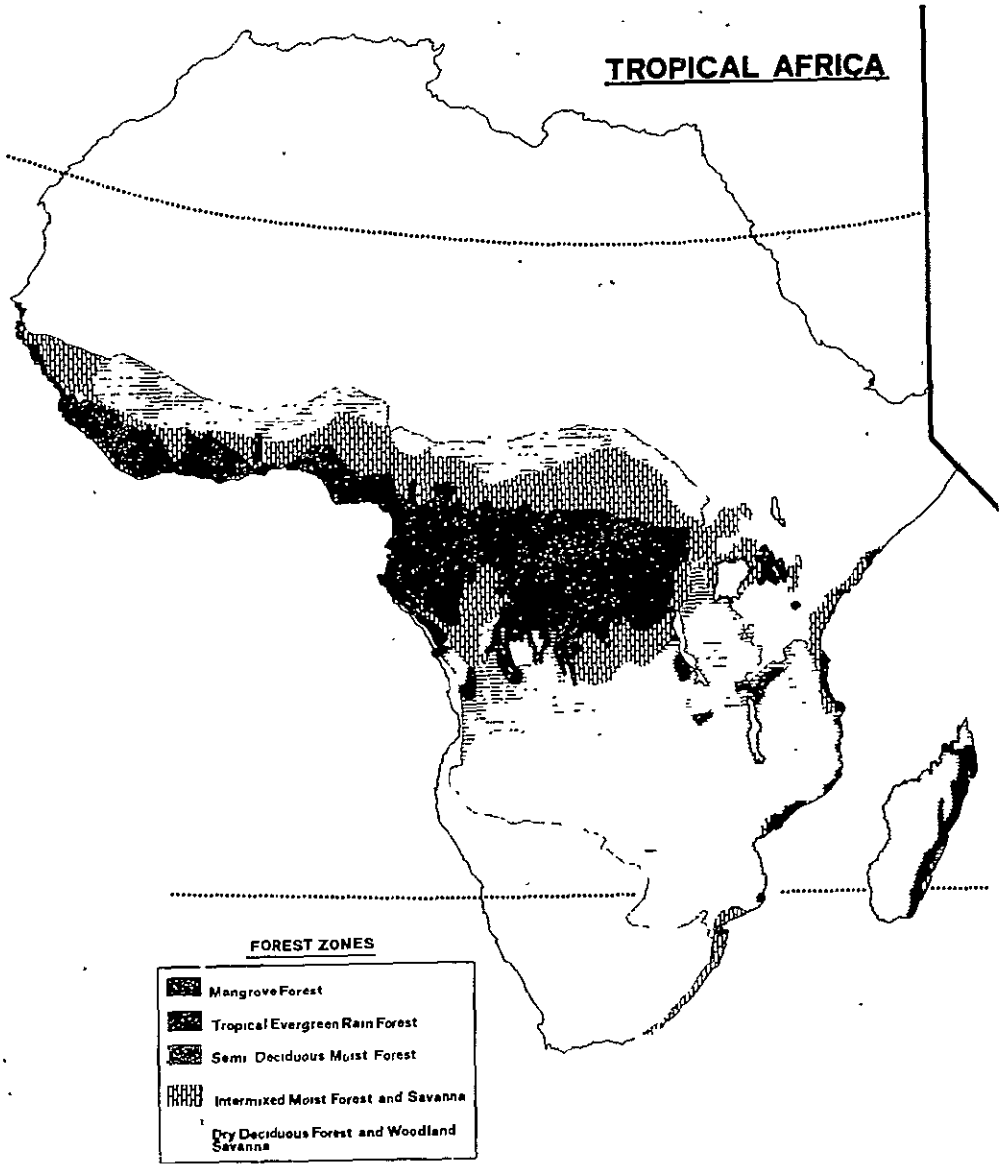
[5] These maps are based on a number of sources and an arbitrary grouping of forest type detail. They draw heavily from Schmithüsen, J., "Atlas Zur Biogeographie," Bibliographisches Institut, 1976, and Oxford University Press "Vegetation Map of Africa," published on behalf of the Association pour l'Etude Toxonomique de la Flore d'Afrique Tropicale, with the assistance of UNESCO, 1959.

[6] A recent analysis by Sommer has indicated that of the 1,600 million ha. of climax area, only 935 million ha. actually remain in this forest condition.

[7] Among larger countries with such surveys within the past two decades might be mentioned Mexico, Ivory Coast, Liberia, Nigeria, Sudan, Zambia, Kampuchea, Malaysia, Philippines, Sri-Lanka, Thailand, as well as India and Indonesia which have work in progress. Other countries, notably Brazil, are in the process of national vegetation mapping.


TROPICAL AFRICA
FOREST ZONES
Mangrove Forest
Tropical Evergreen Rain Forest
Semi Deciduous Moist Forest
Intermixed Moist Forest and Savanna
Dry Deciduous Forest and Woodland Savanna

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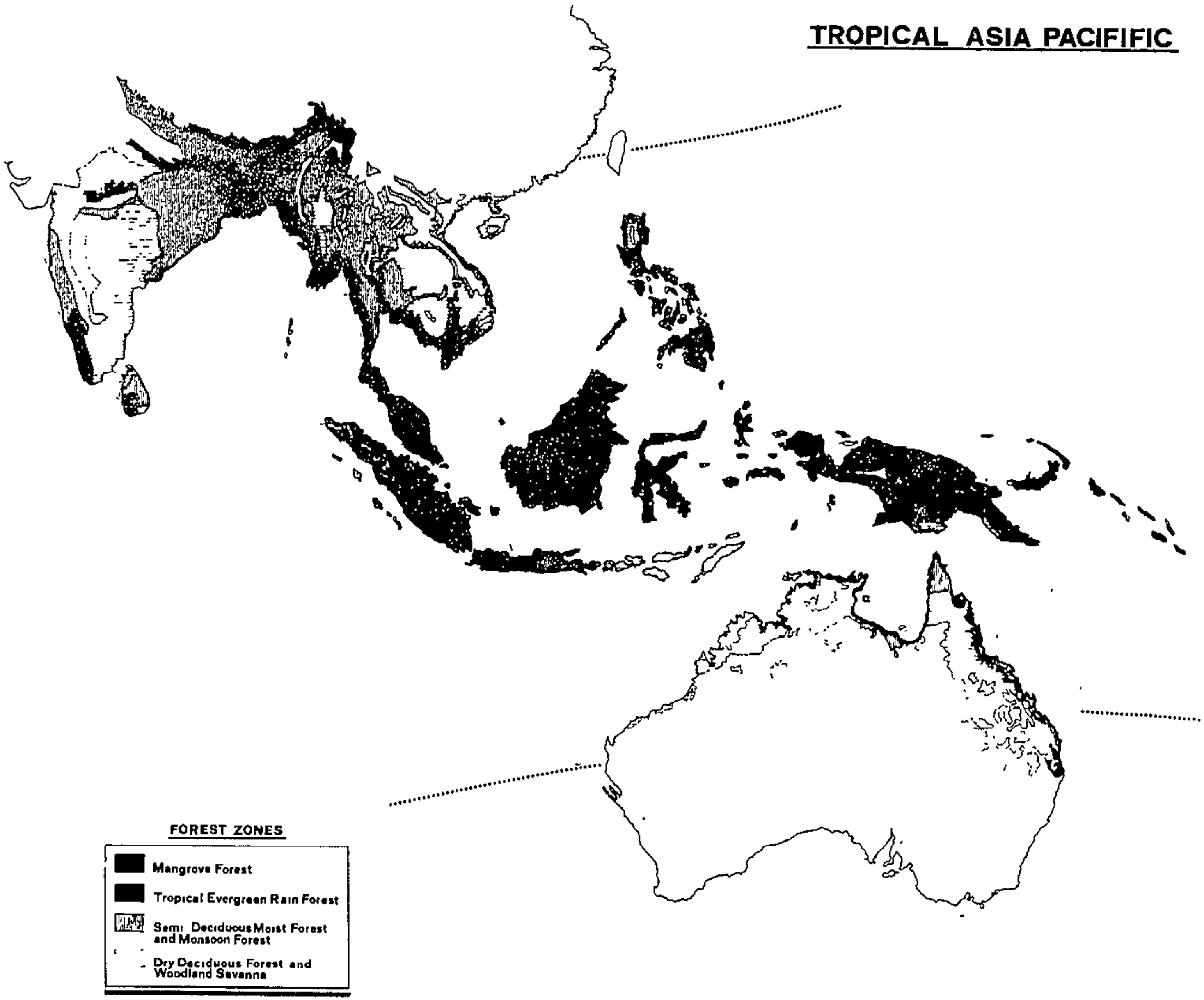
TROPICAL ASIA PACIFIFIC



M. 146 238

TROPICAL LATIN AMERICA

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spite of the marked attention which has been given to the forest sector by the first two over the last decade or so. In the entire region, developments in forest exploitation and land clearing for agriculture have been rapidly putting out of date earlier information.

Nevertheless, overall summaries, albeit sometimes fairly crude, have been made. On the basis of work undertaken at FAO, Persson[8] and Sommer[9] have prepared informative summaries of existing data and made bold estimates which are most useful. FAO has recently published a regional summary of national forest resource information for the Asia and Far East Region[10] and is preparing a similar volume on Latin America. Indicative of the difficulties in preparing such studies is the fact that a recent publication on the Brazilian forest situation,[11] provides a closed forest area estimate which is 18 million ha. greater than that previously being used by FAO (i.e., a difference in area roughly as large as Uruguay).

FOREST AREAS

Table 1 provides a subregional summary of estimated forest areas for all countries with the major part of their area in the tropical belt. The countries included are shown in Annex II. The forest areas are much less than suggested in the accompanying maps which show forest climax areas, not existing forest areas. Of the total land area of slightly more than 5,000 million ha. in these countries, nearly 2,300 million ha. are estimated to have some existing form of closed forest or woodland.[12] However, little more than half of this (1,240 million ha.) is estimated to be closed forest. Of this, a portion, largely in Mexico and Argentina, is in some form of temperate forest, perhaps some 30 million ha.

Of the region's closed forest, only 38 million ha. are estimated to have predominantly coniferous forests. A further 173 million ha. are indicated as being dry deciduous closed forest, leaving some 1,000 million ha. as moist closed forest--what is more commonly thought of as the

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[8] Persson, R. "World Forest Resources," 1974, and "Forest Resources of Africa," Part I, 1974, and Part II, 1975, Royal College of Forestry, Stockholm.

[9] Sommer, A. "Attempt at an assessment of the world's tropical moist forest," Unasylva 1976, Vol. 28, No. 112-113.

[10] FAO, "Forest resources in the Asia and Far East Region," 1976.

[11] Instituto Brasileiro de Desenvolvimiento Florestal, Ministério de Agricultura, "Situaçao Florestal Brasileira," Tecnica Serie 4, Coleção: Desenvolvimiento e Planejamiento Florestal, Brasilia, 1977.

[12] Australia, which is excluded from the table, has some 10 million ha. of tropical forests, largely in Queensland. Of this, some 2 million ha. are tropical rain forests. Most is eucalypt, ranging from dense forest to woodland.

Table 1.--Forest areas in tropical countries (in million ha)

Region	Total land area	Closed forest							Wood-land	Total closed forest and wood-land
		Total	Moist nonconiferous			Dry deci-duous	Conifer	Temperate broad-leaved		
			Total	Mangrove	Bamboo					
Latin America	1,933	735	592	6		100	30	13	368	1,103
Central America/ Caribbean	272	72	36	3		2	25	9	82	164
South America	1,661	663	556	3		98	5	4	286	949
Africa	2,236	184	176	7	1	7	1		607	791
Northern Savannah	525	--	--	--	--	--	--	--	58	58
West Africa	207	16	16	2					74	90
Central Africa	523	151	151	3					225	376
East Africa	801	17	9	2	1	7	1		187	204
Southern Africa	180	--	--	--	--	--	--	--	63	63
Asia Pacific	850	324	251	7	10	66	7	--	55	379
South Asia	347	61	26	1		31	4	--	35	96
Southeast Asia	448	224	186	5	10	35	3	--	20	244
Oceania[1]	55	39	39	1		--	--	--	--	39
Total	5,019	1,243	1,019	20	11	173	38	13	1,030	2,273

[1] Does not include Australia which has considerable area of moist tropical forests.

tropical forests. Of this, 20 million ha. are crudely estimated as mangroves on coastal areas and at least 11 million ha., largely in Burma, are in bamboo. It will be noted that more than half of the closed forest is in Latin America and that Africa has the predominance of woodland but relatively little closed forest. The Asia Pacific area, well known for its production of quality log material, has only one-quarter of the closed forest.

It is interesting to note the percentage of the total land area which is in forest: for combined closed forest and woodland--Latin America 57%, Africa 35%, and Asia Pacific 45%; however, for closed forest only--Latin America 38%, Africa 8%, and Asia Pacific 38%.

Estimates of closed forest area alone tell little of the nature of the forest. For example, of the 8.3 million ha. of closed forest in Peninsular Malaysia, shown in a recent inventory, nearly half had been logged or was disturbed by shifting cultivation. Here, the unit area volume is only half of that in the undisturbed forest. Of the 36.4 million ha. of closed forest in Papua New Guinea, 21.6 million ha. are classed as noncommercial (because it is unproductive, secondary, savannah, protective, or inaccessible). In the Philippines, of 15.9 million ha. of closed forest, less than 5 million ha. are old growth with less than 25% of the volume removed. This area shows a unit volume of 267 m^3/ha. Well over a third is classed as reproduction-brush with a volume of only 15, or so, m^3/ha. and another one-fifth, or so, as young growth with unit volumes of about 140 m^3/ha.

A recent summary of Latin American forest resources estimated only 62% of the closed forest to be "operable"--capable of being "economically incorporated into timber production because of their ecological conditions and location."

VOLUME OF GROWING STOCK

Given the uncertainty in forest area estimates, it is obvious that growing stock volume estimated for the region must have a high degree of inaccuracy, particularly as area, species, and size coverage are so frequently incomplete or incomparable. Nevertheless, attempts have been made to estimate these volumes for all countries and a summary of the latest, and hopefully the best, information is shown in table 2. No attempt is made here to break down the volume estimates for the closed forest beyond nonconiferous and coniferous. A crude estimate for the growing stock volume of woodlands is also provided. It is seen that the estimated volume is heavily concentrated in South America (56%), Central Africa (22%), and Southeast Asia (12%). The coniferous volumes are, however, concentrated in Central America. Also, as might be expected, volume of growing stock in woodlands is largely in Africa.

Average volume per hectare in the closed forest varies considerably from region to region--136 m^3/ha. in Latin America, 228 m^3/ha. in Africa, and only 89 m^3/ha. in the Asia Pacific region. It should, however, be noted

Table 2.--Growing stock of forests in tropical countries (in billion[1/] m^3)

Region	Closed forests			Woodlands	Total	Remarks
	Non-coniferous	Coniferous	Total			
Latin America	98	2.5	100	6	106	
Central American and Caribbean	6	2	8	5	13	1 million m^3 is temperate broadleaved
South America	92	.5	92	1	93	
Africa	42	.3	42	16	58	
Northern Savannah	--	--	--	2	2	
West Africa	3	--	3	1	4	
Central Africa	37	--	37	4	41	
East Africa	1.6	.2	2	7	9	
Southern Africa	.1	.1	.2	1.5	2	
Asia Pacific	26	.5	27	3	30	
South Asia	2.6	.4	3	1	4	
Southeast Asia	20	.1	20	2	22	
Oceania	3	--	3	--	3	Does not include tropical Australia
Total	166	3.3	169	25	194	

1/ 1,000 million.

that for Latin America and Africa the estimates were made on a relatively uniform basis for all countries of each region, while in the Asia Pacific region, the volume is the result of country data which reflect considerably different minimum diameters. The higher figure for Africa may also reflect the fact that relatively less of the area included in closed forest is in lower volume dry deciduous forests.

The growing stock volumes look quite different when consideration is given to current levels of accessibility of forest areas and to merchantability of species and sizes. It is estimated that of the total volume in closed forests of Latin America[13] only 31% is of "currently merchantable species" and only 60% when these are combined with other "potentially commercial species." Indeed, only 19% of the total volume is estimated to be of presently commercial species in "operable" forests. Of the total volume recently estimated in Brazilian closed forests, only 22% is considered accessible.[14]

In the Asia-Pacific tropical regions, three-quarters of the closed forest volume is classed as "operable," but only three-fifths of this is considered as "currently commercial."[15] For Africa, Persson[16] considers only 12% of the estimated gross volume of closed forests to be "commercial volume" (i.e., species and sizes that are merchantable as industrial wood at present). Very little of the woodland volume is considered to be commercial.

These relatively low proportions of "accessible," "operable," and "commercial" growing stock are reflected in the actual harvesting of the tropical moist forest which removes a selected, usually small, portion of the total volumes. Many species, grades, and sizes are left unharvested. Sometimes, the residual stands may be left as a growing forest to provide further harvests at a later date. More frequently it remains an unwanted noncommercial forest, making unsatisfactory use of the land or, at best, being abandoned to unplanned low-intensity agricultural use. In a few cases, these cut-over areas may be part of a reserve for future intensive agriculture.

In the tropical moist forest of West and Central Africa where the initial growing stock may vary from 100 to 800 m^3/ha, the removals in commercial logging range normally between only 5 and 30 m^3/ha, reaching 60 m^3/ha in a few cases.[17] The volume of trees above normal cutting diameters (about 60 cm) is much higher--50 to 150 m^3/ha.

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[13] Unpublished FAO report.

[14] Instituto Brasileiro de Desenvolvimiento Florestal, op. cit.

[15] FAO, op. cit.

[16] Persson, op. cit.

[17] Erfurth, T. and Rusche, H. "Marketing of Tropical Wood," FAO, 1976.

Table 3.--Nonconiferous wood removals from the tropical forest, 1976 (in million m^3

	Fuelwood	Industrial wood			Total
		Logs	Other	Total	
Latin America	199	21	11	32	231
Africa	252	17	13	30	282
Asia-Pacific	316	68	13	81	397
Total tropical region	767	106	37	143	910

Table 4.--Nonconiferous wood removals in relation to growing stock

	Industrial wood/ volume in closed forest	Total/volume in forest and woodland
	Percent	
Latin America	0.032	0.22
Africa	.071	.49
Asia-Pacific	.312	1.37
Total tropical region	.085	.47

In parts of insular Southeast Asia a much larger portion of the growing stock is in species currently marketed. In Sabah, and parts of Indonesia and the Philippines, the dipterocarps make up about 80 percent of stand volume and the volume extracted may average 50 to 60 m^3/ha with a range of 20 to 100 m^3. In other parts of the region average extracted volume is lower, for example about 40 m^3/ha in West Malaysia.

The Amazon moist forests are complex and heterogeneous. Even in relatively homogeneous areas, from which come much of the harvested industrial wood, the volume logged-out ranges, on the average, between only 5 to 10 m^3/ha.18/

ROLE OF TROPICAL FORESTS IN WOOD REMOVALS

Table 3 summarizes the 1976 removals of wood from the tropical forests. Of the total nearly 85% is estimated to be fuelwood and a substantial portion of the industrial wood is in the form of building poles and forests for rural use. Total nonconiferous removals of this region amount to 36 percent of total world removals, but industrial wood removals comprise only 11 percent of total world industrial wood. It should be stressed, however, that tropical sawlogs and veneer logs, which in 1950 made up only 6% of the world's supply of these products, comprised, in 1976, 13%, and made up not only the basic domestic supply but provided about 9% of the consumption of industrial wood products in Japan and Europe combined. In addition they provided the major source of raw material for the export wood industries of a number of developing countries. However, it should be stressed that less than 2% of the industrial wood harvested in tropical nonconiferous forests is used as pulpwood.

USE AND MISUSE OF TROPICAL FORESTS

Much has been said of tropical forest, its use, its potential use, its misuse, and its rapid disappearance. Even in recent years typical statements range from "the inexhaustible tropical forests" to "within 10 or 20 years there will remain only museum relics of the tropical forest." Clearly, the truth lies somewhere between these extremes. Even if it were possible, it is not the primary purpose of this paper to assess the future of the tropical forests, although this is a matter of profound concern.

Nevertheless, it would be inappropriate to conclude the paper without some consideration of the dynamic developments in these forests. Table 4 shows nonconiferous wood removals in relation to nonconiferous growing stock (without any allowance for logging waste or bark). These are expressed in two ways: (a) industrial wood removals in relation to estimated closed forest volume and (b) total removals, including fuelwood, in relation to estimated growing stock volume of all forests.

18/ Instituto Brasileiro de Desenvolvimiento Florestal.

For industrial wood the resultant percentages (0.03 to 0.3) are very low compared to the corresponding values for temperate regions--1.0% for conifers and 0.7% for nonconifers (about 2.5 and 1.5 for these species categories in Europe and Japan). For total removals, including fuelwood, however, the ratios (0.2 to 1.4) are much nearer those of the temperate regions (1.1 and 0.7% for conifers and nonconifers respectively).

These percentages would, of course, look much different if compared to the growing stock volumes reduced to estimated "operable" volumes. In many respects, a consideration of the dynamics of forest areas would be more informative, but even here adequate up-to-date estimates are generally lacking.

In most countries much of the forest, or at least the more accessible forest, has already been "cut-over" with one or more rounds of exploitation.[19/] In very few instances has a continuous management of the residual forest emerged. Notable examples are the Sal forests of India, and some areas of valuable teak. In quite a few instances there has been conversion of parts of the cut-over areas to plantations but in most cases the forest is left unmanaged, often to be utilized for shifting cultivation or conversion to more intensive agriculture with wholesale destruction of residual growing stock.

Alarming figures have been quoted in numerous cases of the rate at which the tropical forest is giving way to these inroads, but in very few instances is there anything approaching a systematic measurement of the forest reduction. FAO in cooperation with UNEP is currently developing assessment techniques which could be efficiently used at the national level and is making some preparation for assisting countries in this task.

The residual growing stocks left after industrial logging pose a challenge to bring about more complete utilization for pulping or for energy production, as well as the development of some form of continuing management through the manipulation of the natural growing stock or conversion to plantations. In a few countries--Papua New Guinea, Bolivia, Central African Empire, and Cameroon, for example--or parts of countries, e.g., the bulk of the Amazon, the upper areas of the Congo, parts of Kalamatin, Sabah, and Sarawak, there still remains some opportunity for a more complete utilization of uncut forests. The need to extend the range of species, qualities, and sizes being utilized is a basic problem inhibiting better management of the tropical forest, whether it is to be exploited, depleted, and converted to other uses or maintained as a productive forest.

[19/] These might be included--India, Nigeria, Ghana, Thailand, the Philippines, and the Ivory Coast--as countries where the forest has largely been worked over; and Colombia, Congo, Gabon, Zaire, Venezuela, Peru, Ecuador, Brazil, Indonesia, Malaysia, Burma, and Cambodia as countries where most of the accessible forest (lowland, coastal areas, etc.) has been cut.

Annex I.--Forest zones of the tropics

Type groups	Brief general description		Major locations	
		Latin America	Africa	Asia-Pacific
Moist Tropical				
Evergreen moist tropical forest (often called rain forest)	(a) Lowland and lower montane evergreen forests with trees at least 30 m. and up to 60 m.; buttressed, woody lianes, three stories (two in lower montane areas); top story continuous, sparse undergrowth; rich in species.	Predominates in Amazon coastal Colombia and Ecuador; eastern Central America; Haiti, Jamaica, and Puerto Rico.	Predominates in middle Congo drainage, in Gabon and southern Cameroons, in Sierra Leone, Liberia and in southern Ivory Coast, Ghana, and Nigeria.	Predominates in Malaysia, the Philippines, most of Indonesia, Papua New Guinea, the Solomons, southern Indo-China, southern Thailand, coastal Burma, southwest portion of India and of Ceylon.
	(b) Upper montane; trees are broad-leaved evergreen, without buttresses, abundant ground vegetation.			
	(c) Tropical montane--conifers, bamboo, or alpine woodland.	See pine forest below.	Conifers of Malawi and Kenya; bamboo forest of equatorial mountains of East Africa.	See pine forests below.
	(d) Moist edaphic formations--alluvial, swamp, and bog; forests frequently with palms, often poor in species.	Common in valleys in Amazon Basin, and mouth of Orinoco; swamps of Costa Rica.	Valley of rivers of Congo Basin.	Western coastal forest of Borneo, east coast of Sumatra, northern New Guinea.

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Annex I.--Forest zones of the tropics--continued

Type groups	Brief general description	Major locations Latin America	Africa	Asia-Pacific
(Mangrove forest)	(e) Limited to tidal range; almost entirely evergreen sclerophyllous broadleaved trees and shrubs with stilt roots or pneumataphores.	Nearly continuous along Atlantic coast of South America from the Orinoco mouth to southern Brazil, Pacific coast of Colombia, Atlantic coast of Costa Rica; frequent on coasts of Mexico, Cuba, Haiti, and southwest Florida.	Very concentrated in coastal Nigeria (mouth of Niger) and Cameroons; common from Senegal to Sierra Leone; at mouth of the Congo, and Mozambique; other frequent but more limited occurrences along East African coast.	General in coastal Bangladesh (Ganges), Burma (Irrawady); east coasts of Sumatra and Borneo, south coast of Papua New Guinea, northeast coast of Australia.
Semideciduous moist forest; Monsoon forest; tropical moist deciduous forest	Seasonal forest; deciduous species usually in dominant noncontinuous storey.	Southeastern Brazil (Sao Paulo, Minas Geraes, Bahia), parts of Guyana, Venezuela, Colombia (mainly south of Orinoco) and includes parts of northern Amazon Basin; much of Cuba, parts of Haiti; coastal Mexico (Vera Cruz, Tabasco, Campece).	Not readily distinguishable as major region.	Predominant in eastern India, Bangladesh, Burma, and much of Thailand and Ceylon, extreme southeast China, eastern Java; includes the important teak-bearing forests of India, Bangladesh, Burma, and Thailand, and Terminalia forests of Bombay. Bamboo is common especially in Burma and India.

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Annex I.--Forest zones of the tropics--continued

Type groups	Brief general description	Major locations		
		Latin America	Africa	Asia-Pacific
Tropical pine forest	Usually in higher parts of rain forest or semideciduous forest. Presence apparently associated with fire history.	Pine-oak forests of southeast Mexico, central Guatemala, Honduras, and northern Nicaragua.		Pine forests of Sumatra, Luzon, and Indo-China.
<u>Dry Tropical</u>				
Tropical dry forest, Campus Cerrado or woodland Savannah	Trees predominantly under 20 m. high, but at least 5 m.; closed canopy more than 40%.	South central Brazil, eastern Bolivia, Paraguay, northwestern Argentina.	South-central Africa; southern Zaire, southern Tanzania, most of Angola, Rhodesia, Zambia, and a belt running across Africa from Senegal and Guinea to southern Sudan; southern Zaire and Congo.	South-central India, central Indo-China peninsula; northeastern Australia (Eastern Highlands of Queensland).

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Annex II.--Country grouping

Regions	Countries
Latin America	
Central America and Caribbean	Belize, Costa Rica, Cuba, Dominican Republic, El Salvador, Guatemala, Haiti, Honduras, Jamaica, Mexico, Nicaragua, Panama, Puerto Rico, Trinidad, and Tobago
South America	Argentina, Bolivia, Brazil, Colombia, Ecuador, French Guyana, Guyana, Paraguay, Peru, Surinam, Venezuela
Africa	
Northern Savannah	Mauritania, Senegal, Gambia, Mali, Upper Volta, Niger, Chad
West Africa	Guinea Bissau, Guinea, Sierra Leone, Liberia, Ivory Coast, Ghana, Togo, Benin, Nigeria
Central Africa	Cameroon, Equatorial Guinea, Gabon, Central African Empire, Congo, Zaire, Angola
East Africa	Sudan, Ethiopia, Somalia, Uganda, Kenya, Rwanda, Burundi, Tanzania, Zambia, Malawi, Mozambique, Madagascar
Southern Africa	Rhodesia, Botswana, Namibia
Asia Pacific	
South Asia	Bangladesh, India, Sri Lanka
South East Asia	Brunei, Burma, Indonesia, Kampuchea, Laos, Malaysia (Peninsular Malaysia, Sabah, Sarawak), Philippines, Thailand, Vietnam
Tropical Oceania	Fiji, New Caledonia, New Hebrides, Papua New Guinea, Solomon Islands, Western Samoa

SOME ANATOMICAL CHARACTERISTICS OF TROPICAL WOODS

By

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INTRODUCTION

Any discussion of the tropical forests of the world should begin by first recognizing the great diversity of species, forms, and properties of the woods found there. This characteristic heterogeneity at all levels is the most basic difference between tropical forests and those of the temperate zone and is the cause of many of the utilization problems connected with tropical woods.

To be sure, within geographical perimeters of the tropics, especially at the higher altitudes, almost pure stands do occur, but these are not truly "tropical forests" according to the usual connotation of the term. The tropical forest is generally envisioned as a hot, moist association of broad-leafed trees, many of them having gigantic proportions. This concept also excludes the conifers or softwoods. While conifer groups, especially the Podocarpaceae and Araucaraceae, do occur naturally in the tropics and plantations of pines have also been established, they are either a very minor part of the association or confined to the higher altitudes or drier sites. At any rate, the conifers are being considered outside the realm of this discussion.

What is under consideration here are the lowland tropical forests composed of a highly heterogeneous mix of mainly hardwood species. The three major areas of the world having such forests are: Central and South America, Southeast Asia, and the west central coast of Africa.

DATA BASE

While some of the information in this report is taken from the literature, most data are based on material collected for the Agency for International Development (AID) project, which was done at the Forest Products Laboratory and summarized in table 1. This project was oriented toward the production of reconstituted wood products from tropical species, and emphasis here will be on the primary anatomical differences between temperate and tropical woods. To obtain a representative sample of wood material from each of the major tropical areas of the world for the AID project, trees were collected from the forests of Colombia, Ghana, and the Philippines.

The mix of tree species selected for testing was known to produce woods that represented the full range of specific gravities, as well as having

Table 1.--Selected properties of woods from the Philippines, Colombia, and Ghana

Species	Sp. grav.1/	Fiber Length (mm)	Fiber Wall thickness (μ)	Fiber Runkel ratio	SiO_2 2/ %	Normal canals
PHILIPPINES						
Alphitonia philippinensis	0.42	1.2	3.3	0.50	--	-
Alstonia scholaris	0.32	1.6	3.0	0.22	--	+
Amoora macrocarpa	0.61	1.6	6.5	0.88	--	-
Anisoptera thurifera	0.55	1.8	8.5	3.99	0.72	+
Artocarpus blanchoi	0.47	1.6	3.0	0.30	4.55	+
Calophyllum obliquinervium	0.57	1.4	4.7	1.06	--	-
Cananga odorata	0.31	1.4	3.0	0.22	--	-
Canarium luzonicum	0.55	1.3	4.7	0.79	0.21	+
Ceiba pentandra	0.24	1.9	4.1	0.40	--	-
Chistocheton pentandrus	0.72	1.5	6.8	2.37	--	-
Dillenia philippinensis	0.59	2.8	14.5	2.18	--	-
Diospyros nitida	0.68	1.4	4.3	1.55	--	-
Diospyros philippinensis	0.72	1.1	4.2	1.60	--	-
Diospyros philosanthera	0.74	1.3	3.9	2.01	--	-
Dipterocarpus grandiflorus	0.62	1.7	9.2	4.59	0.23	+
Dipterocarpus gracilus	0.58	1.9	9.5	2.61	0.43	+
Dysoxylum euphlebium	0.62	1.7	6.9	1.17	--	-
Endosperum peltatum	0.32	2.0	5.9	0.33	--	-
Erythrina subumbrans	0.26	1.9	2.9	0.23	--	-
Erythrophloeum densiflorum	0.65	1.6	4.5	1.03	--	-
Ficus variegata	0.24	1.3	2.6	0.17	--	+
Homalanthus populneus	0.36	1.5	3.4	0.31	--	-
Hopea foxworthyi	0.67	1.4	6.3	2.66	--	+
Lagerstroemia piriformis	0.60	1.3	5.8	1.36	--	-
Leucaena leucocephala	0.74	1.9	4.7	0.81	--	-
Litchi philippinensis	0.79	1.1	5.5	1.48	--	-
Lithocarpus soleriana	0.74	1.7	8.1	3.53	--	-
Macaranga bicolor	0.32	1.6	2.9	0.24	--	-
Madhuca oblongifolia	0.56	1.6	4.7	0.83	2.19	-
Mangifera altissima	0.44	1.0	2.7	0.37	--	-
Mastixia philippinensis	0.45	2.8	12.3	1.30	0.10	-
Melicope triphylla	0.38	1.4	4.0	0.39	0.43	-
Meliosma macrophylla	0.26	1.9	3.8	0.30	--	-
Octomeles sumatrana	0.24	1.6	2.8	0.24	--	-
Parashorea plicata	0.48	1.4	3.2	0.47	--	+
Pentacme contorta	0.40	1.6	4.4	0.57	0.06	+
Pygeum vulgare	0.45	1.4	3.7	0.45	--	-
Sandoricum vidalii	0.39	1.4	4.0	0.34	--	-
Shorea astylosa	0.72	1.6	7.8	6.38	--	+
Shorea negrosensis	0.51	1.8	6.3	0.84	--	+
Shorea polysperma	0.43	1.5	3.7	0.44	0.08	+
Shorea squamata	0.37	1.5	3.8	0.36	--	+
Swintonia foxworthyi	0.56	1.4	4.2	0.68	0.10	+
Syzygium nitidum	0.79	1.4	8.1	4.49	--	-
Terminalia nitens	0.49	1.5	4.1	0.51	0.10	-
Trema orientalis	0.32	1.4	2.8	0.22	--	-
Vatica mangachapoi	0.62	1.5	8.5	4.70	0.22	+
Weinmannia luzoniensis	0.53	1.7	7.8	1.40	--	-
Xanthophyllum excelsum	0.64	1.5	9.1	2.30	--	-
Zanthoxylum rhetsa	0.30	1.2	3.0	0.30	--	-
Average	0.51	1.57	5.35	1.32		

(Page 1 of 2)

Table 1.--Selected properties of woods from the Philippines, Colombia, and Ghana--continued

Species	Sp. grav.[1]	Fiber			SiO$_2$[2]	Normal canals
		Length (mm.)	Wall thickness (μ)	Runkel ratio	%	
COLOMBIA						
Apeiba aspera	0.14	1.7	4.01	0.32	--	-
Aspidosperma sp.	0.69	1.8	13.18	6.39	--	-
Brosimum utile	0.49	2.7	4.09	0.49	--	+
Castostemma alstonii	0.54	2.5	11.30	6.38	--	-
Cecropia sp.	0.25	1.4	3.43	0.16	--	-
Ceiba pentandra	0.23	1.6	3.07	0.20	--	-
Couma macrocarpa	0.55	1.7	6.01	0.58	--	+
Dialium guianense	0.82	1.3	6.23	2.26	1.48	-
Enterolobium schomburgkii	0.63	1.4	4.75	0.95	--	-
Helicostylis tomentosa	0.78	1.3	4.44	1.72	--	-
Jacaranda copaia	0.37	1.3	3.70	0.29	--	-
Nectandra sp.	0.55	1.5	4.83	0.65	--	-
Neoxythece sp.	0.86	1.9	12.04	10.83	0.55	-
Ormosia paraensis	0.67	1.6	8.52	1.35	--	-
Pourouma sp.	0.37	1.4	3.85	0.26	--	-
Vochysia ferruginea	0.45	1.4	4.76	0.45	--	-
Virola sebifera	0.51	1.5	5.62	0.74	--	-
Average	0.52	1.7	6.23	1.93		
GHANA						
Allanblackia floribunda	0.54	1.8	5.5	1.05	--	-
Anogeissus leiocarpus	0.71	1.1	7.3	2.97	0.09	-
Anopyxis klaineana	0.72	1.9	14.1	1.86	--	-
Antiaris africana	0.31	1.1	3.6	0.40	0.20	+
Canarium schweinfurthii	0.31	1.1	3.4	0.32	0.30	-
Celtis adolfi-friderici	0.55	1.2	4.4	0.53	--	-
Cleistopholis patens	0.24	1.2	3.6	0.21	--	-
Dacryodes klaineana	0.69	0.7	4.6	0.63	0.52	-
Discoglypremna caloneura	0.37	1.4	5.8	0.37	--	-
Entandrophragma angolense	0.45	2.0	4.3	0.57	--	-
Guarea cedrata	0.49	1.4	3.4	0.56	0.11	-
Hannoa klaineana	0.28	1.5	3.0	0.30	--	-
Khaya ivorensis	0.41	1.5	3.6	0.52	--	-
Lophira alata	0.81	1.9	11.4	5.92	--	-
Musanga cecropioides	0.30	1.4	4.4	0.25	--	-
Piptadeniastrum africanum	0.44	1.4	5.5	0.77	--	-
Sterculia oblonga	0.59	2.0	2.1	2.65	--	-
Sterculia rhinopetala	0.55	2.0	8.0	3.13	--	-
Strombosia glaucescens	0.70	2.7	13.1	1.93	--	-
Tarrietia utilis	0.46	1.6	5.0	0.53	--	-
Tieghemella heckelii	0.50	1.6	4.8	0.65	0.16	-
Triplochiton scleroxylon	0.30	1.4	4.9	0.64	--	-
Average	0.49	1.54	5.71	1.21		

---

[1] Green volume-ovendry weight.

[2] -- indicates trace only, <0.05 percent not recorded.

(Page 2 of 2)

certain anatomical characteristics that may pose potential problems during processing. These anatomical features given special attention were a high silica content and the presence of gums or resins which are common to some tropical hardwood groups but not found, or only in insignificant amounts, in temperate-zone hardwood species.

To simplify transportation problems, the maximum log diameter of the trees sampled was held at about 30 centimeters and no age determination was attempted.

The first sampling came from the Philippine forests, with 90 trees representing 50 species. All tests of papermaking, fiberboard, and particleboard products from this Philippine sample produced such good products that it was decided fewer trees from other areas could be used to simply verify these initial results. Therefore, from Ghana only 22 trees, each a different species, were collected, and 51 trees representing 18 species were collected from Colombia. Obviously, the decision to reduce the number of species in the second and third shipments severely limited the data base for an anatomical survey.

ANATOMICAL FEATURES

Fibers

Of all the anatomical features of wood, fiber dimensions have received the most attention. Much of this research was aimed at explaining the properties of the wood, or especially the properties of the fiber products produced from wood, such as paper and fiberboard. All fiber measurements reported here were made from safaranin-stained whole fibers of macerated material measured by using a transmitted light microscope.

Fiber length is logically looked to as an indicator of the strength potential, especially for the derived fiber products produced from wood. In paper production it is generally thought that a good proportion of fibers should be 2-4 millimeters long to obtain satisfactory strength and good paper quality. However, as this study showed, very few of the tropical hardwoods have such fiber lengths. The average fiber lengths of all specimens sampled ranged from 0.7 millimeter for *Dacryodes klaineana* of Ghana to 2.8 millimeters for *Dillenia philippinensis* of the Philippines.

The average fiber lengths for all 214 trees sampled was only 1.6 millimeters, but this is slightly longer than the average of 1.3 millimeter for North American hardwoods commonly used in paper production. The averages of all specimens measured from each area of the world were quite similar: Philippines (90 trees, 50 species)--1.7 millimeters; Ghana (22 trees, 22 species)--1.5 millimeters; Colombia (51 trees, 18 species)--1.7 millimeters.

Petroff, Doat, and Tissot, in a 1971 study of the papermaking characteristics of woods of the African Camerouns, report a greater range of fiber lengths, varying from 0.5 millimeter to 3.2 millimeters. However, the average fiber length of all 121 species measured was 1.7 millimeters, which is essentially the same as the overall world average produced by the AID sample. However, Tamolang et al., in 1957 and 1958 studies of Philippine fibers, report lengths ranging from 0.4 millimeter to 2.7 millimeters with an overall average of only 1.3 millimeters. Interestingly, Tamolang et al. make a comparison of average fiber lengths from several other areas of the world, and these also have an overall average of about 1.3 millimeters, the same as their Philippine sample. Africa, however, was not included in this sampling.

These averages, of course, are only indicators and may have little relationship to the values obtained from a commercial sample. But they do point up the fact that tropical hardwoods as a group are short fibered, probably with an average length of about 1.5 millimeters.

In the AID study, fiber wall thicknesses showed a greater range of variation than did the fiber length. The thickest wall recorded was 14.5μ from Dillenia philippinensis, which also has the longest fiber measurement. Sterculia oblongia had the lowest average wall thickness with 2.1μ. The overall average for the cell wall thickness for the 93 samples is 5.62μ, which is again somewhat higher than the 4.7μ range of North American woods normally pulped. By area of the world, the Colombian sample had the thickest average cell wall with 6.23μ, Ghana second with 5.71μ, and the Philippines the thinnest with 5.35μ. This last value generally agrees with Tamolang et al., who report an overall value of 6μ for their extensive Philippine sample of 116 species.

The attention given fiber characteristics by papermakers has resulted in several systems being developed for predicting paper quality. These systems are derived from the dimensions of the fibers. Of these, the Muhlstep system of classification and the Runkel Ratio are best known. Recently, Horn of the Forest Products Laboratory showed that the length of fiber divided by the cell wall thickness can also be used as an indicator of potential paper quality. However, of these systems, the Runkel Ratio seems to be the most widely used and best understood.

The Runkel Ratio is computed by taking twice the thickness of the cell wall of the fiber and dividing it by the lumen diameter. The ratios were divided by Runkel into three groups indicating their potential papermaking quality:

> Group 1, where the value is less than unity, should produce very good quality paper.
>
> Group 2, with a value about equal to unity, produces good quality paper.
>
> Group 3, with a value greater than unity, produces paper quality expected to be poor.

Of all of the trees sampled for the AID study, the overall Runkel Ratio is 1.4, which indicates relatively poor papermaking qualities. However, by removing the 10 species having the highest ratios, as might be done in an actual production operation, the overall ratio drops to 0.85--indicating a very good mix for paper production. By comparison, the Philippine study done by Tamolang et al. reported an overall average Runkel Ratio of 1.08 for the 116 species investigated. Of these, 64 percent were Runkel group 1, 9 percent group 2, and 27 percent group 3. Since groups 1 and 2 are considered good for paper production, 73 percent of the species in the Philippine forests have fibers whose properties should produce good quality paper.

The AID world-wide sample produced essentially the same results: 64 percent fell into Runkel's group 1, 5 percent into group 2, and 31 percent into group 3, indicating that 69 percent of all the species tested should produce paper with good characteristics. Again, these averages can only be viewed as rough indicators, especially since species from various parts of the world are being lumped together. But they are significant in pointing out that, according to Runkel's system of classification, about 70 percent of the fibers sampled in this study can be expected to produce acceptable quality papers. Nevertheless, it should be born in mind that the sample used does not take into account actual volumes of various species present and, therefore, in a given area of the tropical forest, volumes of the various Runkel groups may vary considerably--either good or bad.

To conclude this discussion of tropical wood fibers, it appears that morphologically they are not too much different from those found in the temperate zone hardwood forests and should readily lend themselves to similar uses.

However, other significant anatomical characters are found in tropical woods that make them markedly different from their temperate zone counterparts. Four of these will be briefly discussed here: Axial parenchyma tissue, silica accumulation, presence of resin or gum canals, and the interlocked grain pattern.

Axial Parenchyma

Parenchyma tissue is composed of thin-walled, usually brick-shaped cells that make up the horizontal wood rays and the axial parenchyma in the longitudinal system. This tissue serves, among other things, for food storage; the cells often contain starch, sugars, and oils, all of which are attractive to insects and fungi. Axial or vertical parenchyma is much more common in tropical woods than in temperate species. Few temperate zone woods exceed 10 percent by volume of axial parenchyma. But in tropical species, parenchyma volumes of 50 to 60 percent are known and ratios of 25 percent are quite common. In tropical species, the arrangement of this parenchyma is often associated with the vessels arranged in various patterns from simple vasicentric sheaths to aliform, confluent (fig. 1), and solid bands, several to many cells wide (fig. 2). Some species also exhibit axial parenchyma patterns not associated with vessels. The abundance of axial parenchyma tissue affects the properties

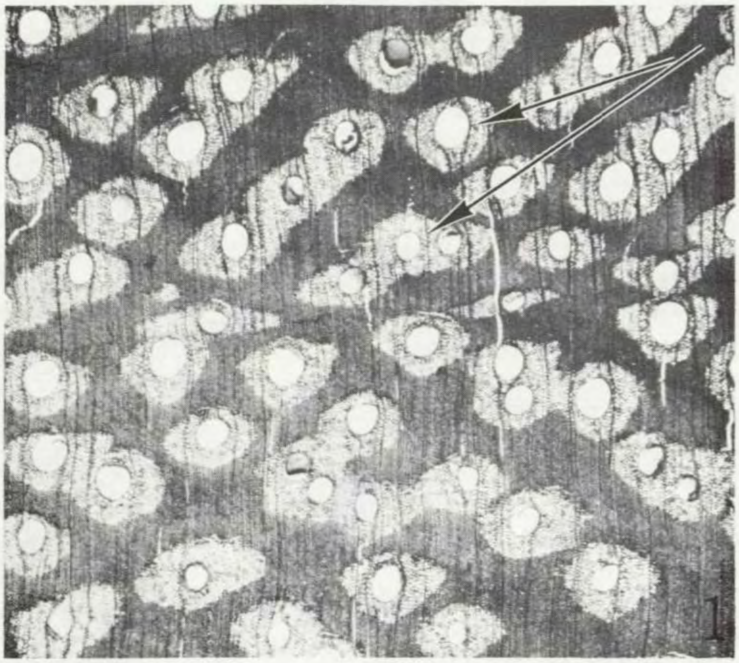

Figure 1.--Cross section (30X) of Enterolobium schomburgkii, from Colombia, with aliform to confluent axial parenchyma.

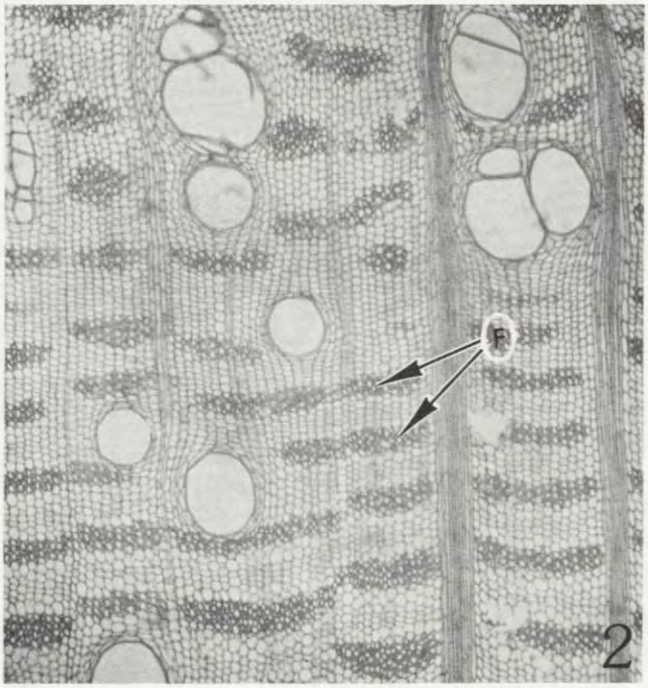

Figure 2.--Cross section (30X) of Erythrina subumbrans, from Philippines, with broad bands of axial parenchyma. Fibers (F) show as darker patches.

of tropical woods in many ways, ranging from a desirable decorative effect to undesirable machining problems and low pulp yields and strength.

Silica

The presence of appreciable amounts of silica deposited in the xylem tissue is a phenomenon unique to some tropical tree species. While temperate zone grasses accumulate considerable amounts of silica within their tissues, only traces are found in the woody tissue of North temperate timbers. The presence of appreciable amounts of silica is of concern because of the rapid dulling effect on cutting tools and the problem of scaling on pulp chemical recovery equipment.

The silicon dioxide found in some tropical woods is an amorphous, non-crystalline substance and is deposited in two basic forms: most commonly as distinct bodies or inclusions within the cell lumen (fig. 3), but in some families (e.g., Moraceae and Verbenaceae) as a vitreous lining of cell walls (fig. 4). The more common form of distinct bodies is rather easily identified since it can be recognized with an ordinary light microscope, while the vitreous form is visible only after being treated with chemicals to dissolve away all cellular tissue, after which it remains as a glass-like cast of the cell wall.

The amount of silica found in tropical species varies from a mere trace to more than 9 percent of the dry weight of the wood. For practical purposes, woods containing less than 0.05 percent silica are considered "silica free," while those with more than 0.05 percent are "silica accumulating." Rapid dulling of cutting edges and other properties of the wood are generally not severely affected until 0.5 percent silica is present.

Such questions as why, under the same growing conditions, one tree takes up large quantities of silica from the soil while its close neighbor remains essentially silica free, or even how the very insoluble silica gets into the plant system in the first place, remain basically unanswered. From a practical standpoint, however, it is important to know those species that contain silica so that one can be prepared to handle the potential problems that may arise during manufacturing processes. Of the sample trees analyzed chemically for the AID study, the silica amount, based on the ovendry weight, varied from less than 0.01 percent to 4.55 percent for Artocarpus blanchoi of the Philippines. While the sample base here is very limited, the values point up the potential silica hazard that may be encountered in tropical woods processing and manufacture. More complete information on silica in timbers can be obtained from the 1952 study by G. L. Amos which surveys most of the woody tropical families.

Canals

Normal canals or ducts are another feature which is entirely lacking from commercial hardwoods of the north temperate region, and even traumatic ducts, such as found in black cherry, are rare. However, several families

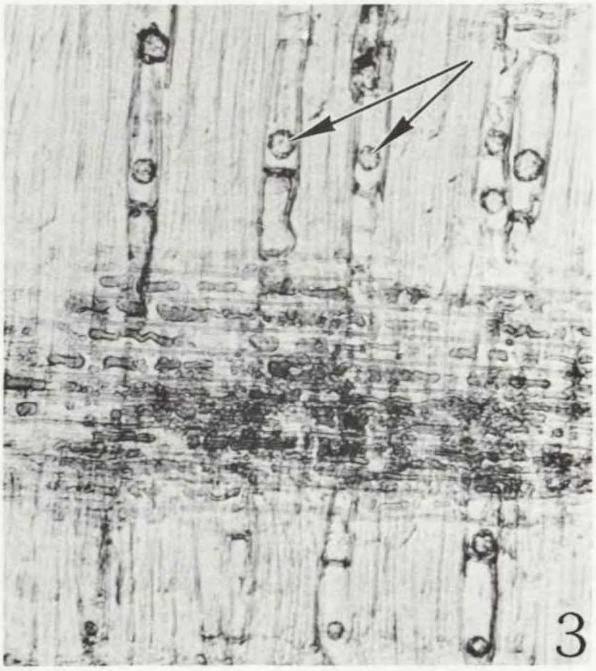

Figure 3.--Radial section (400X) of <u>Dialium guianense</u>, from Colombia, showing silica bodies in the axial parenchyma cells.

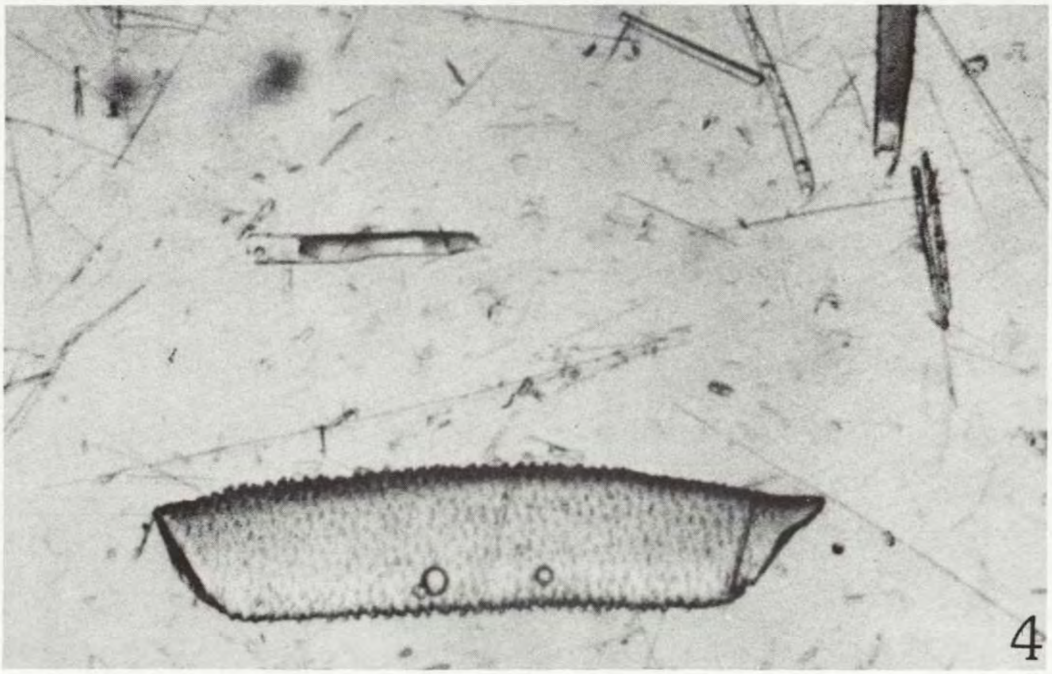

Figure 4.--Maceration (225X). Vitreous silica casts of cells in <u>Maquira guianensis</u>, from Surinam. All lignin and cellulose have been removed.

found in the tropics normally produce resin, gum, or latex in canals. Interestingly, among the hardwood groups, such canals are restricted to either the axial (fig. 5) or horizontal systems (fig. 6), but normally do not run in both directions within a single species, as is typical of softwoods for which resin canals are a regular feature.

The Dipterocarpaceae of southeast Asia is perhaps the best known family of timbers containing resin canals. In the much-used genus Shorea, which produces the lauans and meranties, the canals are of little concern since their oleoresin contains volatile constituents and, therefore, the resin is easily dried. However, in the related genus Dipterocarpus, called apitong or keruing, the resin contained in the canals does not easily dry and may cause processing problems which range from severe gumming of saws, to bleed-out on finished surfaces, to clogging the wire screens of a papermaking machine.

Interlocked Grain

The final anatomical feature of tropical woods that will be mentioned here is that of interlocked grain. While interlocked grain does occur in a few temperate zone species, most notably the genus Platanus and Nyssa, it is more of the rule than the exception among trees of the tropical forest. The exact cause is not known, but for some unaccountable reason a spiral grain is produced which reverses itself at fairly frequent and even intervals. When cut on the quarter, these even-spaced bands of spiral grain produce the desirable and decorative ribbon stripe (fig. 7). While being decorative, this irregular grain pattern is not easily worked, causing problems of pick up, chipping, or tearing out during machining operations, and the wood is nearly impossible to split satisfactorily (fig. 8). Strength properties may also be affected since the fibers are not alined in a single pattern, but this is an area that needs more study.

IN CONCLUSION

This brief survey, covering some anatomical characteristics of tropical woods in general, emphasizes that while tropical hardwoods are similar in many respects to the temperate zone hardwoods, they do have fundamental differences--both good and bad depending upon the end use viewpoint. To utilize the woods effectively and efficiently, these differences need to be known and understood.

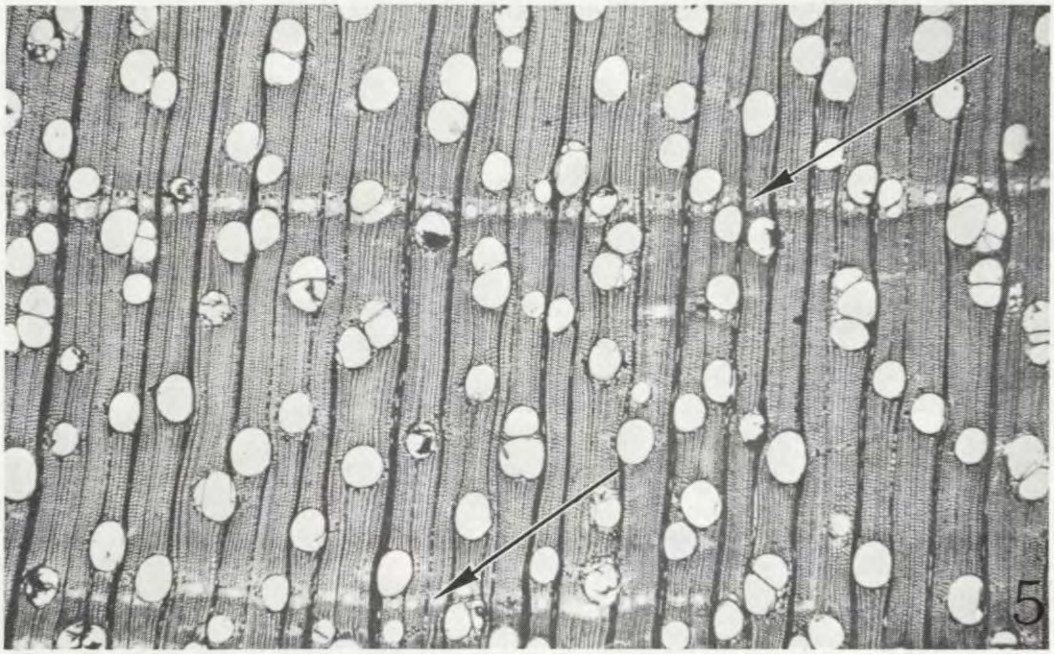

Figure 5.--Cross section (30X) of Shorea polysperma, from Philippines, showing axial canals arranged concentrically.

Figure 6.--Tangential section (30X) of a species of Tetragastris from French Guiana showing horizontal canals running through the wood rays.

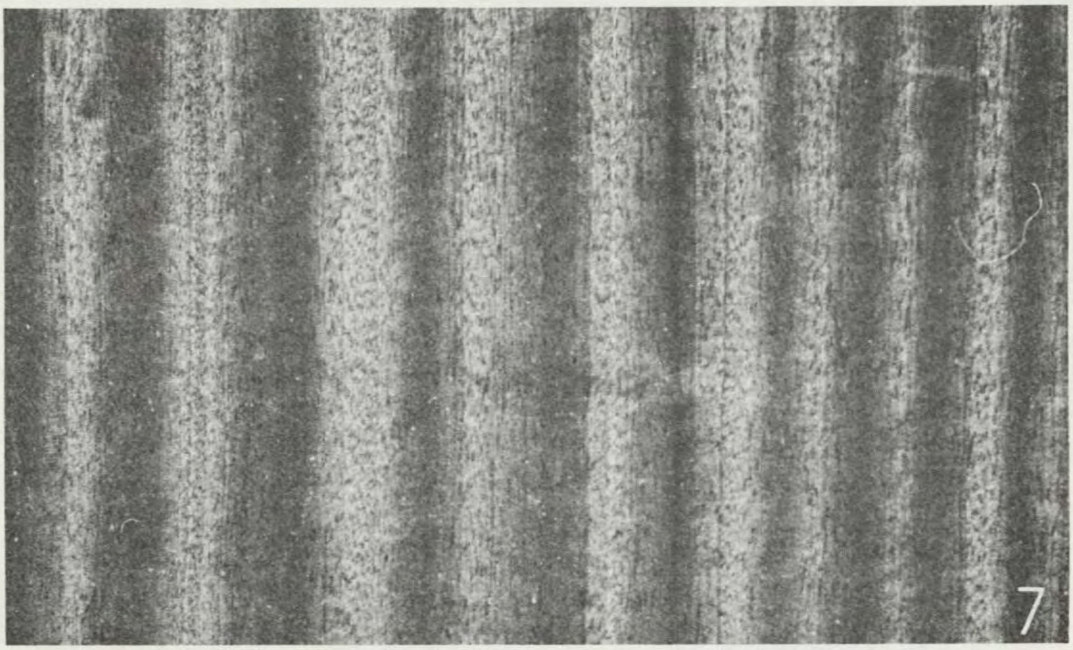

Figure 7.--Ribbon stripe in Entandrophragma cylindricum, from Ghana, produced by slicing interlocked grain radically. (Photo 1X)

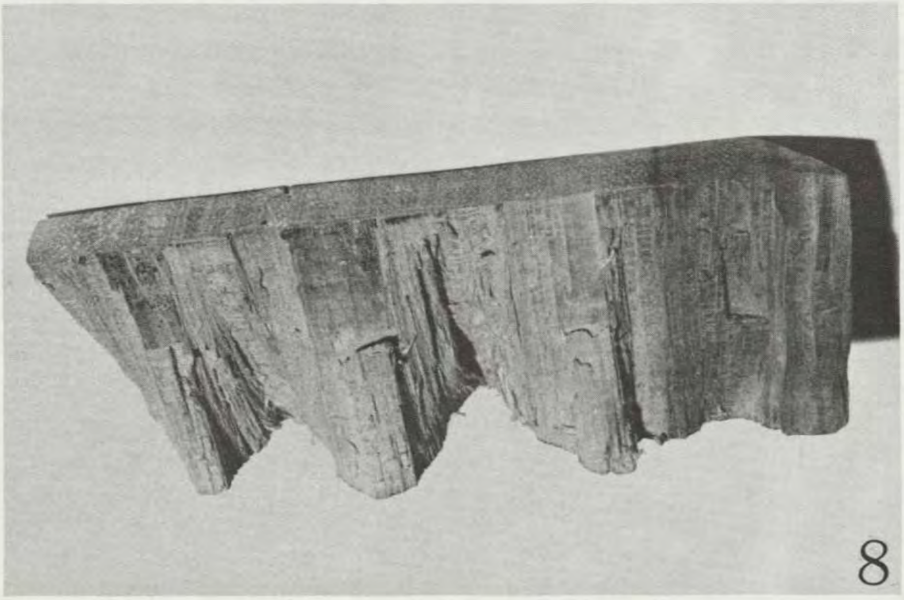

Figure 8.--Interlocked grain of radically split section of Hymenaea courbaril, from Puerto Rico, showing pattern of grain deviation. (Photo 1X)

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SECTION II

ENVIRONMENT AND SILVICULTURE

VALUES OF TROPICAL MOIST FORESTS

By

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VALUES OF TROPICAL MOIST FORESTS

By

Duncan Poore

INTRODUCTION

Extreme views are held about the development of the tropical moist forests[1/] of the world. Some look upon them as the last "frontier," a source of great untapped wealth, all ready for the taking; others think that the whole zone should be left in its pristine state, as untouched wilderness. I have even seen it suggested, in all seriousness, that the timber-importing countries should place a ban on the import or use of any products derived from tropical timbers. It is hard to imagine a better recipe for their total destruction.

The right course must evidently lie between these extremes; and fortunately, as time goes on, more and more people accept that substantial areas of the tropical moist forest must be developed but that this must be done in a responsible manner. The question is not whether such forests should be developed but how much, and where and how?

I begin with some estimates, the best at present available (Sommer, 1976). Tropical moist forests once covered 16 million square kilometres; they still extend over 9.35 million. They are disappearing at 11 million hectares a year. It is important to know what is happening to such a sizeable part of the land surface of the earth. What are these forests being changed into? Is good use being made of their products? How far will the process go? Does it matter? Difficult questions, but questions that a conference such as this has a responsibility to face squarely.

The scientific planning of the use of land and other natural resources is a very recent development in the history of world land use; and, during the short period since it began, it has been honoured more in the breach than in the observance. It is a sad commentary that it is only in the temperate regions of the world that land development has proceeded relatively satisfactorily and has caused little lasting damage to natural resources. Indeed this has owed little, until very recently, to a consciously responsible attitude to the land--land development has been as opportunistic here as elsewhere--but to the remarkable toughness and resilience of temperate soils and vegetation. Yet even in these temperate parts of the world there are many things that might have been done better.

The papers for the United Nations Conference on Desertification (Nairobi, 1977) give a chilling perspective of what is taking place in more

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[1/] The definition of tropical moist forest is that adopted by Sommer, 1976. It includes tropical drought-deciduous broad-leaved forests.

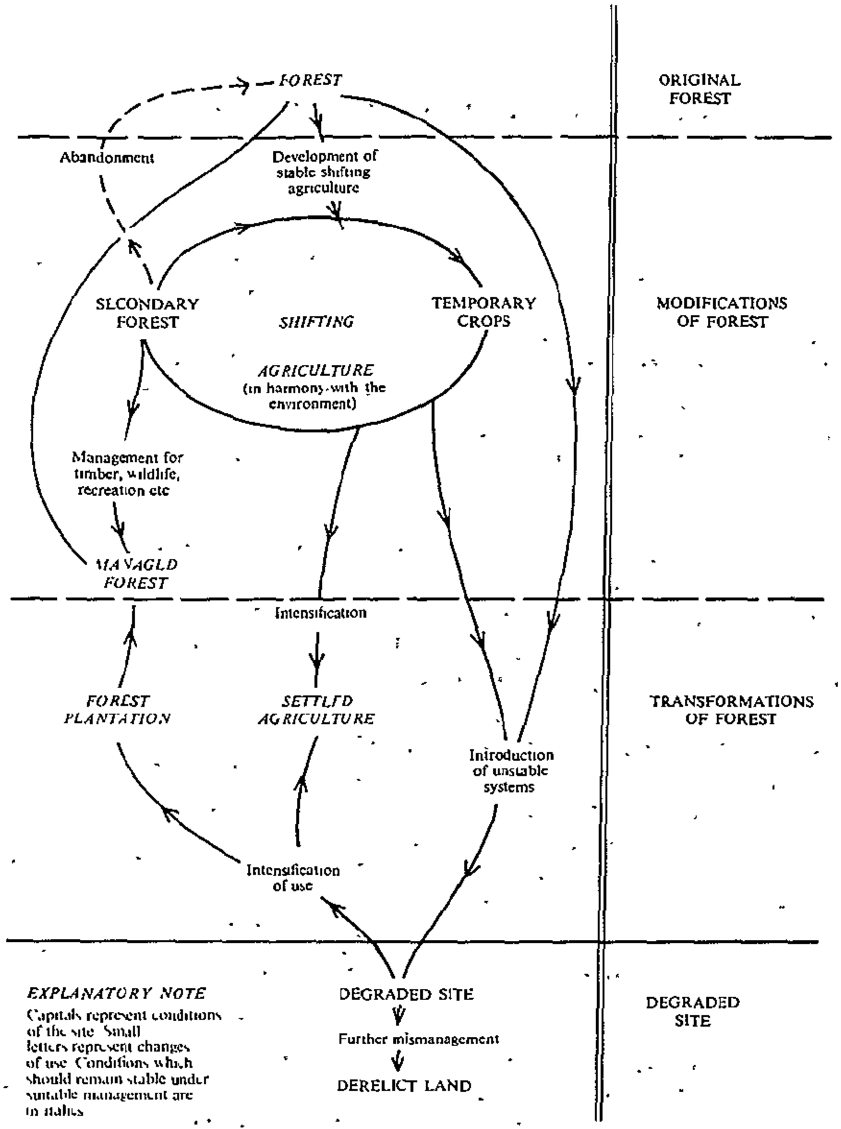

Fig 1: Interrelationships of shifting agriculture with other uses

vulnerable lands. Of the 40 million square kilometres of drylands in the world, 8 million are already climatic desert and thus, by definition, cannot go further in this direction. Of the remaining 32 million almost the whole is under some threat of desertification and about 60,000 sq. km. a year are becoming totally unproductive. According to a consensus of expert opinion, human misuse is largely responsible.

I do not give these examples to argue against development of tropical moist forest but only to illustrate that the record of human endeavour is not good. We are like children who have broken all but the truly unbreakable toys. We must grow up and do very much better in future if we are not to waste the assets of the tropical moist forest too. As much of it is still intact and relatively undisturbed, there is still a chance to develop a balanced and harmonious landscape for the lasting benefit, profit, and pride of these countries in which it occurs. But to do so we shall have to recognize what characteristics of tropical forest lands are of value to mankind and to accord each a due importance in the process of development.

CHANGE IN THE TROPICAL FOREST

As the values associated with tropical forest are closely related to the condition of the site, it is useful to examine the various kinds of change that are taking place, or can take place, in the forest. These are shown diagrammatically in figure 1 (Poore, 1976a).

This distinguishes four levels, separated by horizontal lines: original forest; modifications of forest; transformations of forest; and, degraded site. It links conditions of the site (capital letters) by changes of use (small letters); and distinguishes conditions which ought to remain stable under good management by italics.

There are important values associated with each of the first three conditions; all values are reduced or disappear in the degraded site. Some of these, such as value as a sample of an undisturbed ecosystem, are inherent in the original forest and decrease if the forest is interfered with in any way. Others, the yield of timber or other forest produce, for example, can only be realized if the forest is changed by taking a crop from it. Still other values are latent and advantage can only be taken of them if the forest is removed; no profit can be gained by the potential of a soil under forest for growing rubber and oil palm while the forest remains.

As the terms modification and transformation are used in a very precise sense in this paper, it will be helpful to explain them more fully:

Modification

This is a process by which the original structure, composition, and dynamics of the forest is altered by human intervention. In its slightest form it may be merely a matter of extracting a few good trees or forest produce (fruit, rattan, gum, for example); at the other extreme it can include forms of shifting cultivation which induce secondary succession in the forest. These processes can be called 'modification' provided that continuity is maintained with the original forest ecosystem and that there is no permanent loss of potential (by soil erosion, extinction of species, etc.) so that, in theory at least, there is a possibility that the forest could return in a reasonable time to something like its original condition. (An exact return may be almost unattainable in some characteristics; for example, distribution of species and of age classes within species.)

Transformation

This is a completely different kind of change by which the original or modified forest is totally removed and replaced by a man-made ecosystem or by inanimate structures. Both of the horizontal lines represent points of no return. Once the forest is modified, it can by definition be no longer 'original' or 'untouched' and its values as such cannot be recovered. Transformation implies a wholesale destruction and replacement which cannot be reversed. Similarly the more drastic the modification, the more difficult it is to get back to a less modified state.

This leads to a very simple but fundamental conclusion. If we wish to realize all the values of the forest land in a balanced manner, those uses which require the forest to be left untouched or little modified must be selected and land allocated to them before those that need extensive modification or transformation. It also means that, until a final use has been decided, the forest should be left in an untouched condition as this is the cheapest and most effective way of retaining all its values.

I should emphasize that this does not imply that all protective uses should always take precedence over productive uses; it does imply that there should be priority of choice.

VALUES OF TROPICAL MOIST FOREST AREAS

If natural resources are to be used to the best advantage for lasting human benefit, the ideal should be to balance to the best of our ability the uses to which we put these resources against the values which men and women place on the goods and services that can be derived from them. No one has yet succeeded in devising a satisfactory method of doing this. Some of the complications are discussed by Poore (1976b)[2] and Webb (1977) in relation to the tropical forest. A start can at least be made, however, by trying to enumerate the values that seem at present to be important; but we should always remember that others may become important in the future of which we have no conception. Such a tentative list is presented in Table 1.

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[2] As this paper, prepared for FAO, covers much the same ground, extensive quotations are made from it. These are here acknowledged.

Table 1.--Areas of human concern (impact categories)

1.	Economic and occupational status	Displacement of population; relocation of population in response to employment opportunities; services and distribution patterns; property values
2.	Social pattern or life style	Resettlement; rural depopulation; change in population density; food; housing; material goods; nomadic; settled; pastoral; agricultural; rural; urban
3.	Social amenities and relationships	Family life styles; schools; transportation; community feelings; participation vs. alienation; local and national pride vs. regret; stability; disruptions; language; hospitals; clubs; recreation; neighbourliness
4.	Psychological features	Involvement; expectations; stress; frustrations; commitment; challenges; work satisfaction; national or community pride; freedom of choice; stability and continuity; self-expression; company or solitude; mobility
5.	Physical amenities (intellectual, cultural, aesthetic and sensual)	National parks; wildlife; art galleries and museums; concert halls; historic and archaeological monuments; beauty of landscape; wilderness; quiet; clean air and water
6.	Health	Changes in health; medical services; medical standards
7.	Personal security	Freedom from molestation; freedom from natural disasters
8.	Religion and traditional belief	Symbols; taboos; values
9.	Technology	Security; hazards; safety measures; benefits; emission of wastes; congestion; density
10.	Cultural	Leisure, fashion and clothing changes; new values; heritage; traditional and religious rites

Table 1.--Areas of human concern (impact categories)--continued

11. Political	Authority; level and degree of involvement; priorities; structure of decision-making; responsibility and responsiveness; resource allocation; local and minority interests; defense needs; contributing or limiting factors; tolerances
12. Legal	Restructuring of administrative management; changes in taxes; public policy
13. Aesthetic	Visual physical changes; moral conduct; sentimental values
14. Statutory laws and acts	Air and water quality standards; safety standards; national building acts; noise abatement by-laws

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Principles and Procedures

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Values of Tropical Moist Forest Areas

These areas may have importance because:

(a) Certain parts of the forest are the living areas of indigenous peoples who also derive all their means of subsistence from it. In unmodified forest these are hunter-gatherers who do not attempt to modify or control their environment but are part of it. Others modify it extensively (e.g., by shifting cultivation) but have attained in some instances a stable, dynamic balance with it (Lawton, 1975; Watters, 1973).

(b) They are the habitat of species and genotypes of plants and animals in which these can perpetuate themselves and can express their evolutionary potential. They serve as natural gene banks and areas where evolution can continue.

(c) Certain areas represent undisturbed samples of the range of variation in the ecosystems of the TMF.

(d) The forest covering a catchment area regulates the quality and quantity of water leaving the catchment and prevents erosion, thus maintaining the potential fertility of the area itself and checking siltation and other undesirable consequences downstream. Forest along rivers or streams protect the banks from erosion.

(e) They can serve as areas in which scientific research on natural processes can be carried out or may be places where there is a great amount of valuable scientific information resulting from previous research.

(f) They may be used as standards against which changes in areas outside may be measured and evaluated.

(g) They can provide monitoring stations for the measurement of regional or global changes in certain environmental measures, for example atmospheric components and pollutants.

(h) They are areas in which the public may become educated in natural processes and become aware of their importance.

(i) They can be an important asset for recreation and enjoyment, especially in areas of great natural beauty and near centres of population.

(j) By their physical presence they can act as a moderating influence on climate.

(k) They may act as a buffer against epidemics of pests and diseases affecting both man and his domesticated plants and animals.

(l) The forest contains timber and other forest produce, both plant and animal, which can be cropped to provide a continuing yield or which can be converted into capital for investment if it is decided to remove the forest for other purposes.

Table 2.--Relation between 'values' and the condition of the site[1/]

		Natural forest	Modified forest	Site transformed	Site degraded
(a)	Indigenous forest peoples	R R R	R R R	--	R
(b)	Gene bank	R R R	R R	--	R
(c)	Undisturbed samples of ecosystems	R R R	--	--	--
(d)	Water quantity and quality, and erosion control	R R R	R R *	R *	--
(e)	Research on natural processes	R R R	R R	--	R
(f)	Standards for evaluating change elsewhere	R R R	R R	--	--
(g)	Global monitoring	R R R	R	--	--
(h)	Public education	R R R	R R	R	R R
(i)	Recreation and enjoyment	R R R	R R	R	R R
(j)	Moderating influence on climate	R R R	R R R *	R R *	--
(k)	Buffer against epidemics	L L L	L L	--	--
(l)	Yield of timber and forest produce	L L L	R R R	--	L L
(m)	Economic potential of soil	L L L	L L *	R R R	--

[1/] R = Value being realized
L = Value latent
* = Depends on standard of management
Number of symbols indicates the degree of value.

(m) The sites on which the forests occur may have value for transformation to other uses--agriculture, dam sites, mining, etc. The forest cover maintains the potential and integrity of these sites.

Table 2 attempts to show the relation between the various values and the condition of the site, whether original, modified, transformed, or degraded.

In the sections that follow I take some of these values, either singly or in groups, describe their importance and give an indication of the kinds of conditions, in land planning and management, that should be met if they are to be realized. There is no special mention of those providing for research monitoring or recreation. This is not to belittle their importance, but, if the others are adequately provided for, it should easily be possible to accommodate these also.

Value after Transformation

There is little doubt that the greatest economic benefit comes from transforming suitable sites to intensive agriculture, mining, the impoundment of water and other nonforest uses. In this case the value lies in the characteristics of the site--climate, slope, soil, etc., rather than in the forest itself.

Much land within the tropical moist forest zone has been converted to agriculture in the past (the difference between Sommer's estimates of the original and present extent of forest is 6.65 million square kilometres: Sommer, 1976). Some of this, particularly the rice growing areas of south east Asia, is very fertile and highly productive. As a measure of importance, one might note that the proportions of the gross domestic product contributed by agriculture in three wholly tropical forest countries, Indonesia, Malaysia, and the Philippines are, respectively, 40%, 32%, and 29% (Economist, 1976).

It is probable that, in most of the long settled countries, the best soils have already been cultivated and, indeed, that settlement has tended to take place where the best soils were to be found. But, in certain parts of the tropical moist forest zone, there are still large areas of suitable soils to be opened up for agriculture. There are also vast areas, particularly perhaps in Amazonia, of leached sands and other fragile or infertile soils which are totally unsuitable. It is now generally understood, I hope, that the luxuriance of original forest is no indication that it is underlain by a fertile soil. The luxuriance depends on the circulation within the living system of nutrients accumulated by the vegetation over millenia. In a sense the forest is sitting on the soil, not growing in it. Only soil survey will show whether the soil is potentially fertile or not. It often is not.

It is to be expected that a large part of the fertile soils remaining untilled will ultimately come under cultivation; the needs of the world for food and raw materials are likely to require this.

The important conditions to be met are:

(a) that appropriate areas should be allocated for necessary protective uses before land is allocated for transformation;

(b) that only areas suitable for sustained agriculture are allocated for this purpose;

(c) that full use is made of the timber and other produce present on the area to be cleared;

(d) that the transformation is carried out in such a way that the fertility of the site is retained; and

(e) that the land, once in its new use, is well managed.

Similar kinds of consideration apply to conversion to mining and other nonagricultural use.

Value of Modified Sites for the Sustained Yield of Forest Produce--(1)

Apart from artificial forest plantations, which fall under the last heading, all forest production comes from modified forests. But the modified forest has also a very important contribution to make to many of the values which will be discussed in succeeding sections. Most of these will limit to a greater or lesser extent, total freedom of action in taking a crop off the whole area of modified forest. For example, areas of unstable soils on steep slopes should be managed as 'protection forest' to prevent soil erosion and safeguard water supplies, and should only be cropped in so far as this is consistent with their protective function. Some areas of modified forest may be of great importance for the preservation of certain species of animal (this seems to be the case for both the tapir (*Tapirus indicus*) and seladang (*Bos gaurus hubbacki*) in Malaysia). Good land-use will reconcile these various uses, either by zoning to separate those that are incompatible or combining when this is possible.

Within any constraints which may be set by other uses, the most important condition to be met is that the forest should be managed in such a way that it keeps its potential to provide a sustained yield of forest produce. This is the particular value that must be safeguarded.

Ideally this means that extraction should not begin until enough knowledge is available to ensure the production of succeeding crops. Without this precaution the potential of the sites to provide a sustained yield is bound to decline. This potential is the capital, the only capital, on which productive future land use in these areas can be based. It is frequently said, with some justification, both of the countries which contain tropical forest and those who extract it, that they are carelessly sacrificing the possibility of future production for present gain.

But there is a real dilemma here. Most successful known silvicultural techniques only apply in lowland forest, often on soils that are suitable for agriculture and are likely to be diverted for this purpose. Not enough is known to manage many forests even to meet the needs of orthodox timber production. There is hardly any knowledge about the possibility of sustaining 'total logging.'

Webb (1977) has provided an admirable discussion of the steps that should be taken in establishing a pulp wood industry in Papua-New Guinea. The immediate answers seem to be accelerated research in silvicultural management, and to design any enterprise which is intended to be self-sustaining with provision for monitoring its progress, and changing direction if need be.

Value of Natural Ecosystems and of the Genetic Resources of Wild Plants and Animals--(b and c)

These can be taken together, as the best way of preserving the full range of species is by protecting a representative series of natural ecosystems. In the tropical rain forest the most important are samples of undisturbed forest--hence the urgency in choice; but samples of disturbed ecosystems are important too, and the maintenance of these should be one of the objectives of management in modified forests also.

There is a particular value to science in preserving areas of forest that are still untouched. It is only in them that it is possible to study the natural factors that determine the evolution, distribution, migration, and dynamics of plant and animal species in the forest. As the influence of man pervades the remotest corners of the earth, the value of the remaining untouched area increases. The tropical moist forest is of particular importance in this regard, because it is the richest burgeoning of life anywhere on the planet and, in some places, represents the culmination of the continuous development and evolution of forest <u>in situ</u> since the flowering plants began to evolve during the Cretaceous, some 3,000 million years ago.

Areas of undisturbed forest are not only significant to science for the knowledge that they may yield; they also provide the habitat of the very large number of plants, animals, and micro-organisms of the forest (perhaps one-tenth of the total number of species of the globe). Undisturbed forest allows these to persist and to continue to evolve at practically no direct cost to society. Compare the cost of maintaining an area of lowland forest untouched with that of trying to breed or cultivate or store all the species in zoos, botanic gardens, seed banks, banks of germ plasm, and culture collections--even if it were technically possible!

The economic potential of many of the species in the forest is quite unknown. It has already produced an impressive array of plants of economic value: all the tropical timber trees; rubber and oil palm; fruit trees, such as mango, mangosteen, citrus, rambutan, durian, lychee, avocado pear etc.; coffee, cocoa, tea, bananas; bamboos, rattans, and quinine. The forest contains the wild relatives of all these crops, relatives which are of present or potential value for improving stock or increasing resistance to disease. The properties of others, such as Rauvolfia as treatment for high blood pressure, have only recently been discovered. There is no doubt whatever that the plants and animals of the tropical rain forest will become of increasing importance as sources of economic products--if they still exist.

It is essential for those who work with the tropical forest to recognize that these forests are some of the most fragile and vulnerable in face of the kind of changes which are now being imposed upon them. The biology of the woody species (intermittent flowering, widely spaced individuals of a species, inefficient dispersal, immediate germination of seeds) all mean that very few of the species can spread outside established forest. If the forest structure is destroyed, they perish.

It is therefore of the utmost importance that the selection of tropical forest nature reserves should be made early in land use planning, that they should include a full, representative series of all ecosystems and that, once established, they should be considered inviolate. The future of tropical forestry, and indeed of tropical tree crop agriculture, depends upon this. So may many other unforeseen human benefits.

Value for Indigenous Peoples--(a)

In Latin America, Africa, and Asia alike, there are still many indigenous peoples who live within the tropical forest and whose way of life is adjusted to it. There are, for example, 118 Indian groups in Brazil (Indigena, 1974), many of which live in the tropical forest zone.

Some peoples, such as the Negritos in the Malay Peninsula and the Onga of the Andaman Islands, live entirely by hunting, fishing, and food gathering and can be considered a component of the undisturbed forest. Others may be partially or wholly agricultural, practicing systems of farming that coexist with forest rather than replacing it. Originally these systems of 'swidden' agriculture were in balance with forest regrowth but now, with increasing population, many of them are no longer so and are causing extensive land degradation.

To such peoples the forest land is home, for which they have a strong emotional attachment and which provides their whole livelihood. Webb (1977) has described vividly the extent of the dependence of forest peoples in Papua-New Guinea on their surroundings:

> "...Forest products are directly available in great variety:
>
> > "Important yields include food (fruit, leaves, tubers), spoils of hunting and trapping (bird decoration), clothing, building materials, thatching, lianas (ropes), weapons, poisons, and magic potions...It is difficult for a member of western society to appreciate the dependency on, and the rich supply of goods from, the rainforest" (White, 1976)."

> Plant species yielding useful products in PNG village life have been studied by various workers, and there is a recent comprehensive review by Powell (1975). Tropical rain forests probably contain the highest percentage of alkaloidal species of any community, and these and other physiologically active species used in native medicine throughout the tropics have contributed many important therapeutic agents (Webb, 1969, 1973).
>
> An impressive illustration of the variety and value of biological resources from a special area of the PNG forest was provided recently by D. S. Liem, N. Kwapena, and others who studied the numbers of animals and animal products collected by villagers at Garu village, Talasea. For example, between August 1973 and July 1974, the harvest from the forest included 24,129 megapode eggs and 130 wild pigs (Liem, 1975). Although it is possible to arrive at some estimate of the economic value of such forest resources by 'opportunity cost,' such a method ignores the role of these facets of the forest heritage in the social, cultural, and traditional activities of the people. See also Liem et al. (1976).
>
> Other forms of religious attachment to the forst also exist, and White (1976) refers to 'animist beliefs, and a fear of ill-effects of sorcery in sinister places.' It is clear that specialized help from anthropologists, sociologists, etc., is required to extend knowledge of the social and cultural values of the forests, so that they are not ignored in environmental impact assessments of large-scale forestry operations...."

In some countries, notably those in south east Asia (for example, Papua-New Guinea, the Solomon Islands, and Fiji) ownership of the land is vested in the local people, but elsewhere their legal title may be unreliable or nonexistent.

Where land degradation is taking place there may be good ecological reasons for changing agricultural methods or for resettlement; and those who wish to adopt another way of life should not be hindered from doing so. Indeed it is probable that this trend away from the forest is inevitable.

In this age of very proper insistence on human rights it should be axiomatic that those who wish to remain on their traditional lands should have first claim, that changes should only take place after consultation with them and with their agreement, and that they should be the first to benefit from the fruits of development.

This seems a matter of common humanity, but the record of development, even in very recent times, often makes horrifying reading and shows that humanity is not such a common quality. The well-being of indigenous peoples should be given primacy in the planning and management of forest areas which they occupy or use.

Value for Soil and Water Conservation--(d)

The value of forest is well known for maintaining the fertility of soil, checking soil erosion, and ensuring the regular delivery of water of good quality. Maintaining the original forest cover is likely to be the cheapest and most effective way of protecting catchment areas.

All steep and unstable slopes and a band on either side of stream courses should be left totally undisturbed. If light cropping is undertaken, this should only be after it has been shown that this does not affect the quality of the forest in protecting soil.

Great and lasting damage can be done by unsuitable methods of clearing, by timber extraction, by the careless alignment, construction, and maintenance of forest roads, and by management of cleared land which does not pay full attention to soil conservation measures. The experience of Pereira (1973) has shown that it is possible to transform hill forest to tea estate and largely to retain the hydrological characteristics of the original forest. His conclusions are worth quoting in full:

> "Thus the critical stages in the development of land from protective forest to the cover of a tree crop have been shown to be possible without permanent deterioration in water resources either in quantity or in behaviour. High capital input and the professional skill required to achieve this degree of hydrological control, almost equal to that exerted by the forest, is in sharp contrast to the unplanned invasion of forested catchment areas by peasant cultivators, which has destroyed most of East Africa's forests outside the boundaries of the forest reserves. It is important that the hydrology of this land-use change should be correctly interpreted. Mountain watersheds which are the source areas of important rivers need careful protection.
>
> Natural forest, preserved against fire, felling, and grazing, gives excellent protection. Tea estates planned and developed with full soil conservation at a professional engineering level, have so far, over the first ten years, proved to be a hydrologically effective substitute."

Value of Tropical Forest in Moderating Climatic Conditions and CO_2 in the Atmosphere--(j)

There has been considerable speculation, and alarm, about the possible effects of removing large areas of tropical forest on regional and global climate and on the oxygen and carbon dioxide content of the atmosphere. This has been reviewed in Poore (1976b), and I can only touch briefly on the conclusions here.

It is now generally agreed that there is no problem with oxygen, but the questions of carbon dioxide and climatic change are more complicated.

Carbon dioxide.--The carbon dioxide content of the atmosphere is increasing at present at a rate of about 0.4% per year, an increase that is mainly attributed to the use of fossil fuels. There is a complex dynamic equilibrium of carbon exchange between the atmosphere, the land, the surface, and deep layers of the ocean and sediments. Although too little is known about the transfer rates between these to make confident predictions, the most active exchanges appear to take place between the land systems, the atmosphere, and fossil fuel.

The importance of the tropical forest is not in the carbon of short residence time circulating through leaves, litter, and soil humus, but in that of rather longer residence time locked up in wood. This is estimated as 340 x 10^9 metric tons (Whittaker and Likens in Woodwell and Pekan, 1973), compared with 405 x 10^9 metric tons in all other forests.

If the total of the carbon in tropical forests were to be released in the next 50 years and be replaced by no other stored carbon, it would release carbon at double the present rate for fossil fuels.

"In conclusion, the data on various aspects of the carbon cycle are so inadequate that it is impossible at present to make reliable predictions. It would, therefore, be prudent, pending more accurate models, to avoid aggravating the situation already caused by the burning of fossil fuels and to retain a high biomass on as large a proportion as possible of the tropical moist forest area either in forest or tree crops."

Climate.--The importance of tropical forest in the possible regulation of climate lies in the physical characteristics of its surface as they affect the radiation balance between the land and the atmosphere.

When forest removal leads to sharp changes in these characteristics (e.g., replacement of trees by bare ground), this can have a strong effect on local and possibly also on regional climate.

Normally, however, tropical forest is replaced by vegetation with rather similar physical characteristics in relation to radiation balance--tree crops, secondary forest, irrigated agriculture, or grassland. When this is the case, its removal is unlikely to have striking effects. "The tendency to self-generating aridity could however be important in Tropical Rain Forest areas where soil is very poor, in those areas of seasonal drought where fires could increase the dust in the atmosphere, and erosion could lead to large areas of bare soil being exposed; in the deforestation of areas of ground water or gallery forest, and everywhere in the ecotone between TMF into drier forest types.

With this degree of uncertainty however it is clearly very important to approach changes of land use in such sensitive areas with great caution, and everywhere to try and replace forest, if it must be replaced, with systems of land use which reproduce as far as possible the most significant physical features of the vegetation that is being removed."

THE CHOICE

What are the possibilities for the future?

"In a century we might see 10-15 million square kilometers of the surface of the Earth reduced to unproductive waste. Good agriculture might persist on those fortunate areas which possessed stable volcanic soils completely resistant to misuse; even if these had been abandoned, they could be reclaimed for productive use. But the picture of the remainder would be very different; barren, infertile, deeply eroded soils would be the rule, covered with scrub, fire-climax grassland, and the barest subsistence farming. The possibility of this recovering to forest by natural succession would have gone for ever, for the forest trees would no longer exist. Instead any vegetational change would take the form of colonization by ubiquitous, fire-resistant, and usually useless shrubs and grasses. The total natural capital, in soil fertility, in variety of organisms, in capacity to recover would have been lost. To use a phrase first applied in the Middle East, the land would be 'in a stable state of completed erosion.'

"The means to obtain capital for restoration would have gone too; the original forest which had been used so prodigally and unwisely in the last century. There might be minerals, but they too might be a waning asset.

"Like the trees and animals, the people who once lived in these regions would have disappeared with their knowledge, skills, and culture. At best they would be completely absorbed in an urban economy; at worst they would have largely succumbed to imported disease or be living a miserable existence on marginal soils or in slum settlements on the edge of cities.

"About one-tenth of all the species of plant and animal on the Earth would be extinct or in dire danger of extinction. A few would persist, those that were adapted to the extreme conditions, in areas which were too inaccessible or unpleasant to be reached by man. Many of these would be gone for ever before their utility to man or the pleasure that they might give to him were ever experienced or even understood.

"The eroded soils would have lost most of their capacity to absorb and retain water, so that the lower parts of catchment areas would be subjected to a succession of floods and droughts; and the water would be so laden with silt that it would be entirely unsuitable, without expensive treatment, for domestic or even industrial use. Impoundments would rapidly fill with silt and many dam sites would be lost which might have been used for power, or the regulation of water for irrigation or other uses. Over most of the land there would be effective drought because of rapid run-off and lowered water tables, even if there were not climatic change induced by the catastrophic loss of vegetation cover.

But, probably before all of this came to pass there would also be widespread famine, epidemic disease, and civil strife.

"This is fanciful perhaps; but so may have seemed the warning in Plato two millenia ago--a warning that was not taken, with consequences that are all too clear today. This passage (Criteas, about 400 BC) bears quoting once again because its message is so topical.

"'There are mountains in Attica which can now keep nothing but bees, but which were clothed not so long ago with fine trees, producing timber suitable for roofing the largest buildings; the roofs hewn from this timber are still in existence. There were also many lofty cultivated trees, while the country produced bountiful pastures for cattle. The annual supply of rainfall was not then lost, as it is at present, through being allowed to flow over a denuded surface to the sea. It was received by the country in all its abundance, stored in impervious potter's earth, and so was able to discharge the drainage of the hills into the hollows in the form of springs or rivers with an abundant volume and wide distribution. The shrines that survive to the present day on the extinct water supplies are evidence for the correctness of my hypothesis.'

"This process of denudation and impoverishment has gone on to the present day almost unchecked, though more slowly because there is less to lose. It is now so complete that it is almost impossible to persuade those who live there that it was ever any different. Yet because many of the species of plant have long-lived seeds and efficient dispersal, extinctions may have been relatively few. The building stones are there which could be the foundation of recovery. In the tropics, especially in the area of rain forest, it would be different.

"Unfortunately it is all too easy to find somewhere in the tropical moist forest region, examples of every one of the processes that I have described above. Massive timber concessions have been granted in the Philippines, Indonesia, and Sabah before the ultimate allocation of the land is known. Latin America abounds with examples of land settlement without previous survey of land capability, often on soils where sustained agriculture has no chance of success. In almost all regions there is logging before the silvicultural knowledge is available on which management for sustained yield might be based. The last remaining areas of unique types of forest are being cleared or logged without appreciation of their other values. Indigenous peoples are being displaced to make way for other uses of the land. Even in countries where development is being carried out after careful assessment of land capability, there is inadequate provision for the safeguarding of natural areas and genetic resources. Everywhere development is proceeding without making use of experience which is already available.

"But none of this need happen. There is another possible picture. Adequate and carefully selected areas for the protection of flora and fauna and of ecosystems; other areas of natural land, especially perhaps those of high scenic value, set aside for recreation and enjoyment; the gathering grounds of water and the banks of rivers under natural forest cover; lands not suitable for agriculture managed, wherever this is consistent with other conservation objectives, for a sustained yield of timber or other forest produce; intensively managed plantations of tree crops in suitable sites; and, allowing for the needs of protection, all soils of high potential fertility and few limitations under intensive farming.

"In much of the TMF area this choice is still available. A high proportion of the land surface is still under forest and the climate is favourable for plant growth. But in some areas pressure of population makes it necessary to resort to the slow process of land restoration.

"The true course of events is likely to lie somewhere between the two. It is unfortunately unlikely that Governments will undertake and sustain the high level of long-term planning that would be needed to bring about the second, utopian, picture; and even if they did, mistakes are bound to occur. An additional difficulty concerns the needs of intensive systems for energy and fertilizers. The realization of the type of landscape that has been sketched above depends on the zonation of land. Some parts are protected from modification by intensification of use on the others. This intensification can be brought about either by investment in machinery, fertilizers and pesticides (to simplify somewhat), or by more intensive human involvement in more self-contained systems. Both are possible means of attaining the same objective and both are consistent with the kind of zonation proposed. They will, however, lead to very different kinds of life for the people concerned. The choice will no doubt depend on political preferences and on future trends in costs of energy, the cost and availability of imported fertilizers, and the future demand for the kind of raw materials that can be produced in the TMF region. The point to emphasize here is that good zonation and land management will leave this choice open; bad planning and management will close it inexorably.

"What, then, is the conclusion? It is simple and in no way new. If the greatest benefit is to be derived from the TMF and the undesirable consequences avoided, three things are necessary: good planning for the allocation and use of land; high standards in the conversion from one use to another; and good management. This requires vigorous Government action, above all, as well as much greater public understanding. Although I have from time to time emphasized the lack of information, there is already available in the world the knowledge and experience to implement the great majority of the measures that would ensure the smooth and satisfactory development of the TMF region. The main barriers are in attitudes and in institutions. A failure to appreciate the really vital importance of choosing the right course; a tendency to sacrifice long-term benefits for immediate gains, however untoward the consequences may be; a lack of political will to act; a failure of those who need advice to get in contact with those who can give it; the shortage of trained personnel to carry out operations to the required standards; and a reluctance to obtain information in the fields where lack of information is the main barrier to action. Finally there is the lack of public appreciation of the importance of the issues and that what may appear to be an unnecessary immediate sacrifice is for the sake of a great and lasting benefit. What Pereira has said (1973) about watershed protection applies to the much wider field of wise management of natural resources:

"'This is a case where community discipline must hold the boundary while community education catches up. Persuasion is always the best approach, and offers the only permanent solution, but no country can afford the destruction of irreplaceable natural resources for lack of protection during the long period of public education.'

"Wise use of the TMF in future requires a revolution of attitudes. We should treat the world as we would treat our garden or a valuable work of art. It should be as unthinkable to destroy a unique area of forest as to break up the Taj Mahal for road metal or to burn a canvas of Raphael to keep warm for an hour. In practice this means that the onus of proving their case should lie with those who wish to remove the forest rather than those who wish to retain it. They should be obliged to demonstrate that the changes they propose are genuinely for the lasting benefit of the community."

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ENVIRONMENTAL IMPLICATION OF ANY-SPECIES UTILIZATION IN THE MOIST TROPICS

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The tremendous increases in world demand for wood have, during the past decade, caused rapid acceleration in the rate of logging in the moist tropics. Because relatively few species are harvested, the demand is satisfied by logging tremendous areas. In some cases, the high-graded residual forests are subjected to silvicultural treatment, but more often the land is abandoned to let nature recover as it will. Most commonly, it is cleared off for grazing or shifting agriculture.

If the world demand for wood is to be met without the degradation and destruction of all tropical forests, the only alternative seems to be that of increasing our technical capability to use a wider range of species. Intensive forest utilization and management applied to smaller areas can provide a means for taking the pressure off of other lands while permitting developing tropical nations to tap the high potential productivity of their forests.

In the hands of the greedy, the technical capability to utilize any and all species could lead to unprecedented destruction of tropical forests. Used wisely, however, it could provide us with ecologically beneficial silvicultural tools which could be used to maintain tropical forests as highly productive, diverse, renewable ecosystems.

There is not much data available on the environmental problems which might result from intensified utilization of forests in the humid tropics. Furthermore, the heterogeneity--climatic, floristic, edaphic, and social--is immense, so the environmental problems encountered would vary greatly from place to place. In the following sections we have attempted to signal some of the problems which might be anticipated with respect to soils and nutrients, water, vegetation, and animals.

IMPACTS ON SOILS AND NUTRIENTS

Deep, well-weathered tropical soils, which form under conditions of high rainfall, high, uniform temperatures, and high rates of organic matter turnover, are tightly linked to the vegetation growing upon them. When that link is broken, as through harvesting the vegetation, the soil characteristics change. Under conditions of moderate, short-term disturbance those changes are usually temporary, but if the disturbance is severe and prolonged, the changes are sometimes irreversible.

Tropical soils are infinitely more varied than the uniform bands of red which often depict them on the maps included as end flaps of introductory geography texts. It is, therefore, impossible to describe a "typical" tropical soil and describe its susceptibility to damage due to forest utilization. Some tropical soils can withstand tremendous physical abuse and still respond by supporting a luxuriant vegetation. Others are extremely sensitive and, if disturbed, become the substrate for a different vegetation, often one which is less productive and diverse than the original forest.

Physical Effects

Erosion is one of the most conspicuous physical results of humid tropical forest utilization but should not be an insurmountable engineering problem. All studies of erosion and its relation to logging of humid tropical forests indicate that erosion does increase during and after logging (Pernet 1952, Kellman 1969, Burgess 1971, Anderson 1972, Liew 1974), and if logging is followed by fire, erosion is even greater (Wyatt-Smith 1949). Most studies indicate a general decline in erosion as regrowth develops, although erosion may continue in local highly disturbed areas for many years. Most erosion is typically associated with roads and skid trails, i.e., the areas which sustain the most soil damage.

Other physical effects on soils include compaction and loss of structure. Undisturbed forest soils tend to have higher values for crumb stability and porosity, and lower values for bulk density, than soils which have been cleared. The amount of this type of soil damage depends, in part, on the harvesting techniques used.

Chemical Effects

Unlike many temperate soils which derive most of their cation exchange capacity (CEC) from clays, many soils of the humid tropics owe most of their CEC to their colloidal organic matter content. Accordingly, most chemical changes which occur in tropical soils as a result of forest utilization probably reflect changes in the soil organic matter. Contrary to common belief, however, the rate of organic matter breakdown does not increase after clearing (Ewel 1976). In fact, the soil in a forest clearing is a harsh environment for the micro-organisms responsible for organic matter breakdown. The soil organic matter does decline after clearing, but does so because the organic matter inputs (leaf and branch fall) are cut off, not because decomposition is accelerated. The drop in ECE after clearing releases nutrients into the soil solution, where they are subject to loss through leaching and surface runoff.

Not all of the nutrient loss due to leaching is permanent. Studies indicate that the nutrients immobilized in regrowth and fallow soil quickly approach the levels found under mature forest (Joachim and Kandiah 1948, Soerianegara 1970, Brams 1973, Golley et al. 1975). Some of the leached nutrients are retrieved by deep-rooted plants, especially on sandy, well-drained soils. Such uptake is much less likely in more typical fine-textured, deeply weathered soils, however. Such soils are often imperfectly drained, nutrient poor, and have 90 percent or more of their plant roots in the upper 10-15 cm. Nutrients leached deeply into such soils are almost irretrievable.

If post-harvest burns are used to reduce logging debris, the nutrients tied up in the slash are released and may be lost due to leaching and runoff (Brinkman and Nascimento 1973). If regrowth is rapid, however, as at the onset of the wet season, many of the released nutrients will be available for the new regrowth, thus insuring that the soil is quickly covered with vegetation.

One very important potential loss which has not been well studied is the removal of nutrient in harvested biomass. This may be especially important in tropical forests, where the bulk of the nutrient capital of the site is incorporated in the vegetation, rather than in the soil as in most temperate zone forests. To get an idea of the magnitude of nutrient removal from tropical forests we constructed figure 1. This shows the average total standing crop (soil, litter, roots, and above ground vegetation) of nitrogen, phosphorus, potassium, calcium, and magnesium in sample temperate and tropical forests. The relative size of each circle is scaled to the total standing crop, while the cross-hatched segment indicates the amount removed when boles (with bark intact) are removed. It is clear from these data that nutrient depletion of tropical forests through wood removal is potentially a serious problem and one which must be given strong consideration if increased rates of harvesting are anticipated.

Micro-organisms

The least conspicuous, but perhaps the most important, potential effect of forest utilization on the soil is that on the micro-organisms. These organisms are important in nutrient cycling and maintenance of soil porosity. Of special importance are the mycorrhizal fungi which are essential for the nutrition, and consequently the survival, of almost all tropical trees. The limited number of soil micro-organism studies indicate that some bacterial, fungal, and soil arthropod populations decrease following site disturbance (Coulter 1950, Meiklejohn 1962, Aspiras cited by Blanche 1975, Lasebikan 1975).

Some of the soil bacteria are nitrogen fixers and, as such, may be crucial components of the forest's nitrogen cycle. Nitrogen is frequently a potentially limiting factor in tropical forest growth. Dommergues (1954) reported that, following forest destruction, the density of nitrogen fixing bacteria was 4 to 10 times lower than that of the undisturbed forest. He also reported that the density of cellulolytic bacteria was 8 to 33 times lower than that observed before forest destruction. This, coupled with the reduction of populations of soil and litter-inhabiting arthropods, could significantly reduce the rate of litter breakdown and nutrient cycling.

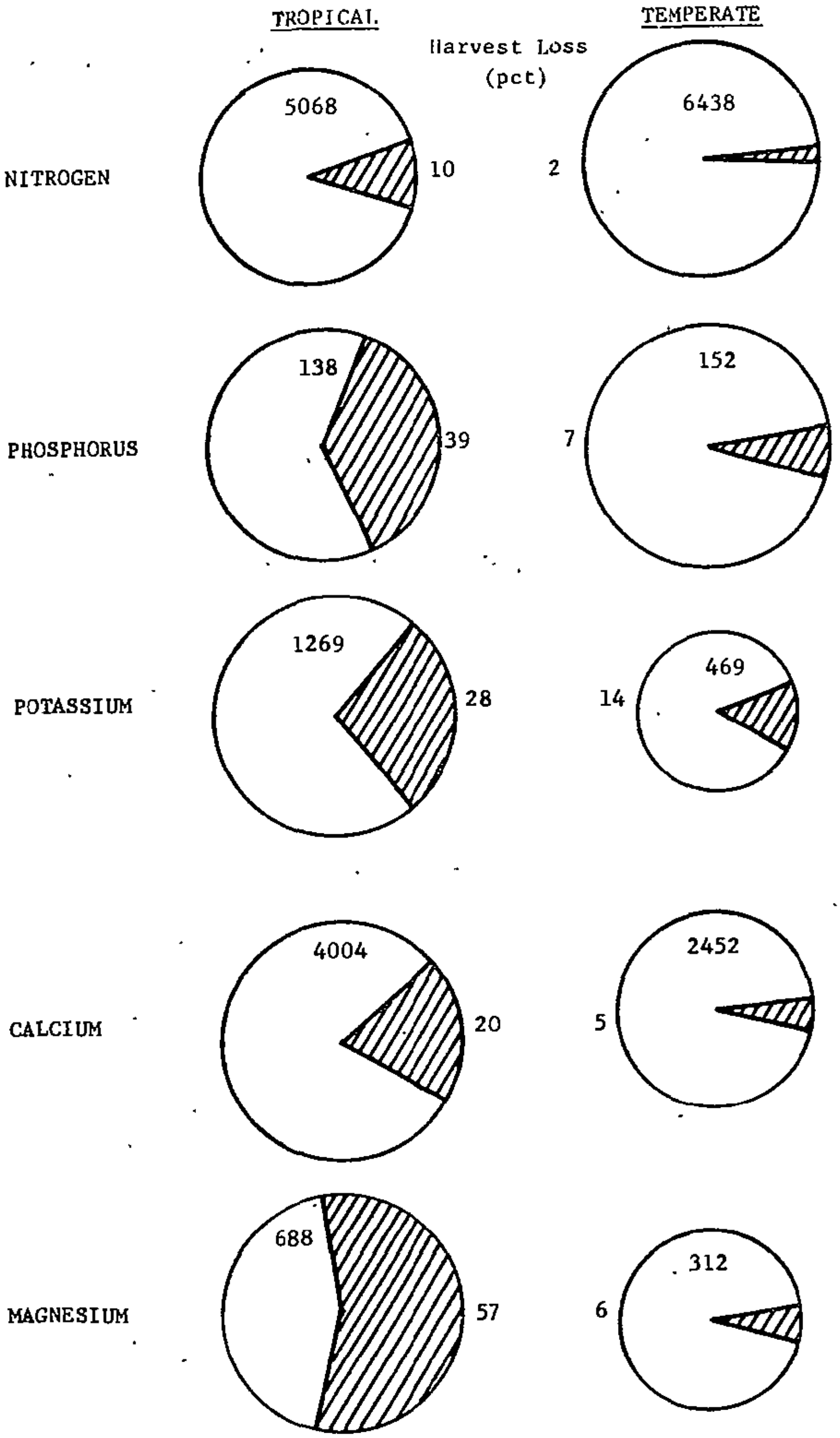

Figure 1. Total ecosystem nutrients (numbers in circle) and the fraction lost through harvest in sample temperate and tropical forests. Values are kilograms per hectare. Cross-hatching indicates the amount removed when trees are harvested (boles only), assuming that all roots, branches, and leaves remain in the forest.

Temperate data are a mean of four kinds of vegetation from Ovington (1962): *Pinus sylvestris*, *Pseudotsuga taxifolia*, *Betula verrucosa*, and *Quercus robur*. Tropical data are a mean of data from Kade, Nigeria and Yangambi, Zaire (summarized in Nye and Greenland 1960) plus Puerto Rico (Odum and Pigeon 1970).

Soil micro-organisms in the humid tropics may be more susceptible to site exposure than those of temperate zones because temperate-zone soil micro-organisms commonly have resistant stages in their life cycles which allow them to survive in a seasonally harsh environment. Tropical micro-organisms, on the other hand, may not always possess such resistant stages and might be drastically affected if their microenvironment is appreciably altered.

IMPACTS ON WATER RESOURCES

Abundant water is one of the great natural resources of the humid tropics: most humid tropical areas receive more than two meters of rain per year and some areas receive eight to 10 or more. Evapotranspiration from natural forest vegetation in the tropical lowlands is about 1600 mm per year, and most of the difference between that and rainfall shows up as runoff. This runoff is crucial for irrigation in drier downstream regions, for urban and industrial consumption, and (possibly most important of all in the future) for the driving force to produce hydroelectric power in fossil-fuel-poor developing nations. Despite the great importance of the water resources of tropical nations and the great potential impact that forest utilization can have upon them, there has been very little study of the relationship between forest utilization practices and water.

Water Yield

Because the combined evaporation and transpiration from a forest returns more water to the atmosphere than does bare-soil evaporation alone, it is generally true that removal of the forest cover results in greater total annual water yield via runoff and streamflow. The amount of leaf area per unit ground area (i.e., leaf area index, or LAI) is generally quite high in tropical forests, with values of seven to 10 commonly reported in the literature. This compares to LAI values of four to six which are frequently reported for temperate forests. The higher LAI of tropical forests may result in proportionately greater transpiration from tropical forests than from temperate forests, so the increases in water yield following forest clearing may be proportionately higher than those following clearing of temperate forests. In some cases, this additional water yield may be a welcome additional resource, but more often than not it occurs as a rushing torrent of post-storm water which frequently inundates agricultural flood plains.

One aspect of water yield and its relationship to forests which is almost unique to the tropics is that situation where the presence of forest vegetation may increase the total yield from a watershed. This occurs in cloud forests, where transpiration is low and the vegetation is buffeted by moisture-laden air, frequently driven by the trade winds. In such cases the tree limbs, leaves, and epiphytes act like a condenser which strips the water out of the air. The increased water input from this filtering action is very substantial, often accounting for half or more of the total (Weaver 1972). Many such cloud forests are dwarfed and do not contain commercial timber, but others are tall and prized by loggers. Any planned forest utilization of such cloud forests should certainly consider the potential downstream effects of decreased water yield that might result from forest cutting. These forests are usually wet throughout the year, and thus supply the continuous streams of water necessary for special uses such as small-scale hydroelectric power.

Water Quality

There have been very few studies of the impact of forest utilization on water quality in the tropics. The scant available data indicate that sediment loads in streams increase two- to four-fold after forest clearing, with immediate post-logging sediment pulses sometimes being 50 times greater than those on comparable forested watersheds (Gilmour 1971). In addition to mineral sediments, the input of organic matter into streams may decrease water quality by increasing the oxygen demand as well as causing increased turbidity. Unless a site is severely disturbed and seed sources are removed, however, succession normally proceeds rapidly in the humid lowland tropics, so the increased mineral and organic sediment load following harvesting should drop more quickly in the tropics than in the temperate zone.

Two practices associated with forest utilization are undoubtedly most closely related to impact on water quality: the type of extraction technique used (tractor skidding, high-lead, etc.), and road and skid trail layout. Much logging of tropical forests is purely exploitative, and it is not uncommon to see streambeds used as skid trails and dry-season streambed crossings made by earth and log fills which are left after logging to be washed out by wet season rains. Such practices are clearly amenable to engineering solutions, and an increase in forest utilization intensity, if done conscientiously, should not greatly increase water quality problems.

The impact of increased intensity of tropical forest utilization on water yields and water quality is likely to be of increasing concern, especially in light of population increases and rising demands for both wood and water. Changes in water yield and decreases in water quality can be expected to accompany increased intensity of forest utilization and may place restrictions on the size of forested blocks subjected to utilization at a given time.

IMPACTS ON VEGETATION

It is probably fair to characterize most of the logging going on today in the humid tropics as more of a mining operation than an exercise in renewable resource utilization and management. The ability to use more species should make it possible to turn this situation around. Less wood will be lost due to logging damage, and current silvicultural practices directed against currently unusable species (e.g., girdling and poisoning, discussed by Meijer 1968) may be obviated.

Residual Stand

Little attention is paid to the residual vegetation during logging, with the result that much of it is irreparably damaged and left to rot. Usually about 50 percent of the residual stand is damaged (e.g., see Burgess 1971). Most damage results from extraction rather than felling (Redhead 1960), but felling damage increases with both the size of the individual trees being harvested and the volume of timber removed per unit area (Nicholson 1958, Mensah 1966).

Extraction not only damages residual vegetation but also disturbs the forest soil. Typically about one-third of the logged area suffers direct soil disturbance in the form of extraction paths, secondary haul roads, skid trails, and yarding lanes. These are the areas most subject to soil erosion. They are revegetated more slowly and by less desirable species than those which colonize undisturbed soils.

Because current utilization standards are so high, a tremendous amount of wood is lost as a result of the way the tropical forest resource is exploited. One benefit that should accrue from technology which enables us to use many more species is that the wood which is currently wasted will be utilized. This, in turn, has two major implications. First, wood demands may be met from less area, thus possibly leaving more land for undisturbed reserves. Second, the number of silvicultural options available to foresters will increase greatly; to be able to ignore floristics would be a boon to tropical silviculture.

In spite of these two great potential benefits, we must recognize that all-species utilization could be a very damaging tool if abused. Its adoption as a means of simply harvesting everything in sight will be a temptation for short-sighted exploiters. Even if used wisely, its adoption is likely to lead to the demise of those species which are not currently used, but which hang on and reproduce in logged stands. Many of these are shade-adapted species with limited ranges and limited capacity for seed dispersal. If the conditions which enable them to reproduce are modified through forest management, then such species are likely to be eliminated if utilized.

Genetic Resources

In the last few years numerous tropical scientists (e.g., Gómez-Pompa et al. 1972, Richards 1973, several sections in the volume edited by Farnworth and Golley 1974, Whitmore 1975, Myers 1976) have called attention to the potential loss and/or degradation of genetic material due to destruction of tropical forests. Gene pool degradation can be broken down into two types. First, there is the "genetic erosion" which occurs when trees with sound boles and good form are selectively harvested in preference to individuals with undesirable characteristics which are left to provide the seed for the next crop. Second, and perhaps more serious a problem than the potential for genetic erosion, is the possibility that entire species, many unknown to science, can be lost forever by mismanagement of the forest resource. The material subject to loss consists not only of the species harvested (these, in fact, are probably the least likely to disappear), but the myriad of other species found in diverse tropical forests.

There is no doubt that an increase in our knowledge of the characteristics of tropical forest species will lead to discovery of products of benefit to people. For example, Myers (1976), in a recent commentary on the possible loss of tropical species, said:

> "Despite the limited knowledge about genetic reservoirs, it seems a statistifal certainty that tropical forests contain source materials for many pesticides, medicines, contraceptive and abortifacient agents, potential foods, beverages, and industrial products. Of particular value for human purposes are the specialized genetic characteristics of many localized species--yet these attributes are associated in many instances with restricted range, precisely the factor that makes them vulnerable to destruction."

The loss of species is potentially an unusually severe problem in tropical forests for two reasons. First, the tropical forests contain so many species that loss of a tropical forest is likely to result in the loss of more species than would be the case if an equal area of temperate forest were lost. Second, species are packed into tropical environments and the resources for plant growth are so subdivided that the forests are much less uniform in space than are temperate forests. Thus, removal of a patch of forest is not only likely to destroy the individuals living there, but that combination of species is much less likely to reoccur in space than would be the case in temperate forests.

There is no reason why the ability to use more species must necessarily lead to increased loss of genetic information from tropical forests. We must, however, recognize that the potential for abuse exists, and that the new technology must be employed with proper safeguards to prevent such abuse.

IMPACTS ON ANIMALS

Intensive utilization of tropical forests is certain to have a significant impact on animal life, yet this important aspect of tropical forest ecology has been almost completely neglected. Just as the potentially useful properties of many of the plants of tropical forests are unknown, it is likely that the animals are a potentially useful resource as well. They certainly play important roles in pollination, dispersal, nutrient cycling, and checking of pest populations; they undoubtedly have a great untapped potential as biological control agents, food resources (domesticated and wild), and recreation. In addition to these direct benefits to humans there is the broad moral issue of the possible elimination of entire species through irresponsible human actions.

Habitat Changes

Loss of habitat is clearly the greatest threat to tropical wildlife (Rabor 1968, Kingston 1971, Daugherty 1972), and much more of it results from agricultural expansion (frequently shifting cultivation followed by conversion to pasture) than from logging. Many animals, in fact, are tolerant of a certain amount of habitat disturbance; some--highly specialized mature ecosystem dwellers--however, are completely intolerant of any disturbance, while still others--the "weedy" colonists of the animal kingdom--thrive in successional vegetation. Forest utilization thus involves shifts in species composition and the limited available evidence indicates that the magnitude of the induced shifts is approximately proportional to the degree to which the habitat is disrupted through utilization.

Arboreal primates are an important, conspicuous group which might be greatly affected by intensive forest utilization. Many of the problems encountered by arboreal primates after logging involve disruption of their aerial pathways. Many species will not descend to the ground except under emergency situations, so opening of the forest canopy excludes them from habitat which might otherwise have all of the resources necessary for their support. Extensive clearcutting, of course, eliminates all arboreal mammals, but second-growth vegetation supports various species, although different ones than those characteristic of mature forest (Wilson and Wilson 1975). Some endangered species, such as the orangutan and the proboscis monkey of Southeast Asia, are found only in undisturbed forest.

In addition to the aerial pathways required by arboreal primates, many other animals found in tropical forests have specific requirements which are incompatible with most intensive forest management. For example, hornbills of Southeast Asia require large "overmature" trees for nesting sites (McClure 1968) and the endangered Puerto Rican parrot nests only in large, hollow specimens of a single tree species (Wadsworth 1975). Other animal species are specialized with regard to their nesting and feeding habits, and intensive forest management might affect them adversely.

Preserves

There is no doubt that extensive areas of natural, unmanaged forest will have to be set aside if the rich tropical fauna is to be preserved. Although such preserve maintenance is not normally thought of as an absolute requirement of forest utilization, there is considerable precedent for such involvement in both public and private forestry in developed temperate zone countries. Such conservation activities would seem to be especially important in the case of multinational corporations which frequently use the developing tropical nations as a raw material source, to be processed into final products in places other than the country of origin. They should be prepared to meet their obligation to preserve a portion of the natural ecosystems which feed them.

One of the main problems associated with the establishment and maintenance of such preserves is the large areas of land required. The habitat requirements of many tropical birds and mammals are quite large. The orangutan, for example, requires an average of 1.5 sq. miles (3.8 sq. km) of forest per individual (Harrison 1968). Large carnivores, including forest cats, and grazers and browsers, such as elephants, gaur, and tapirs, undoubtedly require large tracts also. Furthermore, agriculture and forest clearings act as geographic barriers to many tropical forest-dwelling animals, so the forested preserves must, to be effective, consist of large, unbroken tracts. The area required to sustain population sizes of 5000 individuals (an estimated lower limit of population size to maintain most vertebrates) ranges from about 250 sq. km to 10,000 sq. km, depending on the species involved (Medway and Wells 1971). To assume that developing tropical nations will be willing and able to set aside, protect, and maintain such extensive reserves without outside assistance is probably unrealistic.

Increased intensity of forest management could result in greater productivity from less land. This coupled with social consciousness and action on the part of public and private forestry agencies, should make possible the preservation of adequate tracts of natural forest in most tropical areas, provided that such steps are taken in the very near future.

CONCLUSIONS

Technological advances which permit the utilization of a greater suite of species from tropical forests constitute a powerful tool for resource managers. Most importantly, such advances should greatly increase the number of ecologically sound options open to silviculturists and should permit the development of techniques which would not have been possible previously, when relatively few species could be utilized. Like many potent technological advances, however, the ability to use any tree in the forest could result in ecological disaster if abused. It must be developed only as a means of improving our ability to manage tropical forests as a renewable resource, not as a technique which would enable exploiters to mine all of the wood from the humid tropics, leaving an ecologically devastated landscape in their wake.

Possible Implementation

One management practice which certainly warrants testing in the field would be harvesting all stems of merchantable size from narrow bands, then following up with (preferably) natural and/or artificial regeneration. Most selective logging schemes leave more of the forest intact, but a great deal of loss occurs because of felling and extraction. This is even more true in the tropics than in temperate forests because of the large size of the tree crowns and the presence of lianas.

If harvested strips were kept very narrow (say, 100 meters), many of the possible disadvantages of forest clearcutting would be avoided. Animals would still have access to a large forest habitat (albeit pocked with strips in different stages of regrowth), recolonization of plants from the surrounding forest would be enhanced, impacts on water yields and quality would be minimized, and soil micro-organism populations would probably be quickly reestablished after logging.

The major objections to harvesting in narrow strips are likely to be economic and engineering. It is evident, however, that most of the damage from current methods of harvesting is due to improper felling, skidding, and hauling. If we are serious about managing tropical forests as renewable resources, then current practices will have to change anyway, and narrow clear-cut strips may be a good place to start.

Possible Benefits

There are many possible benefits which might be derived from an increase in our ability to utilize a broader range of tropical woods. a few examples are listed below.

1. Wood needs can be met from less land, leaving more land for the undisturbed preserves necessary for the survival of many plants and animals.

2. It will permit the maintenance of a forest mosaic, consisting of a diverse mixture of high-net productivity ecosystems. Just as within-ecosystem diversity is a desirable attribute in many respects, among-ecosystem diversity is a landscape feature which permits most species to survive, while prohibiting dominance by a few.

3. The prospects for successfully combining food production with forestry would be enhanced if it were possible to more fully utilize the species present. If all species were harvested, it might be possible to follow up with a brief cycle of crop production prior to forest regeneration. Under most current land use schemes shifting agriculture is incompatible with forestry, and incomplete forest harvesting means that the land is unsuitable for any other than the most destructive kinds of short-term agricultural use. There is considerable precedent for such combined (agricultural and forestry) land use in the tropics with the taungya regeneration scheme, but this is most often used only as a means of artificially regenerating forest land and not as a means of permanently combining food and fiber production.

4. Wastage of wood will be reduced by permitting utilization of material damaged in logging and those species which currently are often girdled and/or poisoned because they cannot be used.

5. It will be possible to regenerate and manage the whole forest ecosystem, including most of its component species. Under current forest management practices, in which relatively few species are utilized, the forest is continually degraded. Sometimes desirable species decrease in abundance because they are selectively harvested. Other times undesirable species decrease because they are selected against in management practices

such as post-harvest timber stand improvement. The ability to use all species should make it possible for foresters to perpetuate the entire forest complex, without preferentially eliminating any particular group of species except those which require vast, undisturbed tracts of mature forest for their survival and regeneration.

Potential Problems

In addition to the positive results likely to be realized by an increase in our ability to use run-of-the-woods tropical species mixes, several problem areas should receive attention before such utilization becomes widely practiced. Many of the potential environmental problems were discussed in previous sections and some of these are repeated in the brief list which follows. This list is neither detailed nor all-inclusive. Rather, it suggests broad areas where problems might be anticipated and which require careful consideration before the new technology is implemented.

1. Nutrient depletion may result if large amounts of wood are removed. Solution of this possible problem may require special practices such as debarking at the site of felling and perhaps even forest fertilization.

2. Some species may be lost entirely and the populations of others might be drastically upset if increased utilization intensity is practiced. Population imbalances can easily lead to intolerable levels of pest buildups and impacts on species otherwise thought to be relatively unaffected by the management practices. To maintain populations of all tropical species will require a network of large tracts of undisturbed ecosystems, and foresters will have to work closely with conservationists in establishing and maintaining these preserves.

3. Water resources, including water yield and water quality, are closely linked to land use, and watershed management practices are sure to have an effect downstream. There is no reason to believe that forest management and maintenance of water resources are incompatible (forestry is, in fact, probably the best form of land use from the point of view of watershed management), yet there is little precedence for such considerations in the tropics. The solutions to potential water problems are probably currently available; implementation, however, is lacking.

4. Soil micro-organisms, which play a crucial role in the physical-chemical properties of tropical soils, are likely to be affected by intensive forest management. Their recolonization rates and the impact of their loss are unknown, but they are certain to be important in the long-term maintenance of forest site quality.

5. The quality of the second-growth forest, and its suitability for both economic use and as a habitat capable of maintaining the diversity of tropical life, is an important unknown. In the worse possible case, the regrowth may be an unusable tangle of weedy species, in which case the increased utilization capabilities will have amounted to nothing more than a hastening of our mining of the tropical forests. There is no hard

evidence that this might be the case, but it is a possibility which should be considered before increased utilization intensity is introduced on the ground.

Resource of the Future

Increased intensity of tropical forest utilization is really concerned with two different resources. The first of these is the existing mature forests and all of the species found there. Many of these have high-density wood; they reproduce in mature ecosystems and are unlikely to reappear outside of forest preserves under any sort of forest management program. Currently, many of these species are unusable and are destroyed during or after logging. Improved wood utilization technology will immediately avoid much of this waste.

The second resource of concern is the secondary forests which will be available for utilization after the primary forest has been harvested. What will the nature of this resource be? Should it be a natural species mix or should we strive for more uniform stands, perhaps with the aid of artificial regeneration? Will it be compatible with the long-term maintenance of the quality? Is it, in fact, a high-quality renewable resource which can be managed for permanent yield? Tropical foresters have long debated and studied such questions, but the utilization technology required to put them to the test has not previously been readily available. Along with the potential for increasing our ability to utilize available species mixtures we should simultaneously be concerned with the nature of the forest resource that will be with us in the future.

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SILVICULTURE IN PLANTATION DEVELOPMENT

By

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SUMMARY

Jari Florestal e Agropecuária is a private company operating on owned lands in Brazil. Mixed tropical hardwood forests are being used for local consumption then converted to plantations of melina (*Gmelina arborea*) or pine (*Pinus caribaea* var. *hondurensis*). Silviculture is intensive, the objective being production of pulpwood, sawlogs, and veneer bolts.

No serious problems have been encountered to date.

SILVICULTURE IN PLANTATION DEVELOPMENT

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HISTORY

Jari Florestal e Agropecuária is a Brazilian company, owned by a North American shipping firm. A decision was made in the mid-50s, in anticipation of a projected world fiber shortage in the mid-80s, to establish a large forest plantation to help meet that need.

After several years of observation, it was decided to concentrate on melina (Gmelina arborea L.) as a fast growing species with a good general purpose wood and a history of successful establishment over a wide geographic range.

An extended search was made for a location with (1) an apparently stable government which was interested in investment by a foreign organization, (2) a large uninterrupted block of land, (3) a moist or wet tropical climate, and (4) a deepwater port.

The area finally selected was approximately 1 million hectares on both sides of the Rio Jari, the last major tributary on the north side of the Rio Amazonas, latitude 0° 50' south and longitude 53° west.

Annual rainfall is about 2,500 mm. October and November are normally the driest months; a week without scattered showers is unusual, but an individual station may report more than 30 days without rain during an exceptionally dry year.

April and May are the wettest months, averaging 23-27 days with rain, but rainfall exceeds evapotranspiration virtually every week from mid-January to mid-June.

Extreme temperatures vary from 18° to 35° C.

Elevations are 5-500 m. Soils vary tremendously from deep organic along the Amazon through dune sand alluvium to very deep residual kaolinite clays. Most are latosols, highly leached, deficient in phosphorus and calcium/magnesium, and with high aluminum and iron oxides (table 1).

POLICY

The original policy, as implied above, was to produce wood fiber on a commercial basis.

TABLE 1.--SOIL DATA FOR THE THREE PRINCIPAL SOILS IN JARI PLANTATIONS(1)

DATA	TERRA RÔXA	CARACURÚ	PLANALTO
pH	6.3	4.1	4.6
Organic Matter	4.87%	1.44%	5.62%
P	4.80 ppm	3.40 ppm	5.04 ppm
K	57.12 "	21.00 "	56.38 "
Ca	1174.00 "	34.96 "	135.96 "
Mg	192.00 "	11.64 "	37.23 "
Al	0.68 "	53.38 "	154.08 "
Clay	32%	5%	43%
Silt	33%	1%	33%
Sand	36%	95%	24%

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(1) Each value shown is the mean of 10 samples taken in the A horizon.

This was quickly expanded to include production of commercially viable forest products. From the beginning this has included wood from the native forest to satisfy our own needs, currently 30 species or species groups for lumber and crossties (table 2). Unfortunately, we have virtually no volumes in species accepted on the international market. We have begun attempting to develop internal and export markets for some of the more promising species we do have, with results that are adequate for this stage in our development.

We have also harvested some native forest crops, notably Brazil nuts.

Power generation for our first pulpmill, scheduled to begin operation later this year, will be by woodfueled steam turbines. Practically all of the native species can be utilized in the boilers.

A number of other policies more or less emerged as development proceeded. Perhaps this is the first time they have been listed. Today's objectives:

(1) Produce commercially viable forest products.

(2) Comply with the laws of Brazil.

(3) Use Brazilian personnel, materials, and equipment except for specialized needs not currently available within the country.

(4) Keep in the forefront in social services and real wages, without unrealistic leapfrogging outside the local culture.

(5) Develop personnel; don't pirate them from elsewhere.

(6) Use labor intensively, mechanizing only the jobs for which labor (a) is simply not available or (b) productivity is too low to justify a living wage.

(7) Do not unnecessarily damage or destroy our soils or water.

(8) As a corollary to (7), establish bench marks for monitoring environmental change.

PLANTATION MANAGEMENT

Site Selection

In selecting sites for future plantations, the first step is to eliminate, by aerial photo interpretation, very rough and broken terrain, marshes, and swamps. At present we are also eliminating savana and xerophytic forest although we have research plots in both. Indications are that they are, in fact, virtually the same except for historical treatment, and that both are potentially adequate sites with proper management.

TABLE 2.--NATIVE SPECIES AND SPECIES GROUPS USED BY JARI

USAGE(1)	SCIENTIFIC NAME	COMMON NAME
R	*Anacardium giganteum* Engl.	Caju açu
GR	*Bagassa guianensis* Aubl.	Tatajuba
TGR	*Bertholletia excelsa* Ducke	Castanha do Pará
TG	*Carapa guianensis* Aubl.	Andiroba
G	*Caryocar villosum* Pers.	Piquiá
F	*Cedrela odorata* L.	Cedro
FT	*Cedrelinga cataneaformis* Ducke	Cedrorana
R	*Ceiba pentandra* Gaertn.	Sumahuma
GR	*Couratari pulchra* Sand.	Tauarí
T	*Hymenaea courbaril* L.	Jutaí
GR	*Dinizia excelsa* Ducke	Angelim pedra
FT	*Diplotropis porpourea*	Sucupira
FT	*Euxylophora paraensis* Hub.	Pau amarelo
G	*Goupia glabra* Aubl.	Cupiuba
F	*Hymenolobium excelsum* Ducke	Angelim rajado
FT	*H. petraeum* Ducke	Angelim vermelho
R	*Inga* spp.	Ingá
TGR	*Lecythis paraensis* Ducke	Sapucaia
P	*Manilkara amazonica* Chev.	Maparajuba
P	*M. huberi* Standl.	Maçaranduba
R	*Parkia pendula* Bth.	Visgueiro
FT	*Peltogyne lecointei* Ducke	Pau roxo
G	*Protium* spp.	Breu
G	*Saccoglottis guianensis* Aubl.	Uchirana
G	*S. uchi* Hub.	Uchi
T	*Simaruba amara* Aubl.	Marupa
FR	*Symphonia globulifera* L.	Anani
R	*Virola melinoni*	Ucuuba preta
TGR	*Vochysia* spp.	Quaruba
F	*Vouacapoua americana* Aubl.	Acapu

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(1) F = Furniture; T = Interior trim; G = General construction
R = Rough construction, forms, P = Piling and crossties

A crew then enters an apparently usable area; lays out a grid of survey lines; makes an extensive inventory of native species (table 3) and soils by texture (fig. 1); and recommends whether the area shall be converted and what species to plant.

Logging crews then remove wood for company needs.

Land Clearing

After logging for our needs, the forest is left for 1 to 3 years to re-establish a complete vegetative cover.

Originally landclearing was then done using heavy machinery. This had three major disadvantages: (1) disturbance of the already skimpy topsoil, (2) compaction of soil, and (3) high costs.

Therefore, heavy equipment was replaced by laborers with axes and chainsaws. This eliminated the first two problems and alleviated the third. This system continues to date.

Silviculture

Species

Although the original decision was to plant melina, it quickly became obvious much of our land is not suitable for melina, and in 1973 *Pinus caribaea* var. *hondurensis* Barr. & Golf. was adopted for sandy soils. A substantial number of other species and varieties (table 4) are under trial, but none are yet demonstrably superior to melina and *P. Caribaea*.

Seed Procurement

Pine seed is purchased. Past purchases have been directly or indirectly from Central America; Beliz, Poptún, and Nicaragua sources have all done well. Although we do produce some viable seed, our trees (maximum age is 9 years) do not provide appreciable quantities of seed as yet.

We recently began buying seed from selected trees in Australia. We also just began establishment of our first seed orchard.

Initially our melina seed all came from Africa. The direct sources include Nigeria, Sierra Leon, Malawi, Ivory Coast, Gambia, Zambia, and Uganda, but the original Asian sources are all unknown. We have made a number of fruitless attempts to obtain seed of selected Asian provenances.

Currently all melina seed used is collected from our own plantations. About 1% is from seed orchards; the rest is from seed production areas, rogued of 75-88% of the original stems.

TABLE 3.--SAMPLE INVENTORY OF NATIVE FOREST, VARADOR DO PARÁ COMMERCIAL VOLUMES, m^3/ha

DIAMETER IN CM	20-39	40-59	60-79	80-99	100-119	120-139	140-159	160-179	180-199	200+	All Sizes
Scientific Name											
Bagassa guianensis	0.18	1.71	2.22								4.1
Cedrela odorata				0.89							0.9
Cedrelinga catanaeformis					1.13						1.1
Dinizia excelsa	0.41	0.37	0.89	1.97	1.03		1.37				6.0
Diplotropis porpourea	0.16		1.18	0.46							1.8
Inga spp.	1.25	1.32	1.06								3.6
Peltogyne lecointei		0.10									0.1
Protium spp.	4.05	1.32	0.38								5.8
Saccoglottis guianensis	0.47	0.60	0.44								1.5
Simaruba amara	0.70										0.7
Vochysia spp.	1.13	1.23	3.07	0.53							6.0
SUBTOTAL, species now utilized	8.35	6.69	9.24	3.35	2.16		1.37				31.8
Others (119 species)	37.15	53.51	40.96	24.75	13.74	4.50	4.03		2.80	1.50	182.8
TOTAL, all species	45.50	60.20	50.20	28.60	15.90	4.50	5.40		2.80	1.50	214.6

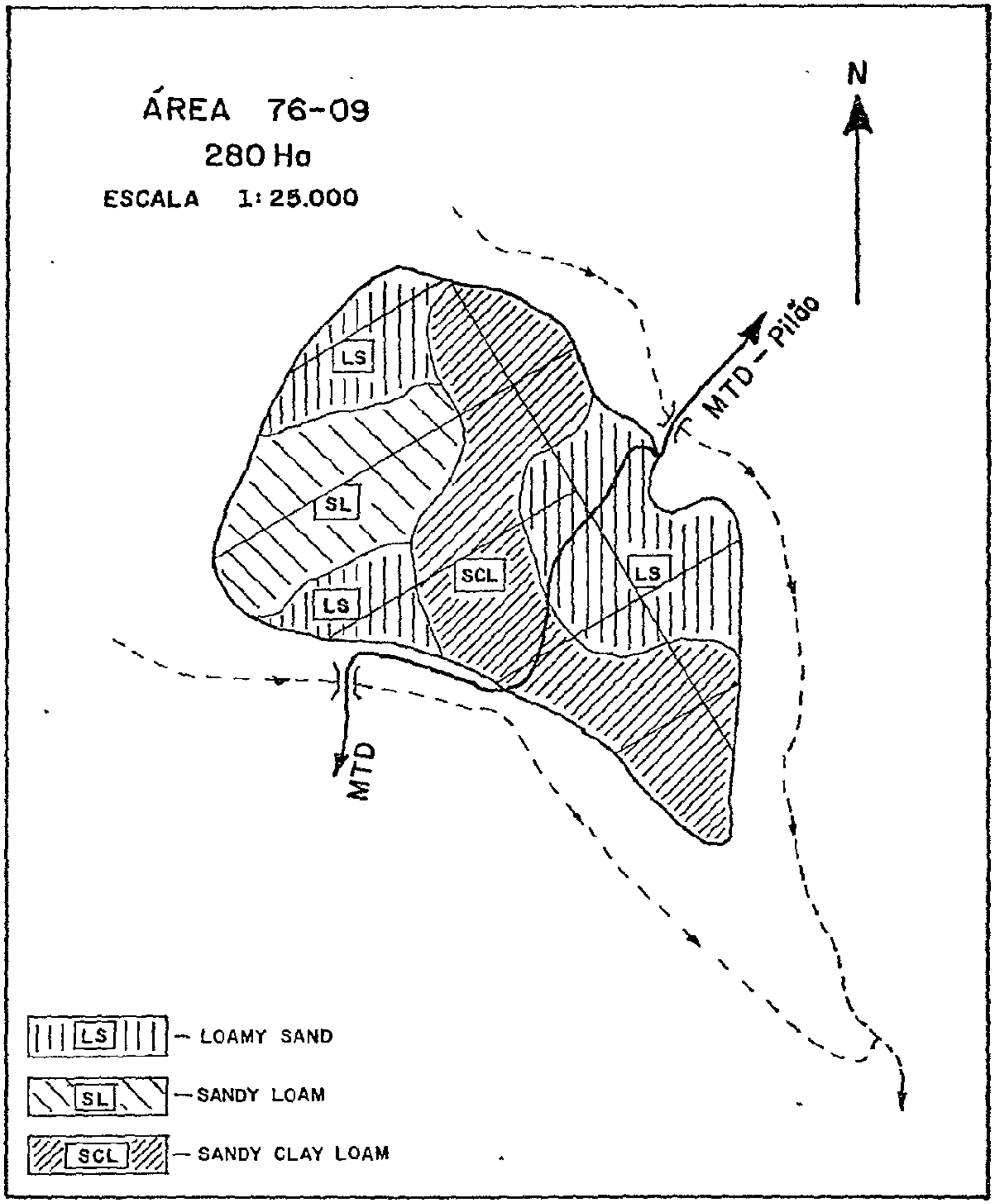

Figure 1.--Sample soils classification by topsoil texture, Jari.

TABLE 4.--SPECIES TRIED OR NOW UNDER TRIAL AT JARI

Anacardium giganteum
Anthocephalus chinensis
Araucaria angustifolia
Bertholletia excelsa
Cinamomus zeylanicus
Coumarouna magnifica
Eucalyptus alba
E. deglupta
E. grandis
E. robusta
E. saligna
Gmelina arborea
Manilkara huberi
Parkia gigantocarpa
Pinus elliotti var. elliotti
P. elliotti var. densa
P. insularis
P. merkusi
P. patula
P. pseudostrobus
P. occarpa
P. taeda
Schizolobium parahybum
Taxodium distichum
Tectona grandis
Vatairea guianesis
Virola melinoni
Vouacapoua americana

Vegetative propagation of melina is relatively easy, and we are also planting cuttings of selected clones, slightly less than 1% of annual plantings.

Nursery

One central nursery is used.

a. Pine seedlings are grown about 6 months in a container. Until recently we used a "milk carton" of plastic coated cardboard 4x4x13 cm which was removed at the moment of planting. At present, we are doing commercial trials of peat wedges, paper tubes, bareroot, and plastic sacks; the list is in descending order of current evaluation. All can be used successfully. In all cases, seedlings are inoculated with soil from under healthy pines at 4-5 weeks after germination. Weeding and pest control are carried out as necessary. Complete liquid fertilizer is applied to attain seedlings with diameter at the root collar 4 mm and with secondary needles. Height is not critical; all seedlings are top pruned to 17 cm before outplanting.

b. Melina seedlings are grown in beds much like any temperate zone hardwood. The greatest problem is simply that we are unable to grow more than 17-20 seedlings $\geq$ 1 cm diameter at the root collar per m^2.

   Melina seedlings are taken to the field and planted as stumps. That is, tops are pruned back to 40 cm 2-10 days before lifting, roots are undercut, then the topped seedling is taken to the packing shed.

   There, lateral roots are pruned close, the terminal root is pruned to 13 cm, the stem is pruned to 2-4 cm long (stem cuttings with minimum diameter $\geq$ 2 cm are planted as cuttings), the stumps are put with moist sawdust in a burlap sack, and moistened sacks are stored in the shade. Time from lifting to planting must not exceed 72 hours; less than 48 hours is normal.

Planting

Planting is begun as soon as the ground is soaked at the beginning of the rainy season. All planting is manual at present, in holes dug with a light mattock.

Distance between rows is controlled by a 100 m rope with varicolored plastic flagging at correct intervals.

Spacing within rows is paced, with frequent checking by crew foremen.

Normal spacing of pine is 4 m between rows and 2.25 m between trees in a row (1,111 trees/ha).

Normal melina spacing is 3.5 x 3.5 m (816 trees/ha), with wider spacing on 35-100% slopes and on poor sites.

Cleaning

Competing weeds and brush are controlled as necessary and possible.

(1) Bunch grass is ignored; it appears to have no measurable effect.

(2) Sod grass is rare; it is cut only if threatening to engulf a seedling.

(3) Forbs are cut if overtopping a seedling.

(4) Vines are pulled if possible, cut back if not.

(5) Woody brush and young trees are cut back when 1-2 times the height of the seedling.

On the average about four cleanings are necessary. Where bunch grass is planted (most pine sites), only one or two cleanings are necessary.

Sprout Removal

Melina has a tendency toward multiple sprouts in the early years. Late in the first year after planting, excess sprouts are removed.

Pruning

Pine and melina on the best sites are pruned to increase production of clear wood. First pruning is to 3 m clear length when top height reaches 6 m. Second pruning is to 5.5 m when top height reaches 11 m.

Third pruning, still experimental, is to 8 m when top height is 16 m.

Thinning

At present, thinning intervals are based on basal area. When data are available, intervals will be based on net value of the timber.

Second and subsequent thinnings never occur less than 2 years after the preceding one.

a. Pine is first thinned when CAI (current annual increment) $\leq$ MAI (mean annual increment). Two additional thinnings are carried out when CAI $\leq$ PAI (periodic annual increment) since last thinning.

b. Where site index (top height at age 10) is less than 25 m, melina is normally managed for pulpwood without thinnings.

Where site index $\geq$ 25 m, first thinning is when CAI $\leq$ MAI or when LCR (live crown ratio) $\leq$ 33%, whichever is earlier. The two subsequent thinnings are made when CAI $\leq$ PAI or when LCR $\leq$ 33%, whichever is earlier.

Clearcut

Within the limitations imposed by mill requirements and long-term product flow, the aim is to end a rotation, whether for fiber or solid wood, when CAI $\leq$ MAI in dollars.

We are still in our first rotation on all sites, but predicted clearcut ages are 6 years for pulpwood melina, 10 years for solid-wood melina, and 16 years for pine.

Research and Development

The necessity for our own research and development was recognized very early and they have grown with the company. Emphasis at present is indicated in table 5.

Virtually all our research is "applied" in the figurative sense, and certainly in the literal sense new information is applied as rapidly as an answer is forthcoming.

We have 12 research professionals, 6 of them foreigners with advanced degrees, the other 6 are Brazilians with bachelor degree equivalents.

Protection

We have had enough incidence of insects, diseases, and fires to keep us wary, but not enough loss to cause real concern as yet.

Harvester ants (*Atta* spp.) require constant battle and are a continuous cost. We use Mirex bait in the dry season and poisonous gas under pressure during the wet season.

A number of defoliators, almost all of them larvae of Lepidoptera, have had local outbreaks on the melina, but natural biological controls have functioned perfectly well so far. Termites have entered heartwood of a few melina, very few. Lightning kills a few clumps of trees each year, but has set no fires.

Needleblight fungus attacks 3-4 year old pine near the end of the rainy season each year, but has subsided during the dry season, so far.

Both species are quite resistant to fire. 1976 was the driest year in 41 years, and 3,500 ha burned over. However, only 12 ha of pine were killed off, and 850 ha of melina had to be coppiced because of damage to the existing top or bole. All fires are people-caused, overwhelmingly by carelessness or indifference.

In a normal year, less than 100 ha are burned, and less than 10 ha are killed.

TABLE 5.-- JARI RESEARCH AND DEVELOPMENT EFFORT

FIELD OF STUDY	PERCENT OF EFFORT
Genetics and Tree Improvement	22
Mensuration	21
Protection	13
Economics	12
Regeneration	10
Silviculture	10
Soils	10
Wood Properties	2

Multiple Cropping

1. Since 1975, we have been sowing bunch grasses in our pine plantations, which is why rows are 4 m apart. As soon as possible after planting the pine, we sow grass seed in a double row down the middle, 1.5 m from the nearest pine. Cattle are put on the grass, at 1 steer/2 ha, after 6-7 months. At about 12-15 months, cattle numbers can be doubled to 1 steer/ha.

No grazing is done in melina plantations.

2. Indian corn (*Zea mays* L.) and manioc (*Manihot utilissima* Pohl.) are grown annually in new plantings of either species, but principally melina. Most production goes to company swine.

3. Small food plots, mostly watermelon, squash, and papaya, are planted every year by individual workers, but the gross area is small because new clearings are remote from permanent population concentrations. No rental is charged, but we are very rigid about damage to the trees.

ADMINISTRATION

The managers of Forest Management and of Harvesting report to the Assistant Director for Forestry.

Plantation Management

The total plantation area is divided into 20,000 ha blocks, with a graduate forester in charge of each. Organization within the block is shown in figure 2.

A Forestry village is being built in each block to house about 750 workers with their families, about 3,500-4,000 people. Besides housing, the village includes a school, infirmary, general store, water system, power plant, and light vehicle maintenance shop. A doctor, nurses, schoolteachers, and other service personnel, besides those in forest management and harvesting, live in the village where they work.

Housing is provided by the company at nominal expense.

Infrastructure

Jari is about 300 miles from the nearest city, Belém, and is not served by roads, railroad, or commercial airline.

Obviously, the company must make available virtually everything except national defense.

Problems

The problems for any such organization are mostly inherent in the situation.

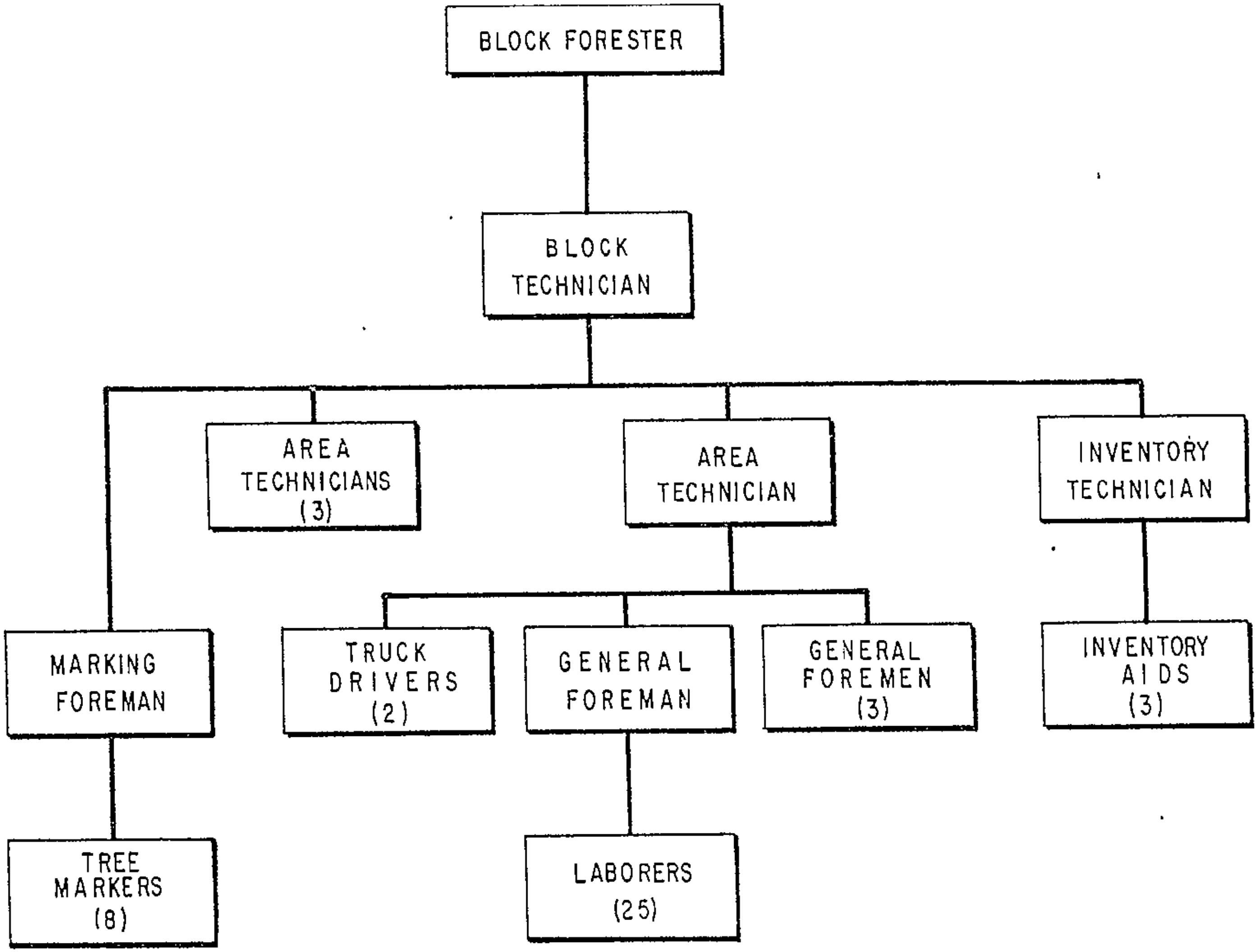

Figure 2.--Organization chart for 20,000 ha block, Jari.

1. Government. As a large (for the region) foreign corporation with an appreciable number of foreign employees, we are conspicuous, and the various cultures occasionally clash. However, the overwhelming percentage of Brazilian officials are actively helpful as well as cooperative. Import restrictions are a constant hindrance, but the same restrictions apply to all companies operating in Brazil, and they have logical bases.

2. Recruitment. Young, inexperienced personnel are readily available without paying premium salaries. Very competent, seasoned people are much harder to find. However, we live where there is no traffic, air pollution, water pollution, noise pollution, organized crime, racial or sexist oppression, TV commercials, saloons, or drug pushers. And that isn't all bad. We look for those who like it this way, and who are willing to give up certain other things.

3. Regulation/Utilization. Technically, the basic problem is we grow all our own wood and utilize all our own harvest. Thus, plantation yields and manufacturing facilities need to match at every stage of development. The ramifications of this need greatly exceed the scope of this paper and will not be treated further here.

UTILIZATION

A 750 TPD bleached kraft pulp mill was constructed in Japan, for installation at our port of Munguba.

Species characteristics permit, and we have plans of varying firmness for, manufacturing newsprint, veneer, plywood, lumber, and coated paper.

Obviously, all future developments, particularly the timing, depend on world markets.

PRACTICES AND EXPERIENCE OF NASIPIT LUMBER COMPANY, INC. AND AFFILIATES IN ITS NATURAL AND ARTIFICIAL REGENERATION OF FOREST AND PLANTATIONS

By

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ABSTRACT

This is a report on the practices and experience of Nasipit Lumber Company, Inc. and Affiliates (NASIPIT for short) in its dipterocarp forest and industrial tree plantations inside areas covered by timber license agreements granted by the Philippine Government. The Nasipit-Anakan forest reserve is managed under Forest Management Plans aimed at attaining sustained yield of sawtimber, pulpwood, minor forest products and other beneficial services.

During the period from 1946 to 1955, the harvesting of the virgin timber was on a 50 cm. minimum diameter limit system, leaving a few big sized trees uncut. Some of these clear-felled areas were preserved and through the years developed into dense and vigorous second growth dipterocarp forest. These stands are being improved by cleaning and thinning. The results are very encouraging.

NASIPIT also pioneered in the practice of "Selective Logging", the Philippine version of the selection system. In the NASIPIT concession today, there are 43,380 hectares of residual forest. Analysis of a 13-year-old residual forest show encouraging results--in regeneration and in growth.

As a complementary move to forest development and expanding wood utilization program, since 1955, NASIPIT has engaged in intensive tree plantation development. Today, its industrial plantations of Albizia falcataria, Gmelina arborea, Tectona grandis, Pinus Spp., dipterocarp species, Eucalyptus spp., Ochroma pyramidale, Aleuretes Mullocana and other species are growing very well. The paper briefly discusses the applied silvicultural practices as it relates to natural regeneration, nursery and plantation operations.

PRACTICES AND EXPERIENCE OF NASIPIT LUMBER COMPANY, INC. AND AFFILIATES IN ITS NATURAL AND ARTIFICIAL REGENERATION OF FOREST AND PLANTATIONS

By

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INTRODUCTION

Nasipit Lumber Company, Inc. (NASIPIT for short) was organized in 1946 to engage in logging and wood processing inside an area covered by a timber license agreement granted by the Philippine Government. Through the years Nasipit Lumber Company and it affiliates have established an integrated wood processing complex of sawmills, hardboard factories, veneer and plywood plants, wood variety shops, finishing plants, dry kilns, wood preservation, gang nail & truss assembly, and sawdust briquette plants.

The forest concession of Nasipit Lumber Company and its affiliates, as of January 1, 1978, covers a forest reserve of 155,000 hectares consisting of 62,260 ha. of operable virgin forest, 43,380 ha. of logged-over areas, 10,142 ha. of industrial tree plantations, and 42,218 ha. of brushlands, mossy forest, settlements and cultivations, and other vegetative covers. Under its timber license agreements, a total regular annual allowable cut of 361,900 m^3 is granted. The average annual cutting area is 1,657 ha. producing a timber volume of 327,770 m^3.

The concession is located in the provinces of Agusan, Bukidnon and Misamis Oriental in the Island of Mindanao, Philippines. It lies at latitude 8°45' and longitude 125°20'. The terrain is 10% gentle to moderate, 70% rough and 20% very rough and precipitous. Elevation is from 100 to 1,500 m above sea level. The soil is generally a deep clay loam with pH values of 5 to 6.8. The average annual rainfall is 188 in. evenly distributed throughout the year.

The Nasipit-Anakan forest reserve is being managed under Government-approved Forest Management Plans which embody 5-year plans for logging the virgin forest, yield regulation, enrichment plantings, and reforestation, utilization, forest protection, forest research, tree plantation development, timber stand improvement, salvaging of logging residues, and related operations. The Plan is oriented on the concept of multiple-use forest management--aimed to attain sustained yield of sawtimber, pulpwood, water supply, minor forest products and other beneficial services. The forest reserve is managed on a tentative 35-year cutting cycle which started in 1956.

To enable the Company to obtain information on growth, species composition, density, structure, and other related data for forest management planning, it has a cooperative project with the Bureau of Forest Development and Forest Research Institute on the establishment of many of them have poorly developed crowns and trunks. The size class and volume distribution per hectare of dipterocarps over a sample area of 8.6 ha. (86 one-tenth ha. plots) are as follows:

DBH Class (cm.)	Trees per hectare	Gross Volume per hectare (m^3)
Seedlings	2,613	--
Saplings	506	--
10 (5 - 15 cm.)	50	--
20	25	4.64
30	10	6.98
40	9	14.54
50	7	18.45
60	5	21.99
70	5	30.11
80	4	32.47
90	3	28.19
100 & larger	8	111.87
Total (20 cms. & larger)-	76	269.24

For an orderly and systematic removal of the virgin timber, a logging plan is closely followed but is subject to some modification to suit actual forest conditions and operational situations. The average volume recovery per hectare in the primary logging is 190 m^3, mainly dipterocarp timber. Immediately after a primary logging of the set-ups, a salvage logging operation using smaller equipment is undertaken inside the log landings, roadsides and cableways to recover knocked-down trees (20 cm. to 50 cm. in diameters and 3m. and longer) and other utilizable wood materials (15 cm. and larger in diameter, 1-1/2-m. and longer) which are later sorted as sawnwood, chipwood for fiberboard manufacture, or firewood for the boilers, as the case may be. The average volume being recovered from this salvage operation is 40 m^3/ha.

Silvicultural Practices in the Virgin Forest

Diameter limit method.

In accordance with the cutting regulations of the Bureau of Forestry, a diameter limit system was used by all forest concessionaires in the virgin forest from 1900 until 1955, throughout the country. It was a cutting system wherein all commercial species (predominantly dipterocarps) 50 cm. in diameter and larger were cut and utilized.[1] There was no tree marking done at the time, before or during logging operations.

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[1] - According to Prof. J. Wyatt Smith (U. N. forestry expert detailed with Forest Research Institute, College, Laguna, Phillipines), who

From 1946 to 1955, Nasipit was using tractor skidding in level to rolling terrain and cable yarding in rough topography, the latter system making use of steam donkeys, tractor-mounted double drum yarders and sled-mounted torque converter yarders. The steam donkeys required tremendous volumes of smaller sized trees for firewood at the areas of operations. Free skidding by tractors and unregulated cable yarding also caused heavy damages to the remaining forest growth. This system of logging rendered the area practically clear of forest growth except a few scattered big defective dipterocarp trees which later substantially added to the remaining regeneration during seed years. Properly protected from kaingin-making, the logged-over area through plant succession was naturally regenerated by herbaceous and medium-sized tree species belonging to the families of Moraceae, Ulmaceae, Urticaceae, Rubiceae, Tiliaceae, and Euphorbiaceae. Wild bananas were also luxuriant in the area. Finally, Endospermum peltatum and dipterocarp species took over the areas. In 1973, samplings (15 one-tenth ha. plots) were undertaken in the dense second-growth dipterocarp forest that naturally developed in the areas cut-over in 1954.

Summarized data of the 19-year-old stands are as follows:

	Dipterocarp species	Non-Dipterocarp	Total
Number of trees/Ha. (10 cm. & larger)	507 trees[2]	285 trees[3]	792 trees
Stand average DBH	18.0 cm.	20.0 cm.	19.0 cm.
Average clear length ...	11.0 m.	12.2 m.	11.6 m.
Average total height ...	16.0 m.	18.0 m.	22.8 m.
Volume/ha.	129.40 M^3	104.13 M^3	233.53 M^3
Mean annual increment/ha.	6.81 M^3	5.48 M^3	12.29 M^3

1/ Cont'd - has recently visited the Nasipit Lumber Company forest areas and seen the regenerated areas under the pre-1956 diameter limit system, only the best areas under the Malayan Uniform System and earlier shelterwood system were comparable. Under the Malayan uniform system, all commercial species down to a minimum limit of 4-1/2-ft. gbh (45 cm. dbh.) were logged.

[2] - Dominant and co-dominant dipterocarp trees (30 cm. - 40 cm. dbh) is 66 trees/ha. - 50.86 M^3/ha.

[3] - Dominant and co-dominant non-dipterocarp trees (30 cm. - 40 cm. dbh) is 58 trees/ha. - 69.25 M^3/ha. mostly Endospermum peltatum.

The dipterocarp stands appear to be almost even-aged. It is therefore evident that under favorable and undisturbed conditions, virtually clear-felled areas with a number of dipterocarp seed trees (5 to 10 trees/ha.) left uncut can regenerate naturally.

Timber Stand Improvement of Second Growth Forests:

Due to the very dense stocking of trees and thick growth of brush and vines in the secondary forests, timber stand improvement operations had to be done by trained forest workers under the supervision of professional foresters and these have been going on over limited areas since 1973. The initial operation involves cutting of big vines, climbing bamboos, wild bananas, saplings of unwanted species, and poor-quality trees. After 3 months when the vines and climbers have dropped to the ground, the trees to be removed are marked by lumber crayon and felling directions indicated by arrow signs on the base of the trunks. A modified low thinning is applied wherein the valuable tree species are favored with the removal of overtopped, diseased, and poorly formed trees, weed species, big cull trees, and some dominant matchwood species. Vigorous dipterocarps and other valuable hardwoods which have good stem and crown development are retained as crop trees. In the process, 50% of the stand is thinned.

To facilitate skidding and to minimize damages of the crop trees, pre-laying of farm tractor routes to the log landings at reopened former roadsides and directed felling with the use of small power chainsaws and improvised felling aids are practiced. The pulpwood removed from the thinning operations are sorted for utilization, either as chipwood for the hardboard factories or as fuelwood for the boilers. To study the response and behavior of the remaining stand, TSI plots are immediately established in those areas. Initial results show higher values of growth and better bole and crown developments in the improved stands than those that were not improved.

Selective Logging in the Virgin Forest

Selective logging has been carried out in the Company's primary logging operations since 1956. It is a system whereby all mature and overmature trees (80 cm. and larger, plus a laid-down percentage of lower diameter trees) of dipterocarp species including *Palaquium spp.* and *Endospermum peltatum*, are carefully cut and removed from the forest and at the same time leaving after logging as many uninjured healthy residuals (20 cm. to 70 cm. diameter groups) of the same species. A tree marking system is done whereby the trees to be felled are marked by arrows showing the direction of the fall and by number and bands on each tree to be retained as residuals. Felling rules and yarding techniques are prescribed and implemented to insure a good balance of satisfactory log production and an adequate number of uninjured residual trees for the next felling operation on a prescribed cutting cycle of 35 years. Until 1972, the marking of trees to be cut or taken out is 70% of 60 - 70 cm. and 100% of 80 cm. and larger diameter classes while the residual tree marking was to mark and leave 60% of the total number of healthy residual trees of the 20 - 70 cm. diameter classes and to allow 40% for logging clearances and damages. In 1973, the Bureau of Forest Development, thru Administrative Order No. 74, amended the tree marking rule by increasing the requirement on the number of healthy residual trees to be left behind after logging. The regulation requires the marking of 70% of the total number of healthy residual trees belonging to the 20 - 60 cm. diameter classes plus 40% of the trees in the 70 cm. diameter group. On the other hand, the number of trees to be cut and removed is only 25% of 60 cm. diameter class and lower, 55% of 70 cm., and all of the 80 cm. and larger diameters, the balance of 5% in each case being a safety factor for damage to marked trees.

Sample plot studies (1.25 ha.) on virgin forest areas selectively logged in 1958, showed the following results: -

Per Hectare basis	DBH Class (cm.)	1959 Data				1972 Data			
		Dipterocarp		Non-Dipt.		Dipterocarp		Non-Dipt.	
		Trees	Volume (M^3)	Trees	Volume (M^3)	Trees	Volume (M^3)	Trees	Volume (M^3)
No. of: -									
Seedlings		29	--	313	--	117	--	202	--
Saplings		28	--	53	--	36	--	66	--
No. of Trees (10 cm. DBH & larger)	10	22	2.07	97	7.91	71	6.90	135	11.79
	20	22	7.17	60	16.37	48	14.07	118	30.86
	30	13	13.81	13	9.39	11	9.22	30	23.94
	40	7	15.95	6	9.86	8	10.93	10	14.91
	50	7	26.35	1	1.55	10	32.67	4	9.39
	60	3	21.79	1	4.58	6	19.35	--	---
	70	2	11.91	--	---	4	28.01	1	5.48
	80 & Up	3	34.40	--	---	8	103.58	--	---
	Total -	79	133.45	178	49.66	166	224.63	298	96.37
Periodic annual Increment (M^3)							7.01	--	3.59

The foregoing example shows that selective logging systems, if carried out properly, can result in good new stands being produced and can be applied in the absence of any other better system. The advantages of this system over clear felling or any other system are as follows:

1. The dipterocarp forest consist of species which need partial shade during the early stages of growth but becomes intolerant or light loving as they mature. The residual trees left after logging provides such condition for growth. They also serve as trainer and nurse trees for the reproduction.

2. Healthy residual trees with varying diameters from 15 to 75 cm. would grow to harvestable sizes in a much shorter time than seedlings.

3. Continuity of logging operation is assured although admittedly lower in yield than the primary logging.

4. The presence of residual trees and other vegetative cover serve as deterrent to illegal occupancy by land settlers. Clear-felled areas are observed to be more susceptible to illegal occupation and cultivation than areas with remaining forest cover and tree plantations.

5. The remaining forest cover protects the soil from erosion and conserves water supply, although it is accepted under tropical forest conditions as found in the Nasipit forest, the soil is never bare even under a clear cutting system.

Timber Stand Improvement in Selectively Logged Areas

Presently, forest improvement is limited only to cutting of vines interferring with reproduction and young residual trees and removal of small-sized defective trees and weed species. The reasons for such limitations are as follows:

1. There are very few research data yet available in the area of timber stand improvement of the dipterocarp forest; hence there are no specific guidelines as to the best time in the life of the stand when cultural work should be done and the degree and manner of application, and possible response of the crop trees. Economics and utilization possibilities will greatly influence these guidelines in practice.

2. The suitable equipment and methods have yet to be experimented in relation to its effects on the existing crop trees, wood recovery, and costs.

SILVICULTURAL PRACTICES IN THE TREE PLANTATIONS

Since 1955, NASIPIT and its affiliates have already established about 10,142 ha. of tree plantations inside its forest concessions, consisting of 6,118 ha. of *Albizia falcataria*; 570 ha. of *Gmelina arborea*; 151 ha. of *Tectona grandis*; 257 ha. of *Pinus kesiya*, *P. Mindorensis* and *P. caribaea*; 503 ha. of *Eucalyptus deglupta*, *E. saligna*, *E. grandis*; 190 ha.

of Anthocephalus chinensis; 83 ha. of Ochroma pyramidale; 120 ha. of Leucaena pulverulenta; 35 ha. of Dipterocarps, 1,000 ha. of Aleuretes Mullocana and 1,115 ha. of other species. The oldest of these plantations are 23 years old. The plantation developments are aimed to produce timber, pulpwood, firewood and nuts, mainly for the integrated wood processing complex of the Company.

Nursery Practices

The main forest nursery of NASIPIT was established in 1954 for the seedling production of Aleurites moluccana and A. trisperma but it was in 1958 that the Company experimented on the propagation of Albizia falcatara and other tree species.

At that time, seed availability for propagation was the main consideration. In recent years, however, the seeds for germination are collected from selected mother trees in the older tree plantations of the Company, from reforestation projects of the Bureau of Forest Development, and other sources from abroad. Delicate and fine seeds such as Pinus kesiya, Anthocephalus chineniis, Eucalyptus spp. are germinated in the greenhouse. The bigger seeds such as dipterocarp species, A. falcataria and Leucaena pulverulenta are sown directly in bamboo pots after treatment. Seedbeds are raised and made of concrete. The soil is sterilized by steam produced by a Jenny steam cleaner and treated with fungicides and nematocides before seeds are sown. When the seedlings are a few days old, they are potted in bamboo tubes, 2 to 3 inches in diameter and 4 inches long. The soil medium is 50% organic top soil and 50% sandy loam. After potting, the seedlings are transferred to raised beds in the hardening sheds roofed with transparent fiberglass. The seedlings are fertilized twice a month during watering. Fertilized fast-growing species are ready for outplanting in 2 months time, while slow growing species require 3 to 6 months. Application of insecticides, fungicides, and burning are done at the slightest sign of insect and disease incidence. Sanitary measures inside and around the nursery are strictly observed.

The NASIPIT forest nurseries have a production capacity of two million seedlings a year.

Plantation Practices

Site Preparation and Planting

The planting sites are categorized into two, namely: (1) denuded portions of newly logged-over areas and (2) unstocked or poorly stocked areas located inside old logged-over areas, the latter are not large in extent. After logging operations in a setting, supplemental or enrichment plantings of the desired species are immediately done in log landings, along roadsides, in wide cableways, and felling sites. Delayed planting of the set-up is discouraged because of the rapid growth of grass and brushes. Site preparation for planting where natural regeneration failed requires clearing the area with power chainsaws or tractors. Utilizable wood materials are removed and slash is pushed to the sides or just left on the area. Healthy dipterocarps and other valuable trees found therein are retained provided they will not cause much interference with plantation development.

Planting is undertaken daily throughout the year. Before planting the seedling, the bamboo pots are carefully split and removed. Spacing in planting is 2 m. x 3 m. for *A. falcataria*, *Gmelina arborea*, *Tectona grandis*, *Pinus spp*. dipterocarp species, *Eucalyptus spp*. and others. The NASIPIT plantations generally comprise about 70% planted trees and 30% naturally growing forest trees.

Ringweeding

Ringweeding to a radius of one meter is done 3 or 4 months from planting and 4 months thereafter for as long as necessary. Young plantations of fast-growing species are fully established at the end of the first year and slow-growing species require six times of ringweeding within two years before they are fully established.

Thinning

Thinning of plantations of fast-growing species such as *Albizia falcataria* and *Gmelina arborea* is done twice within the tentative rotation period of 15 to 20 years. The first thinning is applied at the age of 3 years. The average DBH and total height for 3-year-old plantations of *Albizia falcataria* are 12 cm. and 15 m., respectively; while that of *Gmelina arborea* are 14 cm. and 14 m., respectively. At that age there is a very intense competition among the trees for space and light. Crown classes are already distinguishable. Dying and suppressed trees, poor intermediates, and co-dominants are removed. Vines and weed species are also cut. Only 15 to 20% of the total stand is removed. Marking of trees to be thinned is done well ahead of the cutting by trained forest workers under the supervision of professional foresters.

The *second thinning* is also a low thinning and is usually done at an age of 6 years or 3 years from the first thinning. At that age on average sites, the stand DBH and total height of *Albizia falcataria* are 21 cm. and 22m., respectively; while that of *Gmelina arborea* are 16 cm. and 20 m., respectively. The crown classes are very clearly defined. The operation involves the cutting of all suppressed and intermediate trees and some poor co-dominants and dominants. About 35 to 40% of the original stand are thinned and 30 to 40% are left as final crop trees. Studies are still going on to determine the most appropriate thinning schedule and intensity. Marking of the trees to be thinned and the prelaying of farm tractor routes are done ahead of the felling operations. Directed felling with the use of small-power chainsaws and felling aids are employed to facilitate felling and skidding and to minimize damage to the final stand. Felled trees are delimbed and cut into multiple of 6 meters before they are skidded or winched to the skid road. Thinned materials consist of sawlogs and pulpwood.

Improved *Albizia falcatoria* stands at 8 years old had attained the following sizes and volume: -

Stand average DBH	32.0 cm.
Average clear length	26.0 m.
Average total height	35.0 m.
Vol/ha. (120 crop trees/ha.)	161.30 M^3

The first thinning of plantation of slow-growing species such as Pines is done in the sixth or eighth year. About 20% of the stand is thinned consisting of suppressed trees, some poor intermediates, and co-dominants. The schedule of the second thinning operation will still have to be determined.

Pruning

Pruning of fast-growing species is usually done during the first year to the third year. It is done with the use of pruning knives, pruning saws, and boloes (local jungle knife). On the other hand, pruning of some slow-growing species is done during the second year to the sixth year. Pruning is flushed to the stem and the injury is immediately covered with wood paint. Pruning studies are being conducted.

Harvesting

Clearcutting method. -- Some *Albizia falcataria* plantations have already attained harvestable sizes. In July 1974, the first trial harvest by clearcutting was undertaken in an unthinned 13-year-old plantation. The plantation consisted of 70% *A. falcataria* and 30% dipterocarps and other species. The yield per hectare was 222 M^3 of *A. falcataria* consisting of 21% export quality logs (to Japan), 9% sawlog quality and 70% pulpwood. In better sites and improved stands, the expected yield at rotation age of 15 years ranges from 300 to 350 M^3/ha. with a utilization of 10 cm. diameter and larger, 1-1/2-m. and longer stems and branches. The expected quality will consist of 22% exportable, 30% sawlog, and 48% pulpwood.

At the time of the harvest, the trees were fully laden with mature seed pods. The plantation floor was laid bare and scarified by the tractor skidding operations. One month after harvest, the cleared area was carpeted with *A. falcataria* seedlings. The accumulated dormant seeds in the ground and the newly dropped seeds germinated. A line plot sampling of the reproduction was done 5 months later and there were 87,000 seedlings, ranging from 10 cm. to over 1 m. in height. Periodic cleanings and thinnings were done and at the end of the first year, the regeneration having been fully established. Measurement of the stand in May 1976 showed the following data: -

Number of remaining trees/ha.	856 trees
Average DBH of stand	7.07 cm.
Average total height of stand	8.0 m.

Coppice method. -- In 1968, an experimental harvest by clearcutting was undertaken in an 8-year-old A. falcataria plantation to gather data on yield and data for volume table construction. Three months after cutting, numerous sprouts grew on the stumps. Immediately, the weaker sprouts were removed and only one or two coppices were allowed to grow. Measurements of the coppice stand in April 1977, or after 9 years showed the following data: --

Number of trees/ha.	440 trees
Average DBH of stand	21.0 cm.
MAI (DBH)	2.33 cm.
Average merchantable height	18.0 m.
Volume/ha. (minimum top DBH 15 cm.)	180.00 M^3

Pest and Disease Control

The plantations have not been exempt from the incidence of pests and diseases. The occurrences, however, are mostly of recent years. It was noted in 1974 that young *A falcataria* plantations (3 years old and younger) in some sites had canker.2/ The disease attacked the main stem and the branches, eventually resulting in the death of the trees. The spread of the disease is being controlled by cutting or pruning the diseased trees and burning them. It was noted, however, that some of the infected trees were able to survive but showed retarded growth and poor development. It was also noted in 1975 that some young plantations of *Gmelina arborea*, *Pawlonia tomentosa*, and *Ochroma pyramidale* (3 years old and younger) were being attacked by wood borers.3/ The wood borings at the base of the trunk were caused by the larvae of a moth. These are being controlled by application of endrin-soaked cotton into the holes. Young plantations

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2/ - The causal fungus is presently being studied by Dr. Enriquito de Guzman of the U. P. College of Forestry, Los Baños, Laguna, Philippines.

3/, 4/, 5/ - The causal insects are also being studied by an entomologist of the U. P. College of Forestry.

of Swietenia machrophylla are frequently attacked by shoot borers and Anthocephallus cadamba are defoliated almost throughout the year by larvae of a moth.4/ Recently, it was also discovered that some trees in the Eucalyptus deglupta plantations are being seriously checked in growth and even killed by wood borers5/ that make spiral tunnels in the sapwood. So far, there is no easy and economical control of any of these kinds of infestation.

IMPROVED UTILIZATION PRACTICES AS COMPLEMENTARY MOVE TO FOREST CONSERVATION

Utilization in the Forest and Tree Plantations

Felling of the mature trees in the virgin forest is done by flanging the buttresses first before making the felling cuts. Felled trees are delimbed up to the top most utilizable portion of the main stem and then bucked into specified lengths. After the big timber has been removed from the logging set-up, a salvage operation follows to recover knocked-down trees and other utilizable wood materials.

During timber stand improvement operations in the second growth forests, all thinned materials 10 cm. and larger in diameter and 1-1/2 m. and longer are gathered and brought to the mills. Likewise, in the thinning and harvesting operations of Albizia falcataria plantations, the stumps are cut as close to the ground, and all utilizable wood material 10 cm. and larger in diameter and 1-1/2 m. and longer are also utilized.

Utilization in the Mills

The Nasipit Lumber Company and its affiliates own and operate an integrated wood processing complex of bandmills (2 mills) provided with a gangmill, veneer and plywood factory (3 lines), fiberboard factories (3 lines), finishing mills, dry kilns, wood immunization plant, wood preservation plant, wood variety shops for the manufacture of flush and louver doors, blockboards (lumber core), tilewood (parquet), furniture, brushbacks and others, gang nail and truss assembly plant, and sawdust briquette plant.

In the mill, the logs are prepared and sorted for export as round logs and for wood processing. Logging residues and TSI materials are sorted and separately conveyed to the gangmill, chippers, or boilers. The log trimmings called "lily pads" are converted into chipwood for the fiberboard factories. The edgings, trimmings, and slabs from the sawmills are also utilized as chipwood and firewood. Trimmings from the veneer factory are supplied to the boilers. Dry sander dusts, instead of polluting the air, are gathered and converted into briquettes for the boilers.

It is an obsession of the Company to maximize utilization of its wood production as a complementary move to national forest conservation efforts.

Increasing Danger posed by Land Settlers

The Nasipit forest reserve and its industrial tree plantations are always under threat of gradual destruction by land settlers. The Company and the Bureau of Forest Development are exerting tremendous efforts to minimize forest losses from shifting agriculture, commonly known as kaingin-making, both by the natives on their traditional lands in the concession forest area and by squatters from other parts of the Philippines. Stringent laws against forest destruction had been passed and are being implemented by the Government and the Company. Educational campaigns are vigorously being conducted among the forest population, towns, and cities. A government policy has been set to manage these kaingined or cleared areas under a so-called Kaingin Management Plan in order that destruction can be controlled.

Private Tree Farming

The experience of Nasipit in tree plantation development has spawned widespread tree farming of fast-growing species in private lands inside and around the forest concession and extending in other parts of Agusan and Surigao. Several tree farmers who planted trees several years ago are already embarking on thinning and harvesting operations. Their products are mainly sold to the Nasipit factories and a little is sold to Paper Industries Corporation of the Philippines located some 150 kilometers away by road. The high profitability of tree farming has encouraged hundreds of private landowners, and as of date there are over two hundred tree farmers inside and around the Nasipit area with an approximate tree farm area of 1,000 ha. Idle lands which have failed to traditional agricultural cultivations are now rapidly being converted into small tree farms.

RESUME

The NASIPIT experience, though still a very limited one, is a convincing proof that applications of suitable silvicultural practices in the natural forests and tree plantations will produce good stands and increase utilization. With forest research being intensified, it is hoped that better and reliable data can be obtained and provide together with improved forest protection the basis for even better practices and forest management.

FORESTERS AND THE FAUSTIAN BARGAIN

(A note on some possible hazards of omnispecific woodchip harvesting in the humid tropics)

By

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Note: This paper was originally prepared for the FAO Conference on the Humid Tropics, <u>before</u> the author joined the Asian Development Bank. The views expressed are the author's and do not necessarily represent those of the Asian Development Bank.

FORESTERS AND THE FAUSTIAN BARGAIN

By

S. D. Richardson

I. INTRODUCTION

The dilemma which Mephistopheles presented to Dr. Faustus was one which faces most of us at some time or other--a choice between possible future returns and immediate gain. Since future returns are necessarily hypothetical, the judgment of history upon Faustus has always seemed to me self-righteously harsh. It is a judgment, however, which history may yet come to make upon foresters; and the purpose of this note--it is not a scientific paper--is to sound a warning that, in our current preoccupation with total forest harvesting and whole tree utilization, we may attract (and more deservedly than the unfortunate hedonist) a similar judgment from posterity.

II. BACKGROUND

The past two decades have seen a dramatically increasing demand for reconstituted wood products (pulp and paper, fibreboards, and particleboards) throughout the developed world. In Japan, for example, between 1965 and 1974, production of woodpulp doubled (from 5 million tonnes to over 10 million tonnes); fibreboard manufacturing capacity increased from 63 million m^2 to over 120 million m^2; and particleboard quadrupled (from 10 million m^2). In Europe fibreboard production rose by 25 percent, and particleboard production by 300 percent (from less than 6 million m^3 in 1965 to nearly 20 million m^3 in 1974); pulp and paper production increased by 50 percent. For North America, the respective increases were 25 percent, 300 percent, and 120 percent. During this decade, the demand for woodchip products escalated in a manner unprecedented and unpredicted. Despite the 1974-75 recession, there is little doubt that the upward trend will continue.

These increasing demands have led to impressive developments in the production and transport of woodchips, and in the variety of raw materials accepted by the manufacturing industries. In Japan in 1950, no hardwood was used as pulpwood; by 1970 the hardwood:softwood ratio was 60:40; it is now 80:20. More recently, wood chips have been replacing logs as the delivered raw material, the ratio of chips:logs reaching 75:25 by 1971. These developments have been accompanied by massive imports of wood chips, initially from the West Coast of North America (200,000 tonnes in 1965 rising to 4,000,000 tonnes in 1974), New Zealand (exceeding 160,000 tonnes in 1975), Australia (1,400,000 tonnes in 1971, over 3,000,000 tonnes in 1973, with as much as 30,000,000 tonnes projected for 1988), and Siberia (15,000 tonnes in 1972; 186,000 tonnes in 1975).

Woodchip harvesting operations have now begun in Brazil, Malaysia, Thailand, Indonesia, the Philippines, and Papua New Guinea, with exports of rubberwood, mangrove, and mixed tropical hardwood chips. Other tropical countries are planning similar developments.

The utilization of mixed tropical hardwood chips for reconstituted wood products has a particular significance. Traditionally, as we all know, high forest areas in tropical countries have been exploited for a very limited number of species; in many cases, less than one stem per acre is harvested. Because timber harvesting opens up hitherto inaccessible areas, however, logging is more often than not followed by destructive burning of the forest for agricultural settlement. Thus, the harvesting of mixed tropical hardwood species for the manufacture of reconstituted wood products enables a massive increase in raw material utilization and provides profitable outlets for hitherto unused species (FOB prices for mixed tropical hardwood chips from Papua New Guinea exceed US $25 per Bone Dry Unit--approximately equivalent to US $23 per tonne). It is scarcely surprising that, after living with the problems of underutilized species for so long, foresters should contemplate the prospect of multispecific chipwood harvesting with unmitigated pleasure.

It is not my desire to play the role of the ancient mariner at this marriage between forester and logger, but our excitement must, I think, be tempered by awareness of some possible deleterious (even disastrous) consequences of uninhibited forest clearance in some tropical areas. Chipwood harvesting in the temperate zones, and rubber plantation clearance, present few problems since the objective of such programs is to replace poor resources with higher-yielding species and varieties. Similarly, where in tropical regions the objective of land clearance is the establishment of food crops--and where site selection is based on objective ecological appraisal--there can be no reasonable opposition to chip harvesting. It is otherwise in the mangrove areas, and in rainforest where there is no land hunger. And yet it is precisely these latter areas which are now being sought out for chipping operations.

The reasons for the selection of the more remote areas are not hard to find; because they are unpopulated (or only sparsely settled) there are few problems of land tenure or traditional rights of usufruct to deter the legislators responsible for the allocation of concessions, or to interfere with the operations of the loggers. There are no environmentalist irritants or inconvenient demands for impact statements. And, because of an evident lack of local labor, there is relative freedom for the concessionnaire to import indentured expatriates. (There are, of course, many difficulties in operating in such areas, but they are evidently outweighed by the advantages; in any case they are outside the scope of this note.)

What, now, are the hazards of omnispecific woodchip harvesting? They are primarily ecological and they stem from our ignorance, as foresters, of tropical forest ecology.

III. THE MANGROVE RESOURCES

Mangroves have been selectively exploited on a small scale for generations--for building poles, fuelwood, charcoal, cutch, etc. Most species regenerate readily under these conditions and with a minimum of intervention from the forester; where they do not do so, they can be planted. A chip harvesting operation, however, is not selective, even though lip-service may be paid to the concept of selective cutting; moreover, its scale may be such that the cleared areas are well beyond the biological capacity of the species for natural regeneration, and the resource capacity of forest services for replanting. The effects of chemical defoliants in Vietnam are now sufficiently well documented to demonstrate the limited regenerative potential of mangroves; and there are few foresters who can lay claim to sufficient financial and manpower resources to be able to undertake replanting to the extent required by chip harvesting projects. Most importantly, our understanding of the effects of mangrove clearance on such features as coastal erosion, the mobility of sand bars, tidal and current movements, fish breeding, etc.--as well as the more immediately disruptive effects (albeit on a smaller scale) on villagers whose lives and livelihoods may partly depend on the mangroves--is frighteningly deficient. We can (and do) prescribe the retention of narrow coastal strips and cutting to girth limits, but even when such prescriptions can be effectively policed (an impossible task in some areas), they are at best hopeful palliatives deriving from experience wholly inappropriate to modern chip harvesting practices. The need for practical field investigations of these problems, and for the close monitoring of cutting effects, is urgent and obvious; and I am sure it will not prove difficult to persuade this meeting to endorse an appeal for more extensive and immediate research. The adoption of resolutions in the air-conditioned comfort of a conference hall, however, is a universe away from their implementation in the swamps of the mangrove habitats.

IV. THE RAIN FOREST

The case for caution in our approach to mangrove clearance is a relatively easy one to argue. It is less simple in the case of the rain forest, in view of its vastness, its richness in terms of species, and the apparently unlimited fertility indicated by its luxurious vegetation. Yet these features are all of them illusory. Firstly, the seemingly unlimited extent of the rain forest is more than matched by the speed of its disappearance. What once stretched virtually unbroken over all the lowlands of the humid tropics and remained more or less intact for over 60 million years has, in the last 200 years, become fragmented and is being reduced at a rate greatly in excess of that of earlier forest removal in the temperate zones of America, Europe, and Asia. Through clearance for plantation crops and shifting agriculture, the pace of destruction over the last twenty years has been such that, if it continues, the world's rain forests (and much of the flora and fauna they support) will, except for a few poor relics, vanish within the next half century.

Similarly, the species richness of the rain forest is but a fraction of what it once was; because lines of communication have been cut by fragmentation, the rain forest can no longer play its traditional role as the gallery and issuing house of genetic and evolutionary diversity. Some biologists (and, among them, informed scientists--not merely case-hardened econuts) would go so far as to assert that, through rain forest destruction, man has permanently diverted the course of evolution.

Finally, and most importantly, the alleged luxuriance of the rain forest vegetation is a myth, deriving no doubt from the large size of the trees, the storeyed structure of much of the forest, and the impenetrable appearance of its edges when viewed from rivers, roads, and airstrips. In from the edges, however, the ground flora is often sparse and, even in the clearings, vegetation growth rates are extremely low. The rain forest is no teeming cornucopia; much of it, in fact, is of low fertility adapted to survival by its almost leakfree nutrient system and rapid recycling. In an undisturbed state, losses from the system are made good not by the weathering of the parent rocks (which occurs well below the level of the characteristically shallow root systems of the trees), but by additions in rainfall. (There are, of course, exceptions to this generalization--for instance, in areas enriched by alluvium and volcanic ash; but there are also large podsolic areas, such as the Kerengas of Kalimantan, which support high forest but which, on clearing, cannot sustain even one harvest of rice. There are laterites too which, on exposure, bake hard and can then support no vegetation; and there are abundant steep sites which when cleared will simply erode to barrenness.) The fact that the most successful agricultural crops grown in rain forest areas are those from which only small quantities of nutrients are removed in harvesting (e.g., rubber, cocoa, oil-palm, etc.) is not without significance.

A crude index of rain forest fertility in some areas subject to shifting cultivation is the number of annual harvests which are taken before a new "garden" has to be sought. For most of the rain forest, 3-4 such harvests represent an unusually high number; in some sparsely populated areas--where wood chip operations are being established--a single harvest is the norm. (There may be, in fact, a causal relationship between poor soil fertility and low population densities. Shifting cultivators are not as unintelligent as we sometimes imagine; at least one tribe in Irian Jaya, for example, uses a highly sophisticated site classification based on the use of indicator tree species--an accomplishment not yet matched by our scientifically trained agricultural botanists or foresters. And it is a not unreasonable hypothesis that areas in which no one claims rights of usufruct exist simply because such rights are worthless due to infertile soils.) In any event, the location of wood chip ventures in rain forest areas gives cause for concern because--as in the case of the mangroves--foresters are woefully ignorant of the possible after effects; the credibility of our claim to ecological expertise is already sufficiently stretched for us to be extremely wary of its further extension.

It will, of course, be argued that wood chip harvesting agreements invariably incorporate provisions for reforestation. (The good intentions of such provisions are not in question; but someone--probably John Bunyan, though I am not certain--wrote that "the road to hell is paved with good intention.") Assuming that planting takes place, reforestation will be with fast-growing species, usually exotics. How confident can we be, I wonder, of the capacity of the sites to sustain high growth rates beyond the first short rotation? If they can, the position will be similar to that in nontropical areas where an unproductive resource has been replaced by a more useful one and, in my view, there can be no argument about its desirability. But without present knowledge of fertility distribution within chip harvesting concessions, ultracautiousness surely represents a wiser policy than the Faustian alternative.

What troubles me most is the operational scale of chipwood ventures. The problem is analogous to that of supertankers (and the new dimension assumed by problems of oil spillage) or nuclear fission technology--and it cannot be answered by our new panacea, cost-benefit analysis, however sophisticated. Like the choice which faced Faustus, our problem is essentially ethical, not economic; are we justified in developing a technology which may prove dangerous and uncontrollable?

V. PROPOSALS

In urging caution in approaches to multispecific wood chip harvesting in the tropics it is not enough merely to annotate possible hazards. Positive resolutions, even if controversial, are needed and I have four to present to this conference.

1. That immediate steps be taken in the countries concerned and by the international agencies to monitor the oceanographic, riverine and biological effects of current woodchip operations in mangrove areas; and that until such effects are more clearly known, large-scale harvesting of mangroves be resisted.

2. That countries engaged in--or contemplating--omnispecific woodchip harvesting in tropical rain forest ensure that comprehensive site evaluations precede the granting of forest clearance concessions; and that such concessions be limited to areas where continuity of a productive cover can, as far as is humanly possible, be guaranteed.

3. That in granting woodchip harvesting concessions, the legitimate interests of peoples whose lives or livelihoods may depend upon the continued existence of a vegetative cover be fully protected.

4. That foresters in tropical countries endeavour to limit woodchip harvesting concessions to ongoing logging operations on lands that they suspect will be subsequently converted to nonforest uses--whether by accident or design.

VI. POSTSCRIPT

If the last of the foregoing resolutions could be successfully implemented on a worldwide basis, and the logging residues from existing operations fully utilized, the first three would be unnecessary; there would be sufficient woodchips available (together with those from rubber tree and coconut palm replacement areas, etc.) to satisfy world demand now and in the foreseeable future. And all those so-called secondary species which concern us so much would be fully utilized. It is a chastening fact that the annual growth of extant forest plantations (based on data presented at the World Consultation on Man-Made Forests--which are, admittedly, of doubtful accuracy), amounts to nearly 40 percent of annual world wood consumption. There is, thus, no impending world shortage of wood; but there is a very real danger of a world shortage of natural forests.

To return briefly to my introduction, despite the hypothetical future rejected by Faustus, his torments (as portrayed by the poets, dramatists, and composers) were, when the day of reckoning arrived, real enough. The choice for foresters, surely, is not such a difficult one.

LITTLE-KNOWN WOODS OF THE BRAZILIAN AMAZON

By

P. F. Stäger Carvajal

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Manaus, Brazil

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The forests of the Amazon make up 40 percent of Brazil. Amazonia, the Amazon region, covers 3.5 million square kilometers, and covers five states and three territories.

Three types of forest are found in the Amazon: (1) the forests of the uplands, (2) those periodically flooded, and (3) those continuously flooded (see graph 1).

The upland forest covers 80 percent of the region. Trees grow to 60 to 65 meters in height and are dense and dark green in color. Species such as the Brazilnut (Bertholletia excelsa) and Cauchorana (Micranda spruceana) are found there.

The continuously flooded forests grow to 20 meters in height and are almost impenetrable because of low branches and huge roots above ground. Here are found species such as tachi (Tachigalia spp.) and arapari (Macrolobium acaciaefolium).

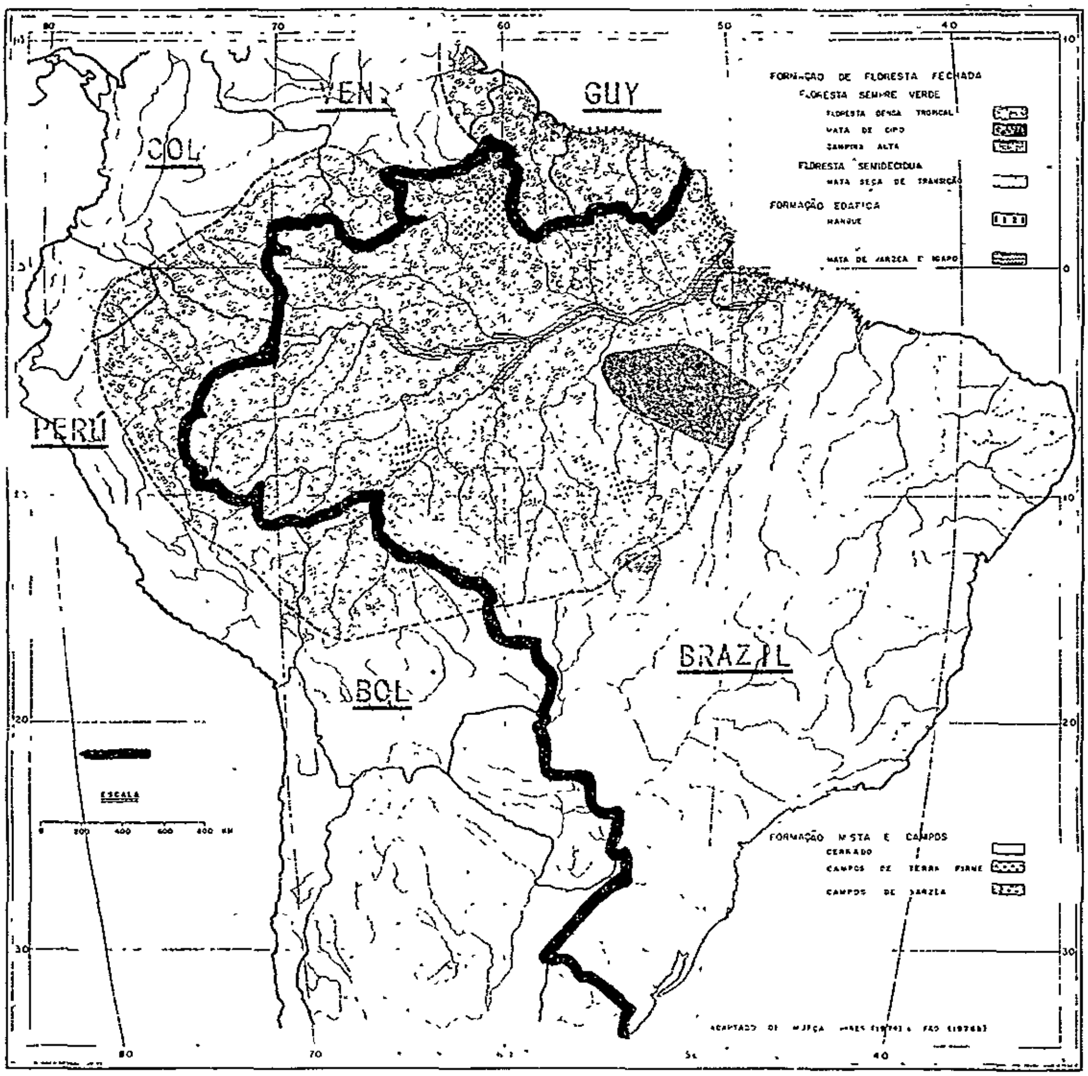
The periodically flooded lands support forests that are intermediate between the other two. In the lower areas they are similar to the continuously flooded forest and in the higher areas similar to the upland forest.

This paper considers only the woods of the continuously flooded areas and of the uplands. The chemical analysis of the heartwood cell walls is practically the same for all Amazon woods: 50 percent cellulose, 16 to 30 percent lignin, and the rest hemicellulose. The wood characteristics vary from species to species because of differences in form, dimension, and position of the anatomic elements and the quantities of resins and oils present. The woods of more than 300 genera thus range from the very light (200 kg/m^3) balsawood (Ochroma pyramidale) to the very heavy (1300 kg/m^3) saintwood (Zollernia paraensis). Differences in color, texture, grain, taste, and odor are found between species and also within species according to geographical regions.

More than 200 Amazon woods have been studied in United States, British, and Brazilian laboratories (4) with many published results. Among the works involved are SUDAM (1), INPA (3), IPT (5), and IBDF-PRODEPEF (8).

GRAPH Nº 1

THE AMAZONIC FLOREST .



Despite its large size the Amazon basin is the source of only 11 percent of Brazil's wood production. In 1973 there were 287 sawmills in the region, 70 percent of them in the lower Amazon. At present the number has increased to about 480, with 70 in the Manaus region, 340 in the lower Amazon, and 70 others in the rest of the region. The wood most used is virola or ucuuba (Virola spp.) making up 38 percent of total production (8,9,10). Other species include mahogany (Swietenia macrophylla), 8.7 percent; crabwood (Carapa guianensis), 6.5 percent; louro (Ocotea cymbarum), 6.4 percent; and cedar (Cedrela odorata), 4.6 percent. No other species makes up as much as 2 percent of the production.

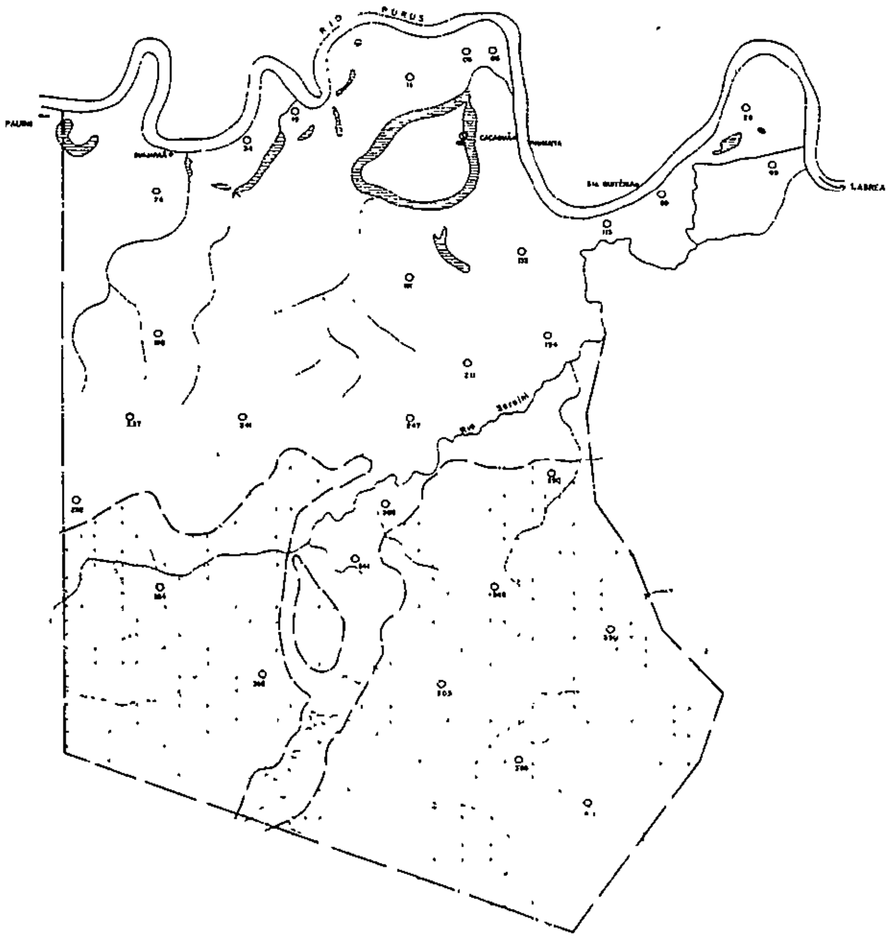
About 46 percent of the production is exported. (Eight species, chiefly virola, crabwood, and mahogany, make up 90 percent of the exports.) Another 9 percent is transported to other regions in Brazil, and the remaining 45 percent is consumed within the Amazon region. In the local market 58 percent of the use is confined to virola, crabwood, mahogany, louro, and cedar. Another 25 species each yield 10,000 cubic meters or more per year. In total some 166 species are sawn commercially at present.

Because of the large size of the Amazon no complete forest inventory has been made. Estimates are being made by the use of satellites (RADAM project). Regional inventories have been made in recent years showing variations with soils, forest types, and water levels. Results obtained by SUDAM appear in table 1.

Local variations require timber operators to make their own inventories. Thus when Manasa Madeireira Nacional S.A. created a subsidiary, Manasa da Amazonia S.A., to develop its 465,000 hectares of forest, the latter undertook an inventory of 56,979 hectares in preparation for a fully mechanized operation. Elsewhere the company is reforesting with Brazilnut (graph No. 2).

The most significant finding from this inventory was the volume of usable timber, averaging 199 trees of 45 cm or more in diameter per hectare. Considering only the uplands where extraction is relatively easy, the 24,290 ha contain about 5,465,000 m^3. Considering the rest of the tract as well, the total volume may approach 12 million m^3. On the area inventoried a total of 438 tree species was found (table 2), of which 47 are commercial. The other 391 are excluded mostly because of size or lack of information as to their utility. There were 38 commercial species with volumes of 10,000 m^3 or more in the area (table 3), with a potential combined yield of 5,049,000 m^3 for the entire 56,979 hectares.

Table 4 includes species well known internationally, some that are known only locally, and some little known at all. Some of the last group with high wood densities are:



GRAPH Nº 2.

MANASA DA AMAZONIA S.A.

INVENTARIO FLORESTAL DA ÁREA DO ALTO PURUS

CARTA FLORESTAL

IMÓVEL ' CAÇADUÁ

ÁREA TOTAL DO IMOVEL, 54920 ha

MUNICÍPIO LABREA – AMAZONAS

ESCALA 1 200 000

CONVENÇÕES

ÁREA TOTAL DE TERRA FIRME	▭	24290 ha
ÁREA TOTAL DE VÁRZEA	▭	29 940 ha
ÁREA TOTAL DE LAGO	▨	[illegible]0 ha
ÁREA DE AMOSTRA	○	
CURSO DÁGUA	←	
LIMITE DO IMOVEL	— —	

EXECUÇÃO

confal consultoria florestal brasileira ltda
EM MARÇO DE 1975

SITUAÇÃO EM RELAÇÃO AO ESTADO

Table 1.--Average density of wood of 63 species in m^3/ha

Species		Areas				
Commercial name	Scientific name	A	B	C	D(*)	Average
Ablorana (s)	*Poutaria spp.*	7.2	4.3	10.2	24	15.0
Acapu	*Vouacapoua Americana*	4.5	--	--	11	9.0
Acapurana	*Cassia adiantifolia*	.0	--	--	22	.3
Axixa (s)	*Sterculia spp.*	.0	--	--	24	2.1
Axuá	*Sacoglottis guianensis*	1.2	--	--	21	.8
Acoita Cavalo	*Puehea speciosa*	--	--	--	22	.3
Amapá	*Parahaucarula Amapá*	1.5	1.3	--	23	.6
Anoni	*Synphonia Globulifera*	1.3	.1	--	23	.6
Andiroba	*Carapa guianensis*	2.2	.4	1.7	23	1.5
Angelim do Mato	*Hymenolobium excelsum*	--	--	--	23	.5
Angelim Pedra	*Dinizia excelsa*	7.8	1.1	--	18	2.8
Angelim Rajado	*Biphecolobium racemosum*	.6	.5	--	21	.6
Acariquara	*Minquartia guianensis*	3.0	1.0	2.8	23	.4
Aracanga	*Aspidosperma album*	.7	--	--	23	.4
Aroeira	*Astronium Lecointel*	.0	--	--	24	1.4
Breu (s)	*Protium spp.*	6.1	1.2	3.2	24	4.9
Breu Sucuruba	*Trattinickia rhoifolia*	--	--	--	24	1.1
Caraipé	*Licania incana*	1.1	.5	.7	24	4.5
Castanheira	*Bertholletia excelsia*	.0	4.4	--	11	5.5
Cedro	*Cedrela odorata*	.0	--	--	16	.1
Coataquicava	*Pelegyne lecointel*	.0	--	--	12	.3
Copaiba	*Copaifera spp.*	--	.3	.3	24	1.0
Cuiarana	*Buchanavia huberi*	--	--	--	24	1.8
Cumaru	*Coumarouna dorata*	3.6	.5	.5	23	1.3
Cupiuba	*Coupia Glabra*	6.0	1.7	--	24	2.7
Envira spp.	*Xylopia, Guatteria e Duquetia spp.*	1.3	1.8	.6	24	1.6
Faveira (s)	*Piptadenia spp. Vatairea spp.* *Enterolobium spp. Parkia spp.*	2.2	1.8	.6	24	9.7
Freijó	*Cortda goeidlana*	--	--	--	17	.2
Gombeira	*Swartenia spp.*	.0	--	--	22	.7
Ingá (s)	*Ingar albà, Ingá spp.*	3.0	.0	2.3	24	1.9
Imbaúba e imbaubarana	*Cecropia spp. Pourouma spp.*	1.0	.3	.6	24	1.3
Itaúba	*Mezilaurus itauba*	--	.2	--	20	1.4
Jarana	*Eschwellera Jarana*	2.6	1.5	.4	24	2.8
Piquiarana	*Caryocar microcarpum c. fabrum*	1.0	.9	1.0	23	1.1
Quaruba (s)	*Vochysia spp. Qualea spp.*	--	--	--	--	--
Mandioqueira	*Qualea anbiflora*	6.4	.0	--	24	2.6
Quarebarana	*Erisha uncinatum*	--	--	--	20	.6
Quinerana	*Gorasespermum sericceum*	.0	--	--	20	1.6
Rosadinha	*Micsophalls guianensis*	.0	1.5	--	24	2.9

(Page 1 of 2)

Table 1.--Average density of wood of 63 species in m^3/ha--continued

Species		Areas				
Commercial name	Scientific name	A	B	C	D(*)	Average
Sapucaia	Lecythis usitata	1.8	—	—	24	1.5
Sorva (s)	Couma spp.	.6	0.2	0.1	20	.2
Sucupira	Bowdichia nitida	1.1	1.4	--	24	1.1
Taxi (s)	Dachigalia spp. Sclerolobium spp.	3.0	2.3	2.1	24	6.0
Tauari	Couratari spp.	--	--	--	3	3.0
Tauari--coco	Cariniana microntha	--	--	--	--	--
Tauari	Couratari spp.	.8	2.5	--	21	3.7
Tento (s)	Ormosia spp.	1.6	--	--	24	7.5
Ucuuba (s)	Virola spp. sem V. surinamensis	1.6	2.6	1.3	24	1.6
Ucubarama	Irvanthera spp.	2.7	6.1	6.0	19	1.0
Parinari	Parinarium spp.	.3	--	--	23	.8
Jutaf--Acu ou Jaraba	Hymenaea courbaril	1.0	.4	.1	24	1.3
Louro (s)	Ocotea spp. Nectandra spp. Aniba spp.	8.8	1.6	4.2	24	4.7
Macacauba	Platymiscium trinitatis	.0	.0	.2	23	.1
Macaranduba	Manilkara huberi	5.2	.8	.7	24	7.6
Momerana ou Cast. de Paca	Scleronema ferox	--	.2	6.4	1	12.0
Maparejuba	Manilkara amazonica	.6	--	.2	24	2.6
Marupá	Simaruba amara	.4	.1	--	24	.5
Muirapixuna	Cassia scleroxylon	.0	--	--	9	1.4
Morototó	Didymopanax morototoni	.8	--	--	22	.4
Matá-Matá (s)	Eschweilwea spp.	9.0	5.2	9.8	24	15.5
Mututi	Pterocarpus rhril	.3	--	--	22	.2
Parápará	Jacarandá copaia	.3	--	--	24	.8
Pau-d'Arco	Tabibula serratifolia, tabibula spp.	.2	--	.3	21	1.5
Pau Amarelo	Euxilophora paraensis	.0	--	--	9	1.1
Pau Jacaré	Laeria procera	.0	--	--	24	.7
Piquiá	Coryocarvillorum	2.1	1.0	--	22	1.3

Ref.: MINISTRY OF AGRICULTURE, Bulletin No. 6/1963.

AREAS: A = Amapá (Amaparí Florest - 50000 ha)
B = Manaus (Ducke Florest Reserve)
C = Benjamin Constant, AM, 20000 ha
D = Amazonic Valley, 19095000 ha

(*) = Number of species (trees) per hectare.

AVERAGE VALUES PER AREAS: (m^3/ha)

A = 1.9
B = 1.3
C = 2.1
D - 2.5
TOTAL AVERAGE = 1.9 m^3/ha

(Page 2 of 2)

Table 2.--Species found in the area of Manasa, Altopurús, Amazônas

Higher lands

Abiurana	*Pouteria sp.*	Sapotaceae
Abiurana branca ou Amapá doce	*Pouteria sp.*	Sapotaceae
Acapurana	*Campsiandra laurifolia*	Leguminosae
Amarelinho	*Pogonophora schomburgkiana*	Euphorbiaceae
Acariuba	*Minquartia guianensis*	Olacaceae
Anani	*Sinphonia globulifera*	Gutttiferae
Andiroba	*Carapa guianensis*	Meliaceae
Apuí ou Mata Pau ou Gameleira	*Cludia sp.*	Guttiferae
Araçá	*Eugenia sp.*	Myrtaceae
Araçá de anta	*Bellucia imperialis*	Melastomaceae
Arapari	*Macrolobium acaciaefolium*	Leguminosae
Araracanga	*Aspidosperma desmanthum*	Apocynaceae
Aroeira	*Lithraea brasiliensis*	Anacardiaceae
Ata brava	*Anona esquamosa*	Anonaceae
Abiurana cutite	*Lucuma riviqua* Gaerth	Sapotaceae
Aquariquara roxa	*Minquartia guianensis*	Olacaceae
Abiurana olho de veado	*Chrysophyllum anomalum* Pires	Sapotaceae
Angelim da mata	*Parkia pectinata*	Leguminosae
Açacu	*Hura crepitans*	Euphorbiaceae
Abiurana roxa	*Pouteria sp.*	Sapotaceae
Açacurana	*Erytrina glauca*	Leguminosae
Breu almescia	*Protium trifoliolatum*	Burseraceae
Bacuri	*Moronobea pulchra* Ducke	Guttiferae
Biribá bravo ou Ata	*Rollinia exsuca*	Anonaceae
Breu	*Protium heptaphyllum*	Burseraceae
Breu manga	*Protium poppiglanum*	Burseraceae
Castanha vermelha	*Eschweilera sp.*	Lecythidaceae
Cedro vermelho	*Cedrela odorata*	Meliaceae
Castanha de macaco ou Macacaricuia	*Cariniana micrantha* Ducke	Lecythidaceae
Cumarurana	*Dipteryx polyphylla*	Leguminosae
Cacaurana	*Theobroma sylvestre*	Sterculiaceae
Capitio	*Siparuna guianensis*	Monimiaceae
Carapanaúba	*Aspidosperma oblogum*	Apocynaceae
Caripé	*Licania canescens*	Chrysobalanaceae
Cariperana ou Sernambí de índio	*Licania micrantha*	Chrysobalanaceae
Castanha jarana	*Holopyxidium latifolium*	Lecythidaceae
Coraçao de negro	*Swartzia corrugata*	Apocynaceae
Copaíba	*Copaifera sp.*	Lecythidaceae
Cumaru	*Dipteryx odorata*	Leguminosae
Cajuí	*Anacardium spruceanum*	Anacardiaceae
Cedro	*Cedrela fissilis*	Meliaceae
Cinzeiro	*Terminalia tanibouca*	Euphorbiaceae
Caroba	*Jacaranda copaia*	Bignoniaceae
Cauchorana	*Micrantha spruceana*	Euphorbiaceae
Casca doce	*Pradosia inophylla*	Sapotaceae
Castanharana	*Eschweilera sp.*	Lecythidaceae
Envira fofa	*Xylopia sp.*	Anonaceae
Envira prêta	*Unonopsis* sp.	Anonaceae
Envira amarela	*Xylopia amazonica*	Anonaceae
Envira branca	*Duroia saccifera*	Anonaceae
Envira pente de macaco	*Guatteria ouregou*	Anonaceae
Envira amargosa	*Pseudoxandra coriacea*	Anonaceae

(Page 1 of 6)

Table 2.--Species found in the area of Manasa, Altopurûs, Amazônas--continued

Higher lands		
Faveira	*Parkia multijuga*	Legúminosae
Faveira camusé	*Vatairea sp.*	Leguminosae
Freijó branco	*Cordia goeldiana*	Borraginaceae
Gameleira	*Ficus doliaria*	Moraceae
Gitó ou Jataúba	*Guarea carinata* Ducke	Maliaceae
Guaruba branca	*Vochysia melinonii*	Vochysiaceae
Genipapo	*Genipa americana*	Rubiaceae
Genipaporana	*Japarandiba augusta*	Lecythidaceae
Goiabinha	*Galycolpus glaber*	Myrtaceae
Gitorana	*Guarea trichilioides*	Meliaceae
Guariuba	*Clarisia racemosa*	Moraceae
Grão de galo	*Cordia excelsa*	Borraginaceae
Inharé	*Maquira sclerophylla*	Moraceae
Imbaubarana	*Pourona ovata*	Moraceae
Ingarana	*Pithecolobium* cf. *latifolium*	Leguminosae
Ingá ou Ingá baio	*Inga spp.*	Leguminosae
Itaubarana ou Saboarana	*Casearia silvestre*	Combretaceae
Ingá vermelho	*Pithecolobium sp.*	Leguminosae
Imbaúba	*Cecropia sp.*	Moraceae
Ipe amarelo	*Tabebuia ondulata*	Bignonaceae
Imbaúba da mata ou Lixa braba	*Cecropia juraniana*	Moraceae
João mole	*Neea appositifolia*	Vochysiaceae
Jutaí ou Jatobá	*Hymenae courbaril*	Leguminosae
Jurema	*Pityrocarpa pteroclada*	Leguminosae
Janaguba	*Micrantha siphonioides*	Euphorbiaceae
Louro abacate	*Ocotea parviflora*	Lauraceae
Louro gamela	*Nectandra rubra*	Lauraceae
Louro cedro		Lauraceae
Louro prêto	*Ocotea neesiana*	Lauraceae
Louro branco	*Ocotea sp.*	Lauraceae
Louro ferro		Lauraceae
Louro amarelo	*Aniba sp.*	Lauraceae
Louro pimenta	*Ocotea canaliculata*	Lauraceae
Louro aritu	*Licaria aritu*	Lauraceae
Louro inamui ou Pau gasolina	*Ocotea cymbarum*	Lauraceae
Lacre	*Vismia guianensis*	Guttiferae
Lontrinha ou Sapateiro	*Miconia sp.*	Melastomaceae
Leiteira ou Amapá	*Brosimum potabile*	Moraceae
Limãozinho	*Siparuna brasiliensis*	Leguminosae
Massaranduba	*Manilkara huberi*	Sapotaceae
Macucu de paca	*Aldina heterophylla*	Leguminosae
Matamatá	*Eschweilera sp.*	Lecythidaceae
Maruré	*Brosinum parinarioides*	Moraceae
Marupá	*Simaruba amara*	Simarubaceae
Muiratinga	*Olmedia maxima*	Moracea
Muiragibóia	*Swartzia recurva* Poepp	Leguminosae
Matamatá rosa	*Schweilera sp.*	Lecythidaceae
Munguba	*Pseudobombax munguba*	Bombaceae
Mamaozinho	*Guarea* df. *trichilioides*	Meliaceae
Macacauba	*Platymiscium trinitatis*	Leguminosae
Maruparana		
Muiragibóia amarela	*Swartzia sp.*	Leguminosae
Merirana	*Couepia subcordata*	Chrysobalanaceae
Munguba	*Bombax spp.*	Bombaceae
Mutamba setebile	*Guazuma ulmifolia*	Sterculiaceae
Macucu	*Macoubea guianensis*	Apocynaceae

(Page 2 of 6)

Table 2.--Species found in the area of Manasa, Altopurús, Amazônas--continued

Higher lands		
Matamatá branco	*Eschweilera grata*	Lecythidaceae
Muiraúba	*Mouriria plaschaerti*	Melastomataceae
Muirapiranga	*Eperua schomburgkiana*	Leguminosae
Macacaúba da vãrzea	*Platymiscium trinitatis*	Leguminosae
Marimari	*Cassia grandis*	Lecythidaceae
Maparajuba	*Manilkara amazonica*	Sapotaceae
Pau mulato	*Calycophyllum spruceanum*	Rubiaceae
Pau rainha	*Brosimum rubescens*	Moraceae
Pracuuba	*Lecointea amazonica*	Leguminosae
Pau pombo ou Breu de tucano	*Tapirina guianensis*	Anacardiaceae
Piranheira	*Sweetia nitens*	Leguminosae
Piquiarana	*Caryocar microcarpum*	Caryocaraceae
Pajurá	*Parinarium sp.*	Chrysobalanaceae
Papa terra ou Aracá de anta	*Belucia imperialis*	Melastomataceae
Purui	*Duroia macrophylla*	Rubiaceae
Piabinha	*Caxeria spp.*	Flacourtiaceae
Pau amarelo	*Euxylophora paraensis*	Rutaceae
Piquiá marfim	*Aspidosperma album*	Apocynaceae
Pau alho	*Agonandra brasiliensis*	Opiliaceae
Pitomba da mata	*Talisia cerasina*	Sapindaceae
Quaruba vermelha	*Vochysia vismiaefolia*	Vochysiaceae
Quinarana	*Geissospermum vellosii*	Apocynaceae
Quaruba	*Vochysia sp.*	Vochysiaceae
Quaruba branca	*Vochysia melionii*	Vochysiaceae
Ripeiro	*Eschweilera sp.*	Lecythidaceae
Seringa	*Hevea brasiliensis*	Euphorbiaceae
Sucupira amarela	*Enterolobium schomburgkii*	Leguminosae
Sucupira preta	*Doplotropis purpurea*	Leguminosae
Sucuuba	*Himatanthus articulathus*	Apocynaceae
Saboarana	*Swartzia laevicarpa*	Leguminosae
Sumauma	*Ceiba pentandra*	Bombacaceae
Seringarana	*Hevea guianensis*	Euphorbiaceae
Seringa verdadeira	*Hevea guianensis*	Euphorbiaceae
Sapateiro	*Miconia sp.*	Melastomacaceae
Sucupira chorana	*Andira sp.*	Leguminosae
Tanimbuca	*Buchenavia sp.*	Combretaceae
Tachi	*Sclerolobium setiferum*	Leguminosae
Tachi preto	*Tachigalia paniculata*	Leguminosae
Tachi de varzea	*Triplaris surinamensis*	Polygonaceae
Tatajuba	*Bagassa guianensis*	Moraceae
Tatajuba de esphinho	*Chlorophora tinctoria*	Moraceae
Tinteiro	*Miconia sp.*	Melastomaceae
Tamanqueira	*Simaruba amara*	Simarubaceae
Tarumá	*Vitex triflora*	Verbenaceae
Taperebá	*Spondias lutea*	Anacardiaceae
Tauari	*Cariniana micrantha*	Lecythidaceae
Urucurana	*Sloanea sp.*	Elaeorcarpaceae
Uxi de cotia	*Saccoglotis sp.*	Humiriaceae
Ucuuba vermelha	*Virola sp.*	Myristicaceae
Ucuuba verdadeira	*Osteofolium platisperma*	Myristicaceae
Ucuuba punã	*Virola sp.*	Myristicaceae
Ucuuba branca da várzea	*Virola* surinamensis	Myristicaceae
Uxi preto	*Couepia sp.*	Chrysobalanaceae
Ucuuba	*Virola venosa*	Myristicaceae
Umiri	*Humiria floribunda*	Humiriaceae
Violeta pau roxo	*Peltogyne catingaea*	Leguminosae
Xixá	*Maytenus guianensis*	Celastraceae
Xixuá	*Maytenus guianensis*	Celastraceae

(Page 3 of 6)

Table 2.--Species found in the area of Manasa, Altopurús, Amazônas--continued

Flooded lands

Abiurana	Micropholis williamii	Sapotaceae
Araracanga	Aspidospermum spp.	Apocynaceae
Angelim rájado	Pithecolobium racemosum	Leguminosae
Apuí	Clusia spp.	Guttiferae
Abiurana cutite	Lucuma rivíqua	Sapotaceae
Amapá	Parahancornia amapa ducke	Apocynaceae
Angelim da mata	Parkia pectinata (hbk)	Leguminosae
Anani	Simphonia globulifera	Guttiferae
Amapá doce	Brosimum spp.	Moraceae
Abiurana branca	Pouteria spp.	Sapotaceae
Ata brava	Rollinia annonoides	Anonaceae
Andiroba	Carapa guianensis aubl.	Meliaceae
Acariquara branca	Geissospermum sericeum	Apocynaceae
Acariquara roxa	Minquartia guianensis aubl.	Olacaceae
Acapurana	Campsiandra laurifolia bth.	Leguminosae
Azeitona da mata	Hirtella americana	Rosaceae
Açacu	Hura crepitans L.	Euphorbiaceae
Amarelinho	Ponogophora schomburgkiana	Euphorbiaceae
Breu branco	Protium df. giganteum	Burseraceae
Breu almescla	Protium trifoliolatum	Burseraceae
Biriba bravo	Rollinia exsucca (dun.)	Anonaceae
Breu	Protium heptaphyllum (aubl.)	Burseraceae
Buchuchu		
Bacuri bravo	Moronobea coccinea	Guttiferae
Balata rosadinha	Micropholis cyrtobotria	Sapotaceae
Bacuri	Platonia insignis	Guttiferae
Caroba ou paraparà	Jacaranda copaia	Bigononiaceae
Caripé	Licania canescens	Chrisobalanaceae
Cariperana	Licania spp.	Chrisobalanaceae
Cupiuba	Goupia glabra	Celastraceae
Cupuí	Theobroma subicanum	Sterculiaceae
Copaíba roxa	Copaifera spp.	Leguminosae
Castanha jarana	Holopyxidium latifolium	Lecythidaceae
Coraçao de negro	Swrtzia corrugata	Leguminosae
Cedrodrana	Cedrelinga catanaeformis	Leguminosae
Carapanaúba	Aspidosperma oblogum	Apocynaceae
Cumaru roxo	Coumarona sp.	Leguminosae
Cumarurana	Taralea oppositifolia	Leguminosae
Castanha de macaco	Caroupita guianensis	Lecythidaceae
Cajuí	Anacardium spp.	Anacardiaceae
Cernambi de indio ou Cariperana	Licania spp.	Chrisobalanaceae
Castanha vermelha	Eschweilera spp.	Lecythidaceae
Cacaurana	Theobroma sylvestre	Sterculiaceae
Cacauí	Theobroma sylvestre	Sterculiaceae
Canjarana	Micrantha spruceana	Euphorbiaceae
Cabeça de urubu	Dukoia saccifera	Rubiaceae
Cedro branco	Cedrela fissilis	Meliaceae
Cedro vermelho	Cedrela odorata	Meliaceae
Cajuacú	Anacardium giganteum	Anacardiaceae
Envira surucucú	Duguetia flagellaria	Anonaceae
Envira fofa	Xylopia sp.	Anonaceae
Envira pente de macaco	Guateria spp.	Anonaceae
Ingá copiaba	Inga sp.	Leguminosae
Inharé	Inga sp.	Moraceae
Ingarana	Pithecolobium latifolium	Leguminosae
Ipé amarelo	Crudia spp.	Leguminosae
Itaúba	Mezilaurus itauba	Lauraceae
Itaubarana ou saboarana	Casearia sylvestri	Flacourtiaceae
Itaúba abacate	Mezilaurus duckei	Lauraceae

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Table 2.--Species found in the area of Manasa, Altopurús, Amazônas--continued

Flooded lands

Jatobá	*Himenae courbaril*	Leguminosae Caes
João mole	*Neea oppositifolia*	Nyctaginaceae
Jutaicica	*Hymenea spp.*	Leguminosae
Jacareúba	*Calophyllum brasiliense*	Guttiferae
Louro branco	*Ocotea guianensis*	Lauraceae
Louro preto	*Ocotea neesiana*	Laureceae
Louro aritu	*Acrodiclidium appelii*	Laureceae
Louro gamela	*Nectandra rubra*	Lauraceae
Louro chumbo	*Cordia excelsa*	Borraginaceae
Louro pimenta	*Ocotea canaliculata*	Lauraceae
Lacre	*Vismia guianensis*	Guttiferae
Lacre vermelho	*Vismia brasiliensis*	Guttiferae
Leiteira	*Brosimum potabile*	Moraceae
Lontrinha	*Miconia sp.*	Melastomaceae
Matamatá	*Eschweilera odora*	Lecythidaceae
Macucu murici	*Aldina heterophylla*	Leguminosae
Muiratinga	*Naucleopsis caloneura*	Moraceae
Mulateiro ou Guatanquiçava	*Peltogyne paniculata*	Leguminosae
Maruré	*Apuleia ferrea*	Caesalpinoideae
Mandioqueira lisa	*Qualea albiflora*	Vochysiaceae
Muirapiranga	*Brosimum paraense*	Moraceae
Mamaõzinho	*Guarea trichilioides*	Meliaceae
Massaranduba	*Manilkara surinamensis*	Sapotaceae
Matamatá rosa	*Eschweilera spp.*	Lecythidaceae
Muiragibóia	*Swartzia cinerea*	Leguminosae
Morototó	*Didymopanax morototoni*	Araliaceae
Manguba	*Pseudobombax munguba*	Bombaceae
Macacaúba	*Platymiscium ulei*	Leguminosae
Marupá	*Simaruba amara*	Simarubaceae
Murici vermelho	*Byrsonima spicata*	Malpighiaceae
Matamatá preto	*Eschweilera collins*	Lecythidaceae
Matamatá branco	*Eschweilera odora*	Lecythidaceae
Mutamba	*Guazuma ulmifolia*	Sterculiaceae
Pau rainha	*Centrolobium paraense*	Leguminosae
Pajurá	*Lucuma speciosa*	Sapotaceae
Piquiá marfim	*Aspidosperma centrale*	Apocynaceae
Pau amarelo	*Euxylophora paraensis*	Rutaceae
Piquiarana	*Caryocar globrum*	Carycaraceae
Pau pombo	*Taipirira guianensis*	Anacardiaceae
Pau mulato	*Peltogyne panniculata*	Leguminosae
Purui	*Duroia macrophylla*	Rubiaceae
Piabinha	*Caxeria spp.*	Flacourtiaceae
Quaruba branca	*Vochysia melinonii*	Vochysiaceae
Quinarana	*Geissospermum sericeum*	Apocynaceae
Quarubarana	*Erisma laceolatum*	Vochysiaceae
Quaruba rosa	*Vochysia sp.*	Vochydiaceae
Ripeiro	*Eschweilera polyantha*	Lecythidaceae
Rosada brava		
Rosada verdadeira		
Seringueira	*Hevea brasiliensis*	Euphorbiaceae
Seringarana	*Hevea guianensis*	Euphorbiaceae
Sapateiro	*Miconia sp.*	Melastomataceae
Sucupira	*Diplotropis purpurea*	Leguminosae
Sucupira vermelha	*Andira parviflora*	Leguminosae
Sucupira chorona	*Andira spp.*	Leguminosae
Sucupira amarela	*Enterolobium schomburgkii*	Leguminosae
Sucupira peluda	*Hymenolobium pulcherrimum*	Leguminosae
Sorva grande	*Couma macrocarpa*	Apocynaceae
Sorva da mata	*Couma macrocarpa*	Apocynaceae
Saboarana	*Swrtzia laericarpa*	Leguminosae

Table 2.--Species found in the area of Manasa, Altopurús, Amazônas--continued

Flooded lands

Tachi preto	*Tachigalia paniculata*	Leguminosae
Tachi vermelho	*Tachigalia spp.*	Leguminosae
Tavari	*Cariniana intergrifolia*	Lecythidaceae
Tento	*Ormosia paraensis*	Leguminosae
Tinteiro	*Miconia spp.*	Melastomaceae
Tanimbuca	*Buchenavia sp.*	Combretacea
Tachi pitomba	*Sclerolobium paniculatum*	Leguminosae
Tachi amarelo	*Tachigalia sp.*	Leguminosae
Tarumã	*Vitex sp.*	Verbenaceae
Taquari	*Mabea sp.*	Euphorbiaceae
Tapura		
Ucuuba branca	*Virola sp.*	Myristicaceae
Ucuuba punã	*Virola sp.*	Myristicaceae
Ucuuba prêta	*Virola cuspidata*	Myristicaceae
Ucuuba verdadeira	*Osteophloeum platyspermum*	Myristicaceae
Ucuuba brava ou Lacre da mata	*Osteophloeum platyspermum*	Myristicaceae
Uxi de cotia	*Saccoglottis sp.*	Humiriaceae
Uxi prêto	*Couepia sp.*	Chrysobalanaceae
Ucuquirana brava	*Ecclinusa balata*	Sapotaceae
Urucurana	*Concereiba guianensis*	Euphorbiaceae
Uxirana	*Saccoglottis amazonica*	Humiriaceae
Umiri	*Humiria floribunda*	Humiriaceae
Ucuquirana	*Ecclinusa balata*	Sapotaceae
Visgueiro	*Parkia pendula*	Leguminosae
Violeta	*Peltogyne catingaea* Ducke	Leguminosae
Xixuá	*Maytenus guianensis*	Olacaceae

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Table 3.--Volume of species found in the area

Fazenda "Manasa", Alto Purus, Municipio de Pauini, Amazonas, Brazil.
Estimated area: 56,979 ha (569,790,000 m^2)
Number of species found: 391

Type of land	Minimum volume in m^3/ha	No. of trees per ha	Area in ha	Total volume in m^3	Total trees
I. TOTAL VOLUME OF WOOD IN THE AREA (OVER 45 CM DIAMETER)					
Higher lands	266.75	199	24,290	6,479,357	4,833,710
Flooded lands	199.86	156	29,940	5,893,808	4,670,640
Lakes and rivers	--	--	2,749	--	--
Total of the area			56,979	12,463,165	9,504,350
II. FOR 47 COMMERCIAL SPECIES WITH DIAMETER OVER 45 CM					
Higher lands	118.33	61	24,290	2,874,896	1,492,663
Flooded lands	81.51	31	29,940	2,437,805	945,521

Resume: 38 commercial species with more than 10,000 m^3 ... 5,048,637 m^3
9 commercial species with less than 10,000 m^3 ... 264,064 m^3

Total of 47 species ... 5,312,701 m^3

Table 4.--Species found in "Fazenda Manasa," Amazonas, Brazil

Species	Volume m^3/ 100 ha	No. trees in 100 ha	Volume total m^3	No. trees total
		1. HIGHER LANDS		
Abiurana (*Pouteira spp.*)	2,322	1,435	564,038	348,565
Castanha jarana (*Holopyxidium l.*)	558	120	135,660	29,148
Cedrorana (*Cedrelinga catanaef.*)	1,180	80	286,768	19,431
Faveira (*Parkia multijuga*)	678	113	184,832	27,446
Leiteira (*Brosimum potabile*)	466	154	113,313	37,405
Louro gamela (*Nectandra rubra*)	235	70	57,154	17,002
Louro preto (*Ocotea neesiana*)	398	236	96,869	57,325
Macucú (*Aldina heterophylla*)	451	403	109,645	97,888
Macucú muricí (*Licania spp.*)	297	252	72,287	61,210
Massaranduba (*Manilkara huberi*)	100	54	24,314	13,116
Matamatá (*Eschweilera grata*)	782	920	190,093	223,488
Muiratinga (*Naucleopsis calou.*)	248	259	60,288	62,911
Piquia marfim (*Caryocar spp.*)	84	56	20,428	13,602
Piquiarana (*Caryocar glabrum*)	451	136	109,742	33,034
Sucupira amarela (*Vatairea ser.*)	89	52	21,691	12,630
Sucupira preta (*Diplotropis pur.*)	281	27	68,279	6,558
Sucupira vermelha (*Andira parvif.*)	186	50	45,179	12,145
Tachi preto (*Tachigalia panicul.*)	82	85	19,990	20,646
Tachi vermelho (*Schlerolobium spp.*)	318	158	77,291	38,378
Tauarí (*Cariniana integrifolia*)	184	48	44,863	11,659
Ucuuba branca (*Virola surinamens.*)	394	119	95,873	28,904
Ucuuba preta (*Virola sebifera*)	90	43	22,031	10,444
Ucuuba punà (*Virola spp.*)	202	204	49,163	73,841
Ucuuba vermelha (*Virola spp.*)	60	65	14,792	15,788
Violeta (*Peltogyne cataingae*)	116	50	28,346	12,144
		2. FLOODED LANDS		
Abiurana (*Pouteira spp.*)	542	314	162,275	94,012
Abiurana branca (*Pouteira surin.*)	156	39	46,916	11,617
Abiurana cotite (*Pouteira macroph*)	72	40	21,736	11,977
Andiroba (*Carapa guaianensis*)	442	248	132,545	74,251
Assacú (*Hura crepitans*)	569	62	170,418	18,564
Catanha jarana (*Holopyxidum rut.*)	55	25	16,557	7,485
Copaiba (*Copaifera spp.*)	298	49	89,341	16,671
Faveira (*Hymenolobium pulcherium*)	214	111	64,191	33,234
Ingarana (*Pithecolobium latifolium*)	42	64	12,545	19,162
Itaubarana (*Mezilaurus itauba*)	48	37	14,401	11,078
Jatobá (*Hymenaea oblongifolia*)	192	84	57,575	25,150
Macucú (*Aldina heterophylla*)	372	425	111,556	127,245
Massaranduba (*Manilkara huberi*)	482	150	144,521	44,912
Matamatà (*Eschweilera grata*)	492	401	147,545	120,059
Matamatà rosa (*Eschweilera spp.*)	241	55	72,335	16,468
Muiratinga (*Naucleopsis calou.*)	307	181	91,886	54,192
Mulateiro (*Peltogyne paniculata*)	2,231	147	668,141	44,012
Piquiarana (*Caryocar glabrum*)	67	57	20,149	16,168
Sucupira amarela (*Vatairea ser.*)	199	51	59,760	15,270
Sucupira vermelha (*Andira parvi*)	86	20	25,718	5,988
Tachi vermelho (*Schlerolobium se*)	97	67	28,982	20,060
Tauarì (*Cariniana integrifolia*)	111	34	33,443	10,180
Ucuuba branca (*Virola surinam.*)	85	40	25,569	11,976
Ucuuba vermelha (*Virola spp.*)	37	48	11,077	14,372

Brazilian name	Botanical name	Total volume m^3	Volume m^3/ha
Abiurana	*Pouteria spp.*	726,314	12.75
Mulateiro	*Peltogyne paniculata*	674,043	11.82
Matamatá	*Eschweilera grata*	337,638	5.92
Cedrorana	*Cedrelinga cataneaformis*	286,768	5.03
Faveira	*Parkia multijuga*	229,024	4.02
Macucú	*Aldina heterophylla*	221,202	3.88

These six species make up 2,475,000 m^3, or 49 percent of the total commercial volume in the area of easy extractability. Other species of medium density include:

Brazilian name	Botanical name	Total density m^3
Assacú	*Hura crepitans*	170,418
Macaranduba	*Manilkara huberi*	168,836
Castanha Jarana	*Holopyxidium rutifolium*	152,217
Muiratinga	*Naucleopsis caloneura*	152,174
Jatobá	*Hymenaea courbaril*	140,112
Andiroba	*Carapa guianensis*	133,638
Piquiarana	*Caryocar villosum*	129,893
Ucuuba Branca	*Virola surinamensis*	121,442
Leiteira	*Brosimum potabile*	118,702
Louro Preto	*Ocotea neesiana*	106,989
Tachi Vermelho	*Tachigalia spp.*	106,273

These 11 medium-density species, all well known commercially in Brazil, make up 1,500,000 m^3 or 30 percent of the total in the area. In summary, these 17 species make up almost 80 percent of the total volume of the area, each with more than 100,000 m^3. The rest is made up of 21 species, each with 10,000 m^3 or more.

The occurrence of the high-density woods can be seen comparatively as follows:

	Density in m^3/ha		
Species	Inventory by Manasa	Studies by Sudam	W. D. de Barros (2) Supren, 1977
Abiurana	12.75	15.0	15.04
Mulateiro	11.82	--	--
Matamatá	5.92	15.5	14.06
Cedrorana	5.03	--	--
Faveira	4.02	9.7	6.17
Macucú	3.88	--	2.8
Total	43.42	40.2	38.07

Average density: 40,563 m^3/ha

If these data were applicable to the entire Amazon region, these six little-known species might yield 140 billions of cubic meters. Whatever their true volumes may be, it is apparent that these six species may become important in future timber markets. The best known of the group--mulateiro--is closely related to purpleheart (Peltogyne catingaea) but has brown heartwood. It is difficult to work, but surfaces well. It is strong, durable, and seasons well and rapidly. Its principal use is as sleepers and interior construction (4).

The densest wood of these six species--abuirana--actually is a group of species, with yellowish brown or rose-colored heartwood weighing about 1,000 kg/m^3, with good mechanical properties, strong, and durable. It is used for sleepers, construction, and flooring.

Matamatá also represents a group of species, varying chiefly in the color of their woods. Texture is medium, density 900 kg/m^3. It is used in construction and for sleepers.

Known characteristics of these six species are seen in tables 5 and 6. The uses of the Amazon species inventoried are presented in table 7.

It is hoped that this paper will draw attention to the continuing need to develop markets for the many little-known woods of the Amazon.

Table 5.--Characteristics of six little-known species

	Abiurana (*Pouteira spp.*)	Mulateiro (*Peltògyne paniculata*)	Faveira (*Parkia multijuga*)	Matamatá (*Eschweilera grata*)	Cedrorana (*Cedrelinga cataneaformis*)	Macucú (*Aldina heterophylla*)
Density						
In gr/cm^3	0.90 to 0.95	0.85 to 1.00	0.50 to 0.55	0.88 to 0.98	0.65 to 0.75	0.85 to 0.95
In lb/cu ft	56 to 59	53 to 62	31 to 34	55 to 61	40 to 47	53 to 59
Heartwood	Pale reddish brown	Reddish brown going easily to dark brown	Light gray-brown with reddish lusters	Light grayish to dark brown sometimes lustered	Reddish brown	Light reddish with clear vessel lines
Sapwood	Not clearly demarcated, but more pale	Yellowish brown, demarcated from heartwood	Not demarcated, very pale	Yellowish, clearly demarcated	More pale and slightly lighter	Yellowish gray with low luster
Grain	Regular	Regular (sometimes irregular)	Straight	Regular	Straight	Interlocked
Texture	Medium	Coarse	Medium	Medium	Coarse (similar to cedar)	Coarse
Odor	Undistinguish.	Undistinguish.	Without	Unpleasant when fresh cut	Unpleasant when fresh cut	Undistinguish.
Taste	Undistinguish.	Undistinguish.	Without	Undistinguish.	Undistinguish.	Undistinguish.
Luster	Medium	Smooth polish	Light polish	Low	Low	Low
Workability	Some difficulties	Moderately difficult	Very easy	Easy	Easy	Easy
Staining	Regular	Good--very decorative	Good	Good with low staining	Good	Good
Durability	Durable	Very durable	?	Very durable	Not durable accept preserv.	Very durable

Reference: (3) of Bibliography.

Table 6.--Present uses of six little-known species

Utilization	Species					
	Abiurana	Mulateiro	Matamata	Cedrorana	Faveira	Macucu
Civil construction	X	X	X	X	X	X
Furniture	--	--	--	X	X	--
Turnings	--	X	--	--	--	--
Structural constrauction	X	--	--	--	--	--
Wooden boxes	--	--	--	X	X	--
Hardwood flooring	X	X	--	--	--	--
Cellulose	--	--	--	X	X	--
Sleeper and poles	X	X	X	--	--	X
Joinery	X	--	X	X	X	--
Naval construction	--	--	--	X	--	--
Internal construction	X	X	X	--	X	--
External construction	X	--	X	--	X	X

Table 7.--Utilization of species from the upper Amazon

Species	Category	Civil construction	Furniture	Veneer and plywood	Turnings	Tool handles	Structural construction	Toys	Matches	Wooden boxes	Hardwood flooring	Cellulose	Sleepers and poles	Joinery	Naval construction	Latex	Internal construction	External construction	Mouldings and blinds	Parquet
Abiurana	D	X					X				X		X	X			X	X		
Andiroba	A	X	X	X		X		X		X				X			X			
Angelim da mata	B	X	X	X	X			X						X					X	
Angelim rajado	B		X	X	X	X	X				X			X			X	X		
Balata rosadinha																X				
Caroba	B	X		X				X	X	X		X					X		X	
Castanha jarana	B	X				X	X				X									Y
Castanha de macaco	D	X				X				X		X					X	X		
Cedrorana	C		X		X					X			X	X	X		X			
Copaiba	C	X	X	X		X								X			X			
Cupiúba	C		X							X				X			X	X		
Faveira	D	X	X							X		X		X			X	X		
Igarana	B	X			X									X			X	X		
Itaúba	C	X			X					X	X			X	X			X		
Jacareúba	C			X		X					X			X	X					
Jatobá	B	X	X	X	X	X	X				X		X	X			X	X		
Leiteira	C															X				
Louro	B	X	X	X										X	X				X	
Louro anamuí	B	X	X	X	X								X				X			
Louro preto	B				X	X	X	X					X			X				
Macacaúba	B	X	X	X	X		X				X			X			X			
Macucu	D	X											X					X		
Macucu murici	D	X					X										X	X		
Marupa	B	X	X	X			X			X								X		
Massaranduba	B	X			X	X	X			X	X		X		X			X		
Matamatá	D	X					X						X	X			X	X		
Muiratinga	D	X		X										X			X			
Mulateiro	D	X			X						X		X				X			
Piquiá marfim	D	X		X	X		X				X		X	X	X		X			
Piquiarana	C	X		X	X		X				X		X	X	X		X	X		
Piquiá verdadeira	C	X		X	X		X				X		X	X	X		X	X		
Sucupira amarela	C		X				X				X	X		X						
Sucupira preta	C	X	X		X		X				X		X	X						
Sucupira vermelha	B	X			X						X		X	X	X					
Tachi preto	D	X					X			X				X			X	X		X
Tachi vermelho	D	X					X		X					X			X	X		X
Tauari	B	X		X	X	X				X				X			X			
Ucuuba branca	C			X						X				X						
Violeta	B	X	X		X						X		X	X	X		X	X		
Andiroba	A	X	X	X	X	X				X				X	X		X			
Acacu	D			X						X							X			
Cedro	A		X	X						X				X	X		X			
Cedro vermelho	A		X	X						X				X	X		X			
Itaubarana	D	X											X		X		X	X		
Marupá	B		X	X					X	X				X	X		X			
Matamatá branco	D	X					X	X									X	X		
Ucuuba da várzea	D		X	X						X										

Categories of the species		
	A:	Very well accepted in the International Market.
	B	Accepted in the National Market with export possibilities.
	C·	Known in the National Market only.
	D:	Known only in the Amazon Region, unknown in Brazil.

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FACTORS AFFECTING PULPWOOD FROM PLANTATIONS AND NATURAL FORESTS IN THE TROPICS

By

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INTRODUCTION

Every informed commentator predicts a large increase in the consumption of paper for the rest of this century--the only difference of opinion concerns the rate of increase. Consequently there is considerable interest in the source of the pulp. Tables 1 and 2 indicate the importance of the countries that are not at present major producers of pulp for this purpose. These tables make it obvious that about 80% of the world's woodpulp is being made in areas which have only 20% of the forest resources.

The forest areas in tropical countries are predominantly mixed hardwood forests. Data for the 41 African countries that were independent in 1972 gave a total forest area of over 565×10^6 ha, but the area of plantations was 530×10^3 ha of softwoods and 746×10^3 ha of hardwoods (FAO 1965). Thus the total area of plantations was less than 0.25% of the total forest area. Although more plantations will have been planted in the last five years, the proportion of plantations to natural forests is still very small. The proportion of plantation to natural forest is similar in most tropical areas. If these areas are to make a significant contribution to the production of woodpulp, a number of decisions are required. Significant questions to be answered are:

1. Should pulp mills be built, possibly using modified pulping techniques, to use the existing forests, or should alternative uses be made of the existing forest, and plantations of desirable species established.

2. If it is decided to use the mixed forest, should these forests be allowed to regenerate naturally, or should there be a policy of reafforestation with desirable plantations species?

The purpose of this paper is to discuss some of the factors that will affect these choices. The fact that inflation is causing continuous changes in costs and that many of the other factors are local and can only be considered in connection with a specific project, means that this paper must be written in general terms and without any effort to quantify the economic advantages of alternative sources of raw material.

Table 1.--Distribution of world forest resources

	Percent
North America	16.7
Europe	3.5
U.S.S.R.	19.0
Rest of the world	60.8

Table 2.--Distribution of wood pulp production

	Percent
North America	52
Europe	26
U.S.S.R.	8
Asia	10
Latin America	2
Oceania	More than 1
Africa	Less than 1

USE OF THE MIXED FORESTS

One problem in making industrial use of the mixed forest is the fact that forests are composed of a large number of species with often widely differing characteristics. At the same time it is the heterogeneity that provides one argument for some industrial use. In one forest area which I visited I was told that fewer than eight trees per hectare were desirable and valuable timber species. If some use were found for the trees that are at present left standing, it would be easier and cheaper to extract the desirable timber species and the profitability of the whole project would be improved by the value of the otherwise unused timber.

The number of species occurring in any given area varies, but it is always large. Recently, at the Tropical Products Institute an examination of hardwoods from a South American country was undertaken. The 20 species occurring most frequently amounted to 70% of the volume of timber. The remaining 30% of the volume included more than 50 species. A survey for an African country included a table "Species list of the commoner trees" and it included 217 species (private communication to TPI). Australian work in Papua New Guinea found between 100 and 200 species that are likely to be considered for commercial utilization in any one area, although in general 30 species would comprise 75% of the total merchantable volume (Higgins et al. 1973).

Since a relatively small number of species comprise a large proportion of the total volume, only six species representing about 46% of the standing volume of trees were examined in the recent trials at the TPI; but since some 10-12% of the standing volume are valuable timber species, the six species represented a little more than half the mixture that would be available for pulping.

However, examination of these six species showed a great variation in pulping properties. Pulping each species separately, using constant digestion conditions intended to produce a bleachable pulp, afforded unbleached pulp yields between 42.4 and 44.8% with kappa numbers from 16 to 35. The variation in pulp strength was also large: Tensile index in the range 60-92; burst index, 3.1-5.0; and tear index, 7.5-12.4; all measured at 300 Canadian Standard freeness. Consequently, it is obvious that the required digestion conditions and the quality of pulp obtained will vary with the composition of the mixture of wood species put into the digester. The prospects of producing a uniform pulp seem to depend on the prospects of attempting a selection of wood to ensure the reasonably uniform wood supply. There are technical problems in making such a selection, and it might be a costly process. Hardwoods in other parts of the world have been found equally varied in their response to sulphate pulping. Twenty-four species from one area in Papua New Guinea, pulped by the sulphate process in Australia, had pulp yields between 42.5 and 52.2% with kappa numbers between 18 and 44 (Higgins et al. 1973).

Table 3.--Area of plantation to supply a 165,000 tonne/annum pulp mill

Rate of growth, m^3/ha/ann	7				15				30				100			
Wood density, kg/m^3	400		500		400		500		400		500		400		500	
Pulp yield, Wt. of ovendry pulp / Wt. of ovendry wood	45	50	45	50	45	50	45	50	45	50	45	50	45	50	45	50
Rotation, years	10	10	10	10	7	7	7	7	7	7	7	7	3	3	3	3
Plantation area required, ha X1000	131	118	105	94	61	56	49	44	31	28	25	22	9	8	7	7

COMPARISON OF AREAS OF FOREST REQUIRED

It is difficult to illustrate the difference between the areas required to supply a pulp mill by the use of plantations and by natural forest. Plantations are planned with a view to continuous yield whilst some projects, at least designed to use natural forests, do not take into account any regrowth. Table 3 gives details of the area of plantation required to supply a 165,000 tonne per year pulp mill, making certain assumptions concerning the rate of growth, wood density, and pulp yield. Estimates at the TPI show samples of *Gmelina arborea* yielding over 30 m^3/ha/annum of wood with a density of around 400 kg/m^3 and yielding over 50% of unbleached pulp; and samples of *Eucalyptus* spp. with growth rates reported to be in excess of 20 m^3/ha/annum, wood density over 500 kg/m^3, and pulp yields in excess of 50%. For such samples total plantation areas in the region of 20,000 to 30,000 ha, of which some 4,000 to 5,000 ha would be harvested each year, would be able to supply a pulp mill of this size. Whether areas of under 10,000 ha are realistic depends on the identification of suitable sites and species, but reports that *Leucaena leucocephala* will produce 24-312 m^3/ha/annum of wood with a density over 500 kg/m^3 does indicate that in some, probably exceptional circumstances, very small areas will suffice.

Estimation of the area required for natural forest necessitates different assumptions. The standing volume of wood in tropical forests has been estimated between 10 m^3/ha and 300 m^3/ha, depending on conditions, although the figure quoted most often is around 100 m^3/ha. Many hardwood species in natural forests have higher wood density than those in plantations, but experience at the TPI in evaluating mixed hardwoods is that it is unusual to obtain pulp yields greater than 45%. Consequently, in order to estimate the area required to supply a pulp mill which is producing 165,000 tonnes of pulp per year, it was assumed that the wood density was 600 kg/m^3 and the pulp yield 45%. Under these circumstances it would be necessary to clear-fell an area of about 2,250 ha with a range of from around 750 ha at the highest stocking to over 20,000 ha at the lowest stocking density. The area would be changed by variation in wood density, by pulp yields, and by the proportion of the wood eliminated as unsuitable; however, the range is so wide and so many variables are involved that the variation is not possible to quantify. Of course this area is sufficient to supply a pulp mill for one year only.

To estimate the total area required, further assumptions must be made. Some authorities say that the total quantities of wood available are so great that there is no need to be concerned with regeneration. Since the total quantity of timber standing in African tropical high forest has been put at 3 x 10^{10} m^3 with another 1 x 10^{10} m^3 in savanna woodlands, it is obvious that there is something to support this argument (FAO 1965). . . . Against it is the fact that, with use, the timber would need to be transported over an increasing distance.

Allowances for regeneration are difficult to quantify. One suggestion has been that seed trees should be left to encourage natural regeneration of the forest of the composition similar to that being felled. However, it is estimated that 40 years after clear felling the stocking density of the regenerated forest would still be only around 100 m^3/ha. This represents a rate of growth barely 10% of that which might be expected had the cleared area been replaced with plantations, and the prospect is that the composition of the regenerated forest would be greatly different from the original. Thus the quality of pulp and probably the process required for producing it would be different (private communication to TPI). However, even this low rate of growth may be optimistic, as in another estimate the growth increment of the regenerated forest was taken as about 0.5 m^3/ha/annum and this would give a stocking density of only 20 m^3/ha after 40 years (Ganguly 1971).

An alternative form of natural regeneration would be to encourage the growth of the "weed" species that are usually the first to develop after clear felling. This would increase considerably the volume of wood produced in the early years after clearing and would justify cutting over the same area again in a very much shorter period, but most of the wood produced would be of low density (200-300 kg/m^3) and would be so different from the original harvest that some difference in necessary pulping technique and quality of resulting wood pulp would be inevitable. The comparisons between plantations and natural forest mean that the 165,000 tonne per annum mill would need some 25,000 ha of plantations to supply the mill indefinitely; but assuming a 50-year life of the mill, the total area of natural forest could be anywhere between 35,000 and 1,000,000 ha, or, allowing for regeneration at the rate of 2.5 m^3/ha/annum, around 110,000 ha. Even the most optimistic assumptions for the area of natural forest required to sustain the mill show that it is greater than that required for plantations. This means that the haulage distance is greater and constantly increasing and that additional roads are required every year. By contrast, for plantations the haulage distance for any given year is known with reasonable precision; since an area is likely to be logged over every 5-10 years, the roads once built can be permanent.

A similar situation is found when comparing natural stands of conifers with plantations, although the rotation period of conifer plantations will be longer than that of hardwood plantations. In an examination of <u>Pinus caribaea</u> in which samples grown in plantations were compared with samples grown in plots of natural regeneration, it was found that the average size of tree was greater for the plantations than for the natural regeneration plots. A greater difference was observed for the stocking density. In the plantations this varied from over 1,000 trees/ha at about 10 years old to 250-300 trees/ha at about 25 years old; in the eight natural regeneration plots studied, the stocking density varied from 124 to 321 trees/ha (Palmer and Gibbs 1976).

Thus, as for hardwoods, the total area of coniferous plantations required would be smaller than that of natural forest.

HARVEST AND TRANSPORT OF WOOD

The harvesting of plantation timber is normally easier than that of natural forest because of the more uniform size of trees and because access to the plantations has already been established. One harvesting problem that occurs sometimes in natural forests but is very rare in plantations is the felling of irregular-shaped trees, especially those which are buttressed. For land transport of logs, the natural forests have an advantage in the higher density of logs, which means that a greater weight of wood can be carried as a single load; a maximum load of a truck of logs is more often determined by volume than by weight. However, excessively irregularly shaped logs could nullify this advantage. If it is planned to float logs, then the natural forests are at a disadvantage because of the high proportion of logs that sink, owing to their higher density, coupled with high moisture content (70-80% has been observed for wood as received).

HANDLING AND PROCESSING OF WOOD

The removing of bark from wood from natural forest is often more difficult than from plantation wood, because the irregular shape of logs makes cleaning more difficult and the higher density makes an extra load for the debarking drums. This is a serious disadvantage only where bleached pulps of high brightness are required, because some hardwoods have relatively thin bark and this can often be pulped. Woods from plantations are not invariably easily barked; some eucalypts are very difficult to debark especially if the wood has started to dry.

Chipping of the wood from natural forests can cause difficulties because their hardness, higher density, and the presence in some samples of high contents of abrasive materials such as silica, lead to higher power consumption and greater wear on chipper knives. In addition, irregular size and shape of wood from natural forests make it more likely that this material would need some pretreatment, such as splitting, before chipping; by contrast, the more uniform plantation material would be grown on a rotation and eliminate this requirement.

COMPARISON OF WOOD FROM MIXED HARDWOOD FORESTS AND PLANTATIONS

The most obvious difference between wood from natural hardwood forest and plantations is the density. As might be expected from a forest containing well over 100 species, the prospects are that the wood density will vary widely and values from under 200 kg/m^3 to over 1,000 kg/m^3 have been quoted. In our experience at TPI, the wood available for exploitation tends towards the upper end of the range, because the low density trees are usually the first to become reestablished when a forest area is cleared, but they are short lived and easily suppressed when the more robust and more dense trees become established.

Thus the mean density of a sample of wood from South America was 735 kg/m^3 with values in the range of 423-920 kg/m^3. This is one respect in which mixed forests from different parts of the world differ; mixed samples from various localities in Papua New Guinea had densities of between 431 and 498 kg/m^3 (Higgins et al. 1973). By contrast with this variation in the natural forest, it is possible to select species to grow in plantations with fairly uniform densities in the range of 400-550 kg/m^3.

The main difference in chemical composition between woods from natural forests and plantations is that the former tend to have higher ash content and the ash contains more silica.

The mixed hardwoods also tend to be harder. At TPI we have not been able to quantify this factor, but we did have much more difficulty in sawing and chipping samples from natural forests in South America than in any plantation species we have examined. These factors are important not only in chipping, as mentioned above, but also in digestion because the higher ash content, and again the high silica content, makes the efficient operation of the recovery system more difficult.

COMPARISON OF PULPS FROM MIXED HARDWOODS AND OTHER PULPWOODS

Ease of Digestion

In work at TPI, a mixture was prepared of six species of wood in the proportion they were found in the forest. This mixture was pulped by the sulphate process, and the digestion conditions and pulps obtained were compared with those for two hardwoods often used for pulping and for some hardwood species grown in plantations in the tropics. The results, given in table 4, show that the mixed hardwoods needed more severe digestion conditions in terms of chemical charge and digestion time. The mixed tropical hardwood needed longer digestion time principally because it was more difficult for the cooking liquor to penetrate these samples; when the temperature was raised rapidly to that required for digestion, there was an excessive amount of screening rejects.

Investigations were made in Brazil to compare mixed hardwoods from the Amazon area with plantation-grown eucalypts, and also in Australia, where hardwoods from Papua New Guinea were compared with eucalypts used commercially in Australia. They also reported that the mixed hardwoods needed more severe pulping conditions (Correa et al. 1974, Higgins et al. 1973).

Yield of Pulp

Investigations at the TPI have shown that at constant kappa number the yield of pulp from mixed tropical hardwoods was lower than that from temperate hardwoods and from most hardwoods grown in plantations in the tropics.

The difference can be as much as 5 or 6% (dry pulp or dry wood) when compared with the best yields obtained from species grown in plantations. Again these findings agree with those of investigations in Brazil and Australia.

Table 4.--Comparison of digestion conditions and pulp strengths (USA mixed hardwoods = 100). All cooks: 25% sulphidity, 170° C maximum temperature and 5:1 liquor to wood ratio

Digestion conditions	Tropical mixed hardwoods		Mixed USA hardwoods	Beech	Eucalyptus saligna	Eucalyptus camaldulensis	Gmelina arborea	
							Highest yield	Lowest yield
Active alkali as Na_2O on ovendry wood	17.5	20	15	15	15	15	15	15
Time to reach maximum temperature, hours	2	2	1	1	1	1	1	1
Time at maximum temperature, hours	2	2	2	2	2	2	2	2
YIELD OF PULP								
Ovendry digested pulp, percent ovendry wood	46.7	45.4	49.4	49.8	51.7	46.6	51.9	46.4
Ovendry screened pulp, percent ovendry wood	46.0	45.2	47.8	45.2	51.0	45.7	51.5	46.0
Ovendry screenings, percent ovendry wood	.7	.2	1.6	4.6	.7	.9	.4	.4
Kappa number	28.4	24.6	27.6	23.2	23.7	28.3	25.5	34.7
PULP STRENGTH AT 300 C.S.F.								
Beating time in p.f.i. mill	127	130	100	113	102	67	96	104
Tensile strength	81	78	100	90	105	99	110	108
Bursting strength	68	62	100	87	104	92	111	104
Tearing strength	99	103	100	79	89	87	90	100

Quality of Pulp

In order to compare the quality of pulps from mixed tropical hardwoods with that from temperate-grown hardwoods and from hardwood species grown in plantations in the tropics, table 4 gives some strength characteristics, compared on the basis of pulp from United States southern hardwoods as 100. The pulps from mixed tropical hardwoods were more difficult to beat, whilst those from plantations were the same or easier. The tensile and bursting strength of the pulps from mixed tropical hardwoods were lower, whilst those of the pulps from the plantation-grown species were equal or higher. The tearing strength of pulps from both the tropical and United States mixed hardwoods were equal, whilst the pulps from the plantation-grown species had a lower tearing strength.

These results indicate that the only technical advantage pulps from mixed hardwood species have over pulp from hardwoods grown in plantations in the tropics are higher tearing strength and higher bulk of pulp sheets. Again these results are in general agreement with those reported in Brazil and Australia (Correa et al. 1974, Higgins et al. 1973).

Cost of Wood

An argument made frequently for the use of mixed forest is the importance of utilizing all this "free" cellulose. However, this is a doubtful argument. In its favour is the fact that to establish plantations, land must be acquired, cleared, and planted. All of this involves capital costs and interest charges with no return until the first rotation is felled. Also, with natural regeneration, there are no replanting costs.

Against this argument are several case studies carried out for FAO in Africa which indicate that the cost of pulpwood grown in plantations (measured by volume) delivered at a pulp mill will be less than that of mixed hardwoods; the cost of the more difficult harvesting, together with the need to exploit a larger area, more than compensates for the cost of establishing plantations (Streyffert 1968). In the case of hardwood plantations, the cost of the second and subsequent crops is reduced by the fact that regrowth (at least for a number of species) is by coppice growth, not replanting.

It would be necessary to study specific proposals to establish that the cost of plantation wood delivered to the mill is less than that of natural forest wood. However, the number of studies showing that 85-90% of the cost of wood delivered to the mill is the cost of harvesting and transport, makes it likely that the conclusions reached in African case studies hold widely in tropical countries.

CONCLUSIONS

This comparison of the relative merits of using wood from natural grown mixed forests and specially established plantations for use as raw material in the manufacture of pulp and paper shows that the balance of cost and technical advantages lie with the plantations. In order to raise some of the capital and to clear land for plantations, it may be necessary to use the mixed forest. It is possible to produce pulp from them, but this pulp will be of lower quality and probably higher cost, though this may be regarded as an acceptable short-term commercial risk. Other uses that do not involve the high capital investment of a pulp mill might be considered; unfortunately, it is difficult to think of alternative uses that would consume the large quantity of wood that could be used by a pulp mill.

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SECTION III

HARVESTING, TRANSPORT, AND STORAGE

FOREST INDUSTRY DEVELOPMENT IN SOUTHEAST ASIA

One Company's Experience and Observations

By

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FOREST INDUSTRY DEVELOPMENT IN SOUTHEAST ASIA

One Company's Experience and Observations

By

Jack R. Schoening

I work with Weyerhaeuser Company, one of the largest private forest product companies in the world. Weyerhaeuser has extensive land and timber holdings with associated manufacturing facilities throughout the United States, Canada, and Southeast Asia. Today I would like to exchange some thoughts and experiences with you regarding the timber industry in Southeast Asia.

Weyerhaeuser Company's first venture into the forest industry of Southeast Asia began in 1966 with the acquisition of a company in the Philippines located on the island of Mindanao, and a company in Malaysia located on the east coast of Sabah. These companies were active operations with much of the initial development completed at the time of acquisition. In addition, the forest industries of both Malaysia and the Philippines, although still developing, had been growing for some years so many of the developmental issues I will discuss today were not experienced in these operations. Today, I will focus on our Company's experience in Indonesia.

Starting in 1966, the Government of Indonesia made political, social, and economic stabilization its first priority. To encourage development of Indonesia's vast forests and other resources, the Foreign Capital Investment Law was created. This opened the way for foreign capital, technology, and skill to be effectively employed to reach many National goals.

In 1968, Weyerhaeuser Company began investigating forestry development in Indonesia. This resulted in the formation of P. T. Weyerhaeuser Indonesia in 1971 to develop a 95,000-hectare timber license area north of Balikpapan in the Province of East Kalimantan, encompassing the eastern portion of the Island of Borneo. Later that same year, Weyerhaeuser Company acquired a majority interest in P. T. International Timber Corporation Indonesia, a joint venture holding a 20-year forestry license on an adjacent 601,000 hectares. This acquisition lead to the development of the largest and most productive timber operation in all of Indonesia.

Of course, before acquiring these prospective operations, detailed analyses and planning work was done to aid the decision-making process. Immediately following acquisition, the planning process was intensified. These plans were very detailed and comprehensive, which I will not go into today. However, in this entire process there were some very basic and fundamental management decisions made that are worth reviewing. These major decisions served as the principal guidelines for short and long-term operating strategy and formed the framework for the detailed planning.

YEAR AROUND OPERATION--STABILITY

From the beginning, a principal objective was to supply a steady flow of raw material from the logging operations. This would enable us to better manage the marketing, structure all aspects of the operations in the most effective way, and provide a steady on-going flow of income to all our employees.

Up to that time, the typical Kalimantan operation was a highly seasonal one. The rainfall in the region ranges from 250 to 350 cm per year. This precipitation varies seasonally, but enough rain can be experienced even in the dry months to seriously affect production. Periods of rain for 30 to 60 days may stop production completely. This is further compounded as the truck hauling distances increase. As a general rule, a dirt road operation can function fairly efficiently up to 25 kilometers. However, when truck hauls extend out to 50 or 70 kilometers, or more, dirt road operations in the tropics become almost impossible because on almost any given day some section of the road is experiencing rain. Our average haul distance this year is approximately 75 kilometers.

Therefore, at the outset, rock crushers and associated equipment were employed to enable us to ballast all of the major haul roads. This provided a permanent all-weather rocked road system to meet all short and long-term objectives. To support the logging requirement, we are building approximately 250 kilometers of road each year.

SUPPORTING INFRASTRUCTURE

The decision was made that complete supporting infrastructure would be provided for all employees and their families. Rather than building just a camp principally to support the operations, a long-term complete community was planned. The typical operation concentrated on facilities such as offices, maintenance shops, warehouses, and logistical support. We immediately planned and developed complete facilities for bachelor and married employees. These included housing, schools, hospital, stores, places of worship, and recreation with treated water, sewerage disposal, and electricity provided to all.

STAGED DEVELOPMENT

The master plan envisaged a staged development broken down into two major phases. Phase I included, basically, the development of a log producing operation of at least 100,000 M^3 per month and the construction of the infrastructure including community development to support that raw material flow. The major elements of Phase I were completed within 18 months.

Phase II of the proposed development encompassed analysis for and development of manufacturing facilities. This whole issue was further broken down into various types of wood processing plants. After considerable analysis, the plan developed called for Step I, construction of a sawmill, to be followed by Step II, with the building of a dry veneer facility, a possible doubling of sawmill capacity, and addition of a chipping plant for the production of wood chips. Longer range, Step III, incorporated some type of fiber or particleboard plant.

Obviously, manufacturing facility proposals are strongly affected by demands and market conditions for those products produced. With a positive economic environment in 1973, engineering and actual site preparation work was started late that year on Step I. However, the worldwide economic recession, beginning in early 1974, and associated decreased demand for most wood products, forced the delay of the sawmill facility. Economic recovery has been very slow. However, actual construction of the sawmill began in 1977, with startup scheduled for 1978.

The other steps in Phase II are still planned. Given the appropriate set of economic factors, these facilities also will become a reality.

UTILIZATION

Another major management decision and philosophy that threads throughout the planning process in this operation is that good utilization of all species and log grades (quality) is the cornerstone of intelligent forest resource development and long-term management.

Our initial exposure to the then existing forest operations in Southeast Asia in the mid to late 1960's revealed a very low level of utilization. Utilization standards were being strongly influenced by markets, customer demands, tradition, logging methods, and transportation restraints. Forest stands with gross volumes upwards to 150 M^3 per hectare often produced utilized volumes running as low as 20 M^3 per hectare. Of course, the selective logging silvicultural systems widely employed accounted for a large proportion of the gross volume being left. However, there were significant quantities of less desirable species, or lower quality material in desirable species that were left uncut or left in the woods after cutting, even within the bounds of a silviculturally sound selective cutting system.

On a historical basis, the forest products industries in every country have followed a trend from very poor utilization, in early stages of development, to a very high utilization level as industry and the economy matures.

However, we were determined, from the beginning, to increase the level of utilization as high and quickly as possible. Even in Phase I of our development, where we were just a log producer, utilization could be better managed by employing proper logging techniques, transportation facilities, and development of markets.

For example, up to 10% of the potentially commercial species in the East Kalimantan timber stands are "sinkers." These species produce logs that will not float. Therefore, they cannot easily be rafted for transportation to the final destination. Consequently, in a typical operation, these species were essentially ignored. In the principal log-producing area of our license area, a dock facility and log yard was constructed and, in combination with large barges, we were able to efficiently handle these species.

Market penetration and development for lesser known species, or lower quality logs, was of extreme importance to utilization. We found at the outset that many fine woods existed that were either totally unknown, or that some species had an undeserved, unfavorable reputation in the market place. Our marketing people were able to overcome this lack of knowledge or misunderstanding, with the result that many of these species became highly desirable as these new markets developed.

Lower quality, more defective logs were also vigorously promoted in the market place with a further increase in utilization. Of course, as demands change, this more marginal log is more subject to change than the higher quality logs. With high, overall demand, the marginal log is profitable, whereas in low markets this marginal log cannot be sold at breakeven, or sold at all.

A combination of these factors has enabled us to achieve utilization levels of 60 to 75 M^3 per hectare as a log producer in Phase I of our development.

UTILIZATION EXAMPLE

Following a number of studies, Weyerhaeuser Company developed some typical case examples to illustrate utilization levels in different types of operations.

A typical stand of virgin timber on an East Kalimantan timber license area would consist of 77 M^3 per hectare of all species over 50 cm DBH. Let us look at the utilization on that average 77 M^3.

Dirt Road Logging

> The dirt road logger is mechanized, but operates on dirt roads only. He traditionally hauls to a river, where he dumps and rafts the logs. Roads are built and maintained with good drainage so that they will dry quickly in the sun. However, because the roads are not of a permanent nature, necessary logging of bypassed areas and forestry work is very difficult to do.

Rainfall patterns make it difficult for dirt road loggers to harvest more than 25 kilometers from a river. They also must limit most of their logging to better ground, bypassing steep areas where roads seldom dry out.

Dirt road logging is seasonal in nature, again because of wet roads. As a result, many operations function on a piecework basis to encourage maximum production when they do work.

A typical dirt road logger operating on a small license area does not normally remove sinkers or low-quality trees. Cutting and skidding are closely coordinated so that very few low-quality logs are produced. Particularly under piecework, no trees which have indicators of low grade are cut.

Our studies indicated that the dirt road logger in an average market removed about 47% or 36 M^3 from the typical hectare with 77 M^3 available.

Contractors

In addition to their own small-license operations, dirt road loggers also operate as logging contractors for larger operators. In this role, their utilization standards, specified by the license holder, are somewhat better than those on small operations. Utilization here rises to 58% or 45 M^3 of the total stand volume.

Dirt road loggers will probably always have a place in Indonesian logging. As they complete their logging near the rivers, they will be used to log inland areas, bringing the logs to all-weather roads built and maintained by the major license holders.

This change will see more of them in the role of contractors on major license areas. Over time, the level of utilization practiced by this type of logger will improve as it is specified by the license holder.

All Weather Logging

Only a few major license holders build permanent, all-weather roads on which to operate. They also use the most modern logging equipment, from chain saws and mechanical skidders to powerful loaders and large logging trucks. With such roads and equipment, the major operator is able to remove most of the volume from each hectare. The harvest of more species, and the higher degree of mechanization, allow the all-weather logger to remove more grades of each species than the dirt road logger can afford.

Log utilization is of utmost importance to the all-weather operator because of his large fixed cost load that results from the infrastructure. His investment in infrastructure provides both the ABILITY to remove maximum volume per hectare and the NEED to remove maximum volume per hectare.

Because of this, the all-weather logger removes 84% or 65 M^3 from the typical stand.

In summary, from our three types of logging operations, we have removals of 36 M^3, 45 M^3, and 65 M^3 from our typical hectare of 77 M^3. Assuming a log value of $40/$M^3$, the differences in total value per hectare of removals by the different types of operations are substantial, with values of $1,440, $1,800, and $2,600 per hectare in each respective case.

FURTHER IMPROVEMENT THROUGH CONVERSION

As I mentioned earlier, in our planned Phase II which dealt with manufacturing facilities, our scheduled first step was a sawmill, which is now under construction. This sequence was deliberately planned to enable us to gain the last incremental increase to utilization as quickly as possible. A sawmill has the potential to utilize lower quality, highly defective logs and still produce a marketable product; whereas by the nature of the processes involved and market demands, the plywood industry is strongly oriented to high-quality logs--the same high-quality logs that already have a favored position in the market place.

A sawmill located close to the raw material source can also use the very highly defective logs, which may not be able to pay their own ship transportation even under the best of market conditions. To illustrate, a 100% sound log worth $40/$M^3$ at producing point with $18/$M^3$ shipping cost would be valued at $58/$M^3$ at final destination. A log only 40% sound would have net shipping costs of approximately $45/$M^3$ because shipping costs are a function of space restraints as well as weight. With a wood value of $40/$M^3$ at shipping point and shipping costs, the total delivered cost would be $85/$M^3$. Assuming the market value at destination for the 100% sound log is appropriate, the maximum any buyer could pay for the 40% sound log at the producing point would be $13/$M^3$ which most likely would be substantially below producing costs. The only solution to the dilemma of defective logs is to manufacture them as close to the stump as possible.

SUMMARY

A combination of enlightened government actions, management skills, employment of technology, and application of capital has produced a rate of development progress that far exceeds any historical trends. Indonesia has experienced spectacular progress in development of its forest resources in a few brief years.

With continuing good management and stability, even further progress at equal or higher rates is very feasible. The forest resources of this Region can become, on a continuing basis, a major supplier of wood and wood products for not only in-country consumption, but worldwide trade.

IMPLICATIONS OF IMPROVED UTILIZATION OF TROPICAL FORESTS ON HARVESTING AND TRANSPORT

By

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SUMMARY

Cost advantages in logging and transport of improved utilization of tropical forests are considerable up to a yield of around 50 cubic meters per hectar. Above that, they fade off.

However, very high utilization of a tropical forest is often linked to both pulpmill establishment and more intense forms of future land use. A change from "exploitation" forestry to "sustained yield" forestry takes place from the point of view of economics. Investments in infrastructure, roads, and other permanent installations will serve not only in the harvesting of the "virgin" crop but also in future croppings, which may fall out much closer in time. The costs of these items per unit of wood can then drastically decrease.

Some problems related to location of the forests, wood species, tree size, and species mix are briefly elaborated upon.

The hot and humid work environment reduces man's capacity for heavy work. Attempts, in research and practice, to combat heat stress should have very high priority in developments in tropical forestry.

IMPLICATIONS OF IMPROVED UTILIZATION OF TROPICAL FORESTS ON HARVESTING AND TRANSPORT

By

Ulf Sundberg

INTRODUCTION

The discussion of the influence of a fuller utilization of the forest biomass in moist tropical forest will start with a brief account on the relationship between inputs (cost) and output (quantity of biomass) in the harvesting of the "crop." Silvicultural operations are not included. For the purpose of this paper this account will be greatly simplified. It will be followed by some remarks on a few problems of special significance in comparison with the harvesting of wood in temperate forests and situations.

RELATIONSHIP OF COST TO QUANTITY

It is now well understood that inputs in harvesting are related to the area of the harvest and to the utilized quantity of wood.

Some inputs have no relation to the quantity of utilized wood but are fixed per unit area, e.g., aerial photographs or similar mapping and surveying work. Other inputs are directly related to the quantity, e.g., scaling. However, for most operations inputs are correlated to both area and quantity. These relationships are fairly well known for the harvesting of temperate forests. The knowledge is scanty for tropical logging but still sufficient for a meaningful analysis.

In the following table the costs of various harvesting operations are broken down in toto (column 1). The cost per unit volume of wood is used as the efficiency index as it is decisive for the feasibility of the enterprise. It is emphasized that the breakdown does not represent any statistical averages. Such information simply does not exist. But it is believed that it fairly well represents a normal cost distribution for tropical logging in which only a few species are extracted and the harvest is in the range of 10 to 30 cubic meters per hectar. (Logging in dipterocarp forest does not fall in this range.) Cost of infrastructure, royalties, etc., with the exception of roads, is not included.

Breakdown of Inputs (Cost) on Main Work Operations

All figures in percent

Work Operation	Share of Cost	Fraction Proportional to			
		Unit Quantity		Quantity	
		Partial	In toto	Partial	In toto
	(1)	(2)	(3)	(4)	(5)
Surveying, mapping	10	20	2	80	8
Felling	5	90	4.5	10	0.5
Extraction	15	30	4.5	70	10.5
Feeder Roads	15	20	3	80	12
Access Roads	15	40	6	60	9
Haulage	20	30	6	70	14
Managm., Superv.	20	40	8	60	12
	100		34		66

In the columns (2) to (5) the costs are broken down on "Unit Quantity" and "Quantity." An explanation is perhaps needed. The extraction of logs consists of two distinct phases, the loading/unloading resp. the moving of logs. Loading/unloading cost is fixed per unit quantity, whereas moving is related to the length of transport. This length is determined by the intensity (quantity utilized per unit area) as feeder roads are closer spaced for higher quantities. Cost of haulage similarly consists of loading/unloading resp. moving. Cost of moving depends on distance and road standard. The higher the "Quantity" (per unit area) the higher is the road standard and the lower is the cost per unit volume. This principle underlies the division in columns (2) to (5) for all operations. All indirect costs, such as fringe benefits for labour, machine shops, camps, etc., are charged on the work operations.

We now find in this example that 34% of the total cost (C) is fixed per "Unit Quantity" and 66% to "Quantity" (per unit area), (Q). Let us approximate to one third resp. two thirds.

To arrive at the total cost per unit volume at various degrees of utilization we now need to explore the more precise partial relation between the "Cost" and "Quantity" (per unit area). We know that a good and realistic approximation is that this partial cost per unit of wood is inversely proportional to the square root of quantity harvested per unit area. Thus, the harvesting of Q_i cubic meter per hectar will cost

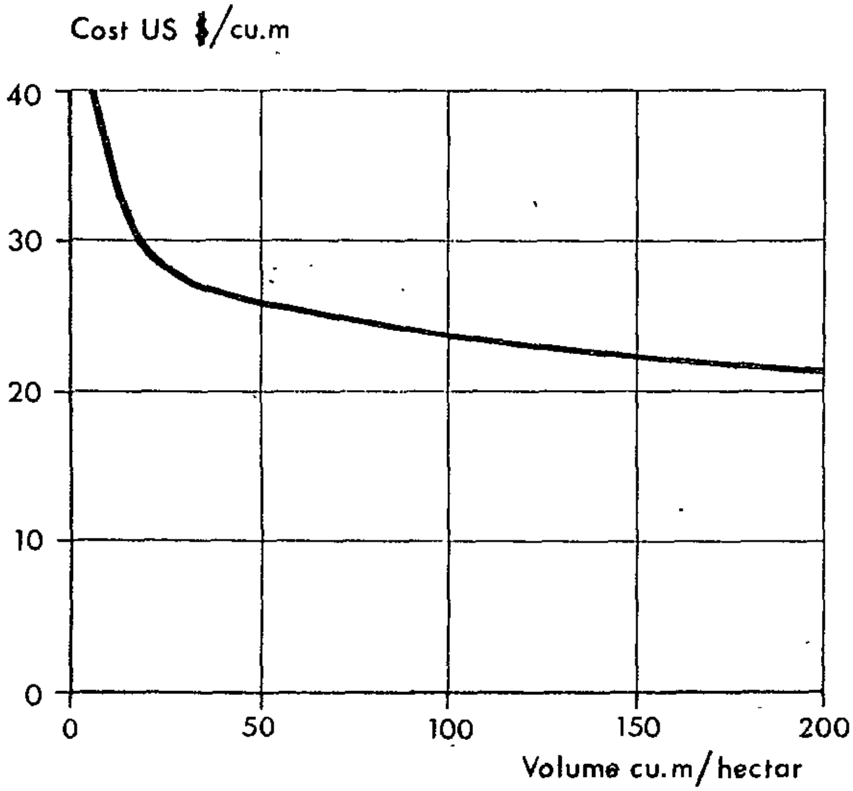
$$c_{Q_i} = a \cdot \left(\frac{1}{3} + \frac{2}{3\sqrt{Q_i}}\right)$$

where "a" is a derived constant.

If in an operation, where 16 cubic meters per hectar is utilized, the cost is 30 US$ per cubic meter, the cost for other degrees of utilization, using this formula, are likely to be as follows:

Volume, cubic meter per hectar	5	10	20	50	100	200
Cost US$ per cubic meter	37.90	32.70	29.00	25.70	24.00	22.80

This cost relationship is shown in the graph.



Relation between cost per unit of wood and harvested volume per unit area is the referred example.

Even if not too far-reaching conclusions should be made from this example, it illustrates that the cost per unit of wood is greatly influenced by changes in harvested volumes per unit area in the range of 5-50 cubic meters per hectar, whereas above 50 cost differentials are much smaller. Above 100 cubic meters per hectar the cost advantage may very well be offset by other influences not considered in this example.

SPECIAL PROBLEMS IN TROPICAL LOGGING

It must be underlined that the previous analysis deals with the influence on cost of improved utilization. The figures presented should by no means be applied for a special case as the situations vary widely with a change in cost relationships as a consequence. The analysis is also based on a set of fixed situation factors or assumptions. A few of the major factors which may change this relationship as well as a few problems of more technical nature related to the issue under discussion will be elaborated below.

Infrastructure

The infrastructure at hand in tropical regions is often rudimentary in relation to the needs in an industrial operation. Mr. Jaakko Pöyry, head of a worldwide consulting firm, at a meeting at the Forestry Week in Stockholm 1977, stated that in the estimate for starting up a pulpmill in a West African country based on mixed tropical hardwoods, the cost of infrastructure was equal to the cost of the construction of the mill. This cost impediment for developments in tropical countries will not be further elaborated here. Only the cost of roads is included in previous cost analysis.

Time Horizon

Improved utilization of tropical forests can be that existing mills or marketing agencies now and then add one or a few new species on their line of production. The increase in utilization is gradual, and it usually does not change the character of the operation. Even if logging is followed by some silvicultural treatment, such as enrichment planting or release felling of unwanted species, the time span to the next foreseen harvest is usually long, perhaps in the range of 30-60 years. This time span usually exceeds the time horizon with which industrial investments in tropical forestry are viewed. The character of the operation remains a "cut and get out" type or an exploitation cut.

However, improved utilization can also be linked to new wood processing ventures, such as the production of pulp and paper. Then, not only a dramatic increase in utilized volume per unit area is incurred, but it is also linked to a much more intensive and sustained form of land use, such as the complete clearing of the land and the planting of a new crop. If this crop is a forest, a rotation period as short as possible is often looked for, perhaps in the range of 5-15 years. This time span is so short that it definitely becomes essential and interesting for investors to make investments that serve not only the harvesting of the "virgin" crop but also the subsequent rotations.

It is outside the scope of this paper to elaborate on the financial or economic consequences of a change from "exploitation" forestry to "sustained yield" forestry. But it is evident that there is and should be far reaching implications.

The point is that the investment in a pulpmill or any other capital intensive mill is so large that this capital must be defended by securing a sustained supply of wood. Forestry becomes a long term and stable venture and a completely new look must be taken in planning infrastructure, roads, labour recruitment, and training as well as a large number of other cost items. The immediate effect is that the initial harvest of the virgin crop does not need to be burdened with the full cost of depreciation of capital investments. The full utilization of the biomass in the tropical forests has also merits per se as it can be a tool for a more intensive land use and thus contribute to limiting the scale and speed of their destruction.

Location of Forests

The distance from the forest resource to the mill site and the facilities for further transport of the processed wood bear strongly on cost and profitability. The public road net--rail or truck--is often of a low standard or nonexisting. Increasing distances or absence of roads "lifts up" the cost curve in the graph whereas its form remains unchanged. In other words, these factors do not bear on the cost advantage of higher utilization in absolute terms, but they decrease the advantage in a relative sense.

Increased utilization, in principle, opens up two options:

1. Increased mill production with the subsequent advantage of the economy of scale. The supply area can be considerably increased without increasing the average cost of wood at mill yard. This is a consequence of better economy of roads and of truck haulage.

2. Unchanged mill capacity. This will lower the wood cost at mill yard as the supply area can be shrunk.

Intermediate solutions to these two options are possible. As road and haulage costs are high, the influence of location on wood cost is strong.

It should be noted that the influence of location is not fully included in the introductory analysis in this paper because of the complexity of it and of problems of generalizing situations. However, it might be of interest to note that we again meet the magic $\sqrt{Q_i}$. E.g., if we double the harvested volume per unit area, the variable truck hauling cost, at unchanged mill capacity, should approximately be reduced to the value $\sqrt{\frac{2}{2}} = 0.70$. If we want to keep wood cost at mill yard constant, the average hauling distance can be increased by 40%, or more precisely ($\sqrt{2} - 1$), except for cases when a road net of very high standard already is there. Assuming unchanged yields per unit area, the supply to the mill could be stepped up by 40%. (These figures are valid for cases when the supply area extends congruently from the mill site and the forests have equal stocking over the area.)

Wood Species

Tree species with high silica content, often some 5-15% of the standing volume, cause problem in logging and mill operations. Such wood very quickly blunts the edges of tools, e.g., power saws and chippers.

Tree Size

Higher utilization of tropical forests involves handling of logs in a much wider range of log sizes. As most equipment is tailored for a rather narrow variation in log size, one is faced with two principal options, both leading to cost increases: Either log the whole quantity with equipment designed for the larger size fraction, in which case the cost of logging of the smaller logs easily will become unduly high; or carry out two or more operations with equipment designed for large or small logs respectively. The uniformity of softwood forests, especially if managed and thinned, is a big advantage rarely encountered in tropical forests.

Another problem is the utilization in pulpmills of logs too large to be fed into a chipper. Most wood species from temperate forests split very nicely along the fiber so that the logs can be reduced to pieces of desired size at low cost. Tropical wood species often do not split. No other solution is known other than sawing which is a very costly operation.

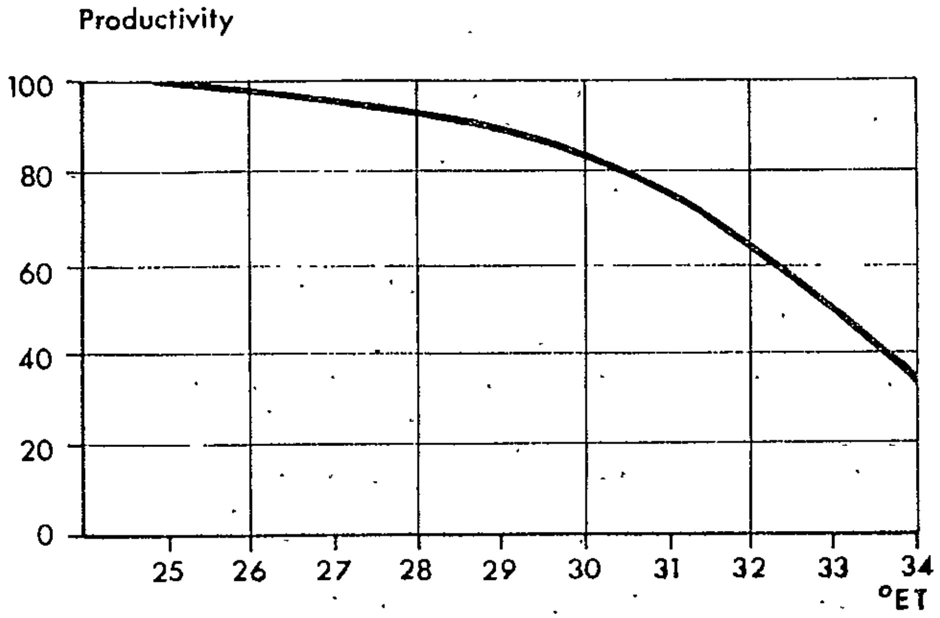
Species Mix

Improved utilization may involve new lines or mills for the industrial processing of wood. This may call for more sorting of the wood at some stage in the transport flow. In the pulping of the wood, there may be need to maintain a constant species mix. Such "homogeneous inhomogeneity" is not always prevailing in the forests, perhaps calling for a staggered layout of logging areas. Both events are complications leading to higher costs.

Climate

Workers in tropical forests are exposed to a number of health hazards and environmental extremes. Only the hot and humid weather will be elaborated here.

Heat stress reducing man's ability to work begins at 25° C. At 34° C and 100% humidity, sustained physical work is impossible. Not much is known about the impact on the work capacity of the hot environment in tropical forests but most likely it is very strong. The graph below is an attempt to quantify the productivity reduction in heavy work due to heat stress.



ET = effective temperature, derived from globe temperature and humidity. Estimated reduction of work productivity, due to heat stress (according to: Axelson, O.: Heat Stress in Forest Work. FAO, Rome 1974).

No actual studies have been made which could support the assessment of work productivity reduction in tropical logging due to heat exposure, but it is certainly considerable.

Considering the many millions of people who live and perform heavy work in outdoor hot environment, it is astonishing and even shocking to learn that the scientist who made this curve had to base the assessment on studies of deep-mining. The problem of heat stress in tropical conditions up to now is almost completely ignored by researchers, institutes, and development agencies.

The lack of knowledge, among experts and operators in tropical settings, of ways and means to counteract the impact of heat stress in heavy work is just incredible. Attempts to combat the impact of heat stress should have a very high priority in forestry developments in the tropics.

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IMPLICATIONS OF LOGGING SYSTEMS FOR MORE COMPLETE UTILIZATION

By

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ABSTRACT

Logging in the tropical areas of the world can be divided into two main categories: highland and lowland. The two systems applicable to each category are mechanical and manual or labor-intensive. The bulk of the manual systems are confined to the lowlands and generally in marshy areas. Conventional mechanical logging systems such as cable, tractor and rubber-tired skidder are used in the highlands where the topography is more difficult.

The recent advent of all tropical species utilization has been a big step towards more complete utilization of tropical forests. It is evident that maximum utilization will mean the handling of smaller pieces of wood. The type of logging system employed will depend on economic considerations.

IMPLICATIONS OF LOGGING SYSTEMS FOR MORE COMPLETE UTILIZATION

Timber harvesting in the tropical forest areas of the world can be divided into two categories: Highland tropical forest and lowland wet tropical forests. Logging methods used are either highly mechanized or a manual system that is labor-intensive. Therefore, four harvesting combinations are possible:

1) Highland mechanized
2) Lowland mechanized
3) Highland labor-intensive
4) Lowland labor-intensive

Mountainous areas normally require a mechanized logging system because of difficult topography. Cable systems, both hi-lead and skyline are used as well as crawler tractors and rubber-tired skidders in the lower hills. Degree of utilization is usually determined by the silvicultural practice used - clear cut or partial cut - and the harvesting constraints such as diameter limits, species and size. End use has been a very important factor in the degree of utilization of tropical forests. Export of prime logs is big business in tropical areas such as Indonesia and Malaysia. This practice involves high-grading for a few valuable species and results in the waste of much wood left on the forest floor. Better utilization will be realized when more underdeveloped countries process their wood resources in the country. In striving for more complete utilization, there have been encouraging developments in the use of all tropical species for pulp. Japan is currently operating a plant in Papua, New Guinea, where all species are chipped for pulp.

A large percentage of the tropical forests are located in marshy areas along the coastal plain. In these areas, mechanized as well as manual harvesting systems have been used. An example of a labor-intensive manual system is the "kuda-kuda" system used in the coastal plain of the province of South Sumatra on the island of Sumatra in Indonesia. Power saws are used to fall and buck the trees. After the tree has been bucked into logs, the bark is removed and the log is positioned for skidding. The skidding crew of eight men build a skidway with small logs and limbs on which to manually skid the logs. The peeled log is then rolled onto a sled-type conveyance called a "kuda-kuda." With ropes attached to the logs, the men pull the logs across the greased cross members of the skidway. Once the log moves, it gains momentum and it is easily guided to the loading ramp adjacent to a narrow-gauge railroad. Logs up to a diameter of 1½ meters have been skidded in this manner. The workers are very skillful, work well in unison and take pride in their ability to do a good job.

The logs are then manually rolled up a ramp onto a lorry, a small railroad car 1.6 meters long and 0.9 meters wide. One to three logs, depending on size, are loaded on each lorry. Three-ton diesel locomotives are used to haul the logs to the dump at the main river. The locomotive is situated in the middle of a string of 25 to 30 lorries. At the dump, the logs are pushed off the lorries manually. Swimmers collect the dumped logs and make up rafts which are eventually towed to the inland seaport of Palembang.

The above-described system is currently being used primarily for the extraction of export logs, which results in much waste of the resource as previously mentioned. Establishment of more wood processing industries in the underdeveloped areas of the tropics will result in more complete utilization of the resource. It is conceivable that the labor-intensive "kuda-kuda" system, with certain modifications, could be used to harvest smaller pieces of wood to supply a facility such as a pulpmill. Governments in underdeveloped countries are interested in labor-intensive harvesting operations so as to help alleviate their high rate of unemployment. Labor costs in these countries are much lower than they are in countries in the Western world, so in many cases an operation of this type could be economically feasible.

In addition to using narrow-gauge railroads for transporting logs to the main rivers in the coastal plain of South Sumatra, small canals are constructed for floating of logs from the forest to the main waterways.

An example of a mechanized system of extraction in lowland marshy areas of the tropics is the barge-mounted double-drum yarder used on the Pacific Coast of Colombia, South America. One large yarder and three small yarders are used to extract logs from settings 1000 meters by 500 meters in size. Utilizing a herring-bone pattern, the small yarders bunch the logs in the center of the area for subsequent skidding by the large yarder. When extraction of the area is complete, the yarder winches itself across the area that was logged and commences to log a new setting. Logs are floated in small canals and streams from the settings to the main waterways where rafts are constructed for eventual towing to the mill site. Only a few desirable species are currently being harvested in this manner. Again, the development of more intensive wood-processing complexes will contribute to more complete utilization of the wood resource.

Two examples of all tropical species utilization are Carton De Colombia in Cali, Colombia, with logging operations near Buenaventura and a Japanese operation at Madang, Papua, New Guinea.

The Colombian operation is both mechanized and labor-intensive. The trees are felled and bucked into 1 meter lengths with axes. The shortwood is then carried to a skyline operation where bundles averaging 750 kilograms in weight are formed and subsequently yarded to the landing where the wood is then manually loaded onto flatbed trucks. The soil in this area is very unstable and with an average of 8 meters of precipitation per year, erosion is a major problem. To minimize the incidence of erosion limbs, tops and other vegetation are left on the forest floor. In addition, much of the understory is left intact because of the labor-intensive nature of the operation. Carton De Colombia has been utilizing all species for pulp since 1961.

In the New Guinea operation, conventional machines skid the logs to landings where they are hauled by log trucks to the chipping site at Madang. This is a highly mechanized operation utilizing all species and logs of all sizes for conversion into chips for pulp.

In summary, it is apparent that harvesting of all tropical species for conversion into a wood product is now a reality. The logging system employed is dependent upon both economic and social considerations of the developing country involved. Combinations of labor-intensive and mechanized systems which are prevelant in Colombia and Sumatra, for example, have proved to be successful. Highly mechanized, sophisticated harvesting systems have proved to be unworkable in many areas of the tropical world.

EXAMPLES OF COSTS FOR DELIVERED PULPWOOD IN VARIOUS REGIONS OF THE WORLD[1]

REGION	US $/M^3
United States	
Southeast	11
Pacific Coast	16
Scandinavia	29
Africa	
East	11
West	18
South America	
Brazil, Lowland	14
Colombia, Highland	18
Colombia, Lowland	15
Southeast Asia	
Philippines	17
Indonesia, Borneo, Highland	20
Indonesia, Sumatra, Lowland	14
Papua, New Guinea, Highland	18

SUMMARY OF TROPICAL HARVESTING COSTS BY EXTRACTION SYSTEM[1]

SYSTEM	US $/M^3
Highland, Mechanized	17
Highland, Labor-Intensive	18
Lowland, Labor-Intensive	15

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[1] From "Mixed Tropical Hardwoods Harvesting and Chip Manufacturing Case Study for Chas. T. Main, Inc.," January 1978 by H. C. Mason & Associates, Portland, Oregon.

OUTSIDE CHIP STORAGE IN THE PHILIPPINES

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ABSTRACT

Outside-chip-storage (OCS) for 12 months showed that the weight-loss rate of the chips was greatest during the first three months of storage at 1.36% per month while the lowest monthly loss rate of 0.99% per month was during the nine months' storage. Significantly, the unsaponifiables were decreased by 52% and fatty acids by 42%, which should reduce pitch troubles during pulp and paper manufacture.

Data on rainfall, temperatures in the chip pile, moisture content and chemical analysis of chips, weight loss of stored chips, and sulfate and neutral sulfite semichemical (NSSC) pulping are included.

It was concluded that, under the conditions prevailing in the experimental site, OCS could be done up to 9 months without serious loss in strength properties of sulfate pulp.

INTRODUCTION

Outside chip storage or OCS is now a widely accepted practice in Europe, North America, and in Japan. Even in a tropical country like the Philippines, outside chip storage is being practiced by the Paper Industries Corporation of the Philippines (PICOP) and, on a smaller scale, by the Bataan Pulp and Paper Mills Incorporated.

It has been reported that, in the 1930's, outside storage of sawmill chips was a general practice in Scandinavia but the practice gradually declined and was eventually only practiced by fiberboard manufacturers (1).

OCS for sawmill and veneer plant residues was introduced in the U. S. West Coast in the early 1950's (2). OCS is not limited to sawmill and veneer plant wastes and other residues but is now also used for freshly chipped pulpwoods.

The advantages of outside chip storage are as follows (1, 2, 3,):

1. The possibility of using sawmill and veneer waste.

2. The freedom which chip piling allows for a more flexible wood supply program.

3. The possibility of increasing wood storage volume within a given area.

4. Chip storage accelerates seasoning of the resin, thus facilitating sulfite pulping. However, in the sulfate pulping of conifers, OCS results in some loss of tall oil and turpentine, resulting in low yields during the recovery of these by-products.

5. OCS can result in a smoother flow of wood to the yard.

6. There is reduced fiber loss since chips from green wood are more uniform than those from stored roundwood which may be partially dry. Dry wood may break and broom during debarking and chipping.

7. Debarking of roundwood as it is received at the yard results in increased bark yield. The greater use of bark can reduce fuel costs and at the same time results in easier and better housekeeping in the woodyard.

8. With mills that pulp several species of wood, more accurate handling of species is possible. Chip piles tend to be more uniform in moisture than stored roundwood, so that digester furnishes involving several species can be improved.

9. Large savings in manpower in the woodroom and woodyard operations are possible.

On the other hand, the consequences from improper handling of chip storage are as follows (1):

1. Loss of wood substance.

2. Wood discoloration, which may cause a loss of brightness of the unbleached and bleached pulp or an increased consumption of bleaching chemicals.

3. Increase in the volume of fines, creating problems with continuous digesters and dust on the surroundings.

4. Increased consumption of cooking chemicals.

5. Losses in pulp and paper strength.

As stated by Hajny, (2) each mill has its individual characteristics and problems so that the advantages obtained with OCS may not be the same for all mills. In addition, no two mills are situated exactly alike so that problems differ from mill to mill.

The number of studies on outside chip storage conducted in the tropics has been very limited and these have been conducted on woods in New Guinea. A 1971 study in New Guinea dealt only with the microbiological aspects of presumably mixed, but unidentified hardwood species. An experimental, 3-month-old noncompacted chip pile containing preservative and untreated wood chips was studied. Sodium pentachlorophenate was found to be effective in preventing biodeterioration. Bacteria was the most frequently isolated group of microorganisms while Penicillia made up a large proportion of the fungi. Soft rot and bacterial attack were found up to depths of 4.9 m. inside the pile. Blue stain and other microbial discoloration occurred throughout the pile (4).

Later studies were conducted on the outside chip storage of tropical hardwood chips composed of mixed species from 35 genera in Papua, New Guinea. These studies were more extensive than the 1971 investigation, covering moisture content and specific gravity changes during 2- and 4-month storage of chips, the corresponding pulping and papermaking properties, and the microbial ecology of the chip piles (5, 6, 7).

The maximum temperature attained, 64° to 66°C, was much below the level (80°-100°C) at which the risk of loss through spontaneous combustion or charring might occur (1, 5). The specific gravity of the chips was reduced from the original 0.394 to 0.373-0.397 during chip storage. It was estimated that the average wood loss would be about one percent per month for 2 months of storage and about 0.75% per month for 4 months of storage. There was a reduction of moisture content from 38.3% (wet weight basis) to 25.5-36.0% (excluding a 61.4% sample near the "wet zone" boundary). The loss of wood substance did not appear to be a major problem for storage of up to 4 months. However, relatively high losses in the zones near the bottom and outer surface of the pile of 2.3 to 4.1% were observed (5). With the exception of hot-water soluables which increased on 2 months' storage, there was little change in chemical composition of the chips (6).

The chips stored for either 2 or 4 months were pulped readily by the sulfate and NSSC processes. The pulp yields from stored wood were slightly higher than those obtained on control samples cooked under the same conditions. Pulps from the stored wood also had slightly higher Kappa numbers, indicating that such samples may be marginally harder to cook than freshly felled wood. The loss of wood substance on storage did not cause any appreciable difference in terms of pulp yield obtainable from a given weight of freshly felled wood, provided storage was not in the wet zone (greater than 60% moisture) of the piles (6).

Chips stored for either 2 or 4 months gave sulfate and NSSC pulps with similar papermaking properties and these showed little difference from pulps made from the freshly felled wood. However, chips stored in the wet zones of the piles gave sulfate and NSSC pulps with slightly lower tearing strength. Bleached sulfate pulps prepared from stored chips had slightly lower brightness values and slightly higher pulp yield loss compared with that from the control chips. Storage did not influence bleached pulp strength (6).

EXPERIMENTAL

Chip Pile Establishment

The experimental chip pile was installed with the cooperation of the Paper Industries Corporation of the Philippines (PICOP) at their mill site at Bislig, Surigao del Sur in the southern Philippines.

Wood going to the chipper consisted by volume, of 80 to 90% Philippine mahogany species such as almon (Shorea almon Foxw.), red lauan (Shorea negrosensis Fox.), and tangile (Shorea polysperma (Blanco) Merr.). (Two other Philippine mahogany species, bagtikan (Parashorea plicata Brandis) and mayapis (Shorea squamata (Turcz) Dyer) are segregated due to their known pitch-forming tendencies.) The balance of 10 to 20% consisted of miscellaneous non-commercial species which were harvested together with the more valuable Philippine mahogany species during clear-cutting operations in certain areas of PICOP's concession.

The Philippine mahogany logs were debarked on the hydraulic debarker while the non-commercial logs were debarked manually. The type of wood chipped were the following:

Roundwood	50.9% by volume
Cants	24.7
1.22 m. cores	4.0
2.44 m. cores	20.4
Total	100.0%

The roundwood included the non-commercial logs and the bolts trimmed off from the Philippine mahogany logs which had been found suitable for the sawmill or plywood plants. The cants came from the sawmill while the cores came from the plywood plants. The species and type of wood chipped represent the usual run-of-the-mill material used in the regular commercial production of kraft pulp.

The wood was chipped in a Soderhamn chipper, screened in a Soderhamn chip screen, and blown to form a pile separate from the chips used in the daily production of the pulp mill.

A chip pile with the final dimensions shown in Figs. 1 and 2 was constructed. One end was used as a ramp for a front-end bucket loader and a bulldozer which were used to bring from the ground level and to level the chip pile. As the 7m.^{3} chip capacity dump trucks brought the chips from the temporary pile near the pulp mill building and unloaded them at the experimental pile site, representative samples were separated while the pile was being built up to the first 1.5 m. high layer. Eighty-eight large nylon mesh bags were each filled with 16 kg of the thoroughly mixed samples set aside initially.

As the first 1.5 m. level was attained, four filled nylon bags were placed at each of the designated four sample points. A thermocouple element was inserted on one of the bags at each sample point. The four bags at each sample point were tied with a 1-cm-diameter polypropylene rope of sufficient length that a 5-m length protruded from the side of the chip pile. The free length of the rope was intended to serve as a guide in subsequent recoveries of the sample bags. The same procedure was followed for every additional 1.5 m. high addition to the chip pile until the required number of sample points was installed. In building up the first 1.5 m. level, the dump trucks could bring up and discharge to the first 1 m. height. Above that height and up to about 2.5 m. high, a front-end bucket rubber-tired loader was used to push the chips up the pile.

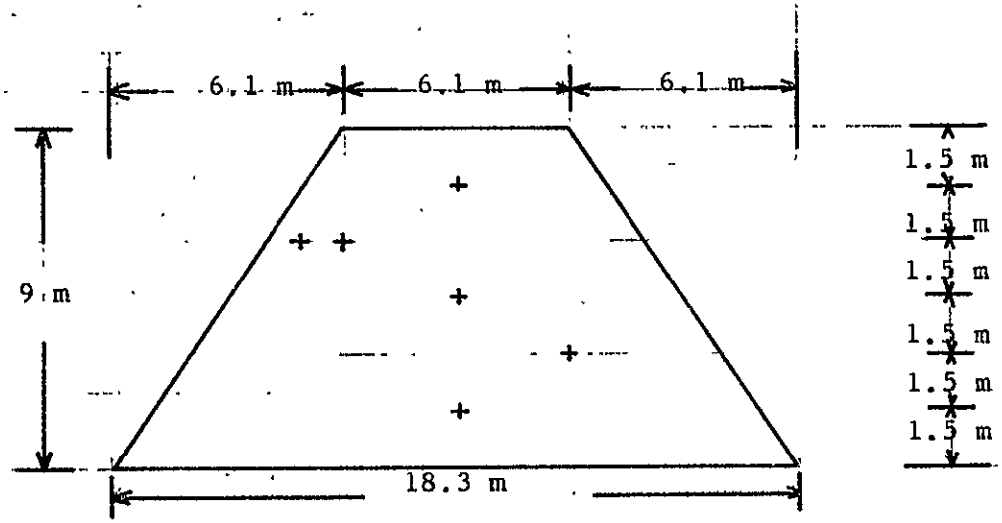

Fig. 1 Front view of experimental chip pile

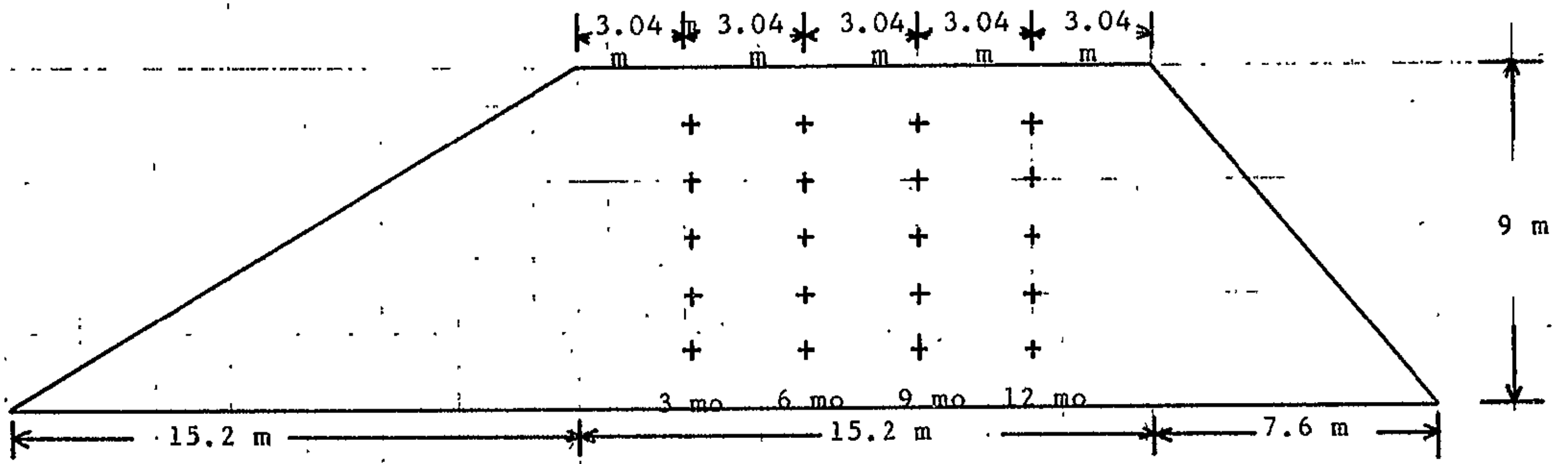

Fig. 2 Side view of experimental chip pile

Beyond the 2.5 m. level, a track-type bulldozer was used for chip pile construction.

Eight sample bags set aside were placed within polythylene bags in order to maintain the moisture content of the chips. This constituted the control samples and was brought to FORPRIDECOM.

The 20 thermocouple leads from the 20 sample points plus a thermocouple for ambient temperature were connected to a Honeywell 25-point potentiometric recorder. The recorder was housed in a 2.5 m. x 2.5 m. shed about 3 m. from one side of the chip pile.

The control samples and the samples withdrawn from the pile after 3, 6, 9, and 12 months' storage were brought from Bislig, Sirigao del Sur in the southern Philippines by air cargo to the FORPRIDECOM laboratories in College, Laguna in Northern Philippines. Total travel time was about 3.5 hours. Upon arrival at the laboratory, the chip samples were immediately placed in a cold-storage room with a temperature of 4.4°C. Samples for chemical analysis, pathological study, and pulping were withdrawn as necessary.

Using the ropes protruding from the sides as a guide to the approximate location of the chip samples in sacks, a bulldozer was used to recover the samples. After the recovery of the samples for each stated time interval, the shape of the chip pile was restored as much as possible to the original. Upon recovery of the sacks, they were immediately placed inside thick plastic polyethylene sacks in order to avoid moisture loss. Recovery time took about four hours.

Chemical Analyses

Chemical analyses for lignin, carbohydrates, pentosans, 1% caustic soda solubility, hot-water solubility, ash, and alcohol-benzene solubility were made. Lignin was analyzed by a method of Saeman et al (8), and carbohydrates by the method of Nelson (9). The appropriate TAPPI methods were used for the other components (10).

Pulping

Sulfate pulping in duplicate, was carried out in 22.7 l capacity stainless steel, cylindrical rotary, indirectly-steam heated digesters using the following conditions:

Pulping chemicals:

15% NaOH

5% Na_2S

Liquor to material ratio, 4:1

Maximum temperature, 170°C

Time to maximum temperature, 1.5 hours

Time at maximum temperature, 1.5 hours

Neutral sulfite semichemical (NSSC) pulping in duplicate was carried out in the digesters mentioned above followed by fiberizing in a 20-cm (8-in.) diameter Bauer disk refiner using the following conditions:

Pulping chemicals:

15% Na_2SO_3

3.5% Na_2CO_3

Liquor to material ratio, 4:1

Maximum temperature, 170°C

Time to maximum temperature, 1.5 hours

Time at maximum temperature, 1 hour

Bauer disk refining:

1st Pass, 1.27 mm plate clearance

2nd Pass, 0.25 " " "

3rd Pass, 0.15 " " "

The specific gravities of the chips were determined by the TAPPI methods T18 m - 53. The appropriation TAPPI methods were also used for the beater tests and physical tests on the handsheets (10).

Data on the chemical composition of the ether extract of the chips and on the microbiological aspects were taken from associated reports (11, 12).

RESULTS AND DISCUSSION

The results are given in Tables 1-32. The summaries of the analyses of variance are given in Tables 33-37.

A. The Chip Pile

A.1 Temperature Within the Chip Pile

The average monthly temperatures are shown in Fig. 3. Within one week after the start of the chip pile construction, a temperature of 32° - 46°C was already attained within the pile. While the maximum average monthly temperature of the chip pile was obtained during the second month of storage, 55°C, at position C, the maximum daily temperature, 61°C, was attained at position E, 18 days after the start of chip pile construction. The New Guinea pile attained relatively higher maximum temperatures, 64° - 66°C (5).

It was noted further that rainfall or variation of the ambient temperature within a particular 24-hour period did not cause any discernable difference in the chip-pile temperatures.

The average equilibrium temperature in the PICOP pile was about 50°C attained sometime during 12 to 40 days of storage, and was maintained up to about the seventh month of storage. Thereafter, the temperature began to decline gradually, influenced no doubt by the continuous rainfall in the area which added more moisture to the chips than could be removed by the high chip temperature.

Spontaneous combustion or charring in any part of the chip pile could not, therefore, occur since the maximum daily temperature attained at any point, 61°C, was still much below that at which charring takes place, 80° - 100°C (1). Besides the relatively low temperature, the moisture content was already relatively high by the sixth month, 55 to 66%. Most modern wood-fired boilers can directly burn wood, without pre-drying equipment, with up to 50-55% moisture only.

The temperature in a new chip pile rises rapidly as heat is released during respiration, which subsequently accelerates the respiration rate until an equilibrium temperature is reached. As the reserve nutrient is consumed, the temperature of the pile should slowly fall to the ambient temperature. However, the thermophilic microorganisms produce heat, which, in a compacted pile, results in a further temperature increase. The temperature at which the equilibrium temperature is reached, varies from pile to pile and even within each pile. The wood species, degree of compaction, microflora, as well as the temperature and humidity of the air surrounding the pile, influence the equilibrium temperature (1).

It was noted that every time the chip pile was opened to retrieve the samples, water vapor was immediately visible escaping from the pile interior. The 3-m. horizontal distance between the samples to be withdrawn at 3-month intervals seemed to be acceptable since no temperature fluctuations were observed during the sample withdrawal in the samples adjacent to those being withdrawn. Furthermore, the degree of pile compaction attained minimized the collapse of the chip pile at the portion between the

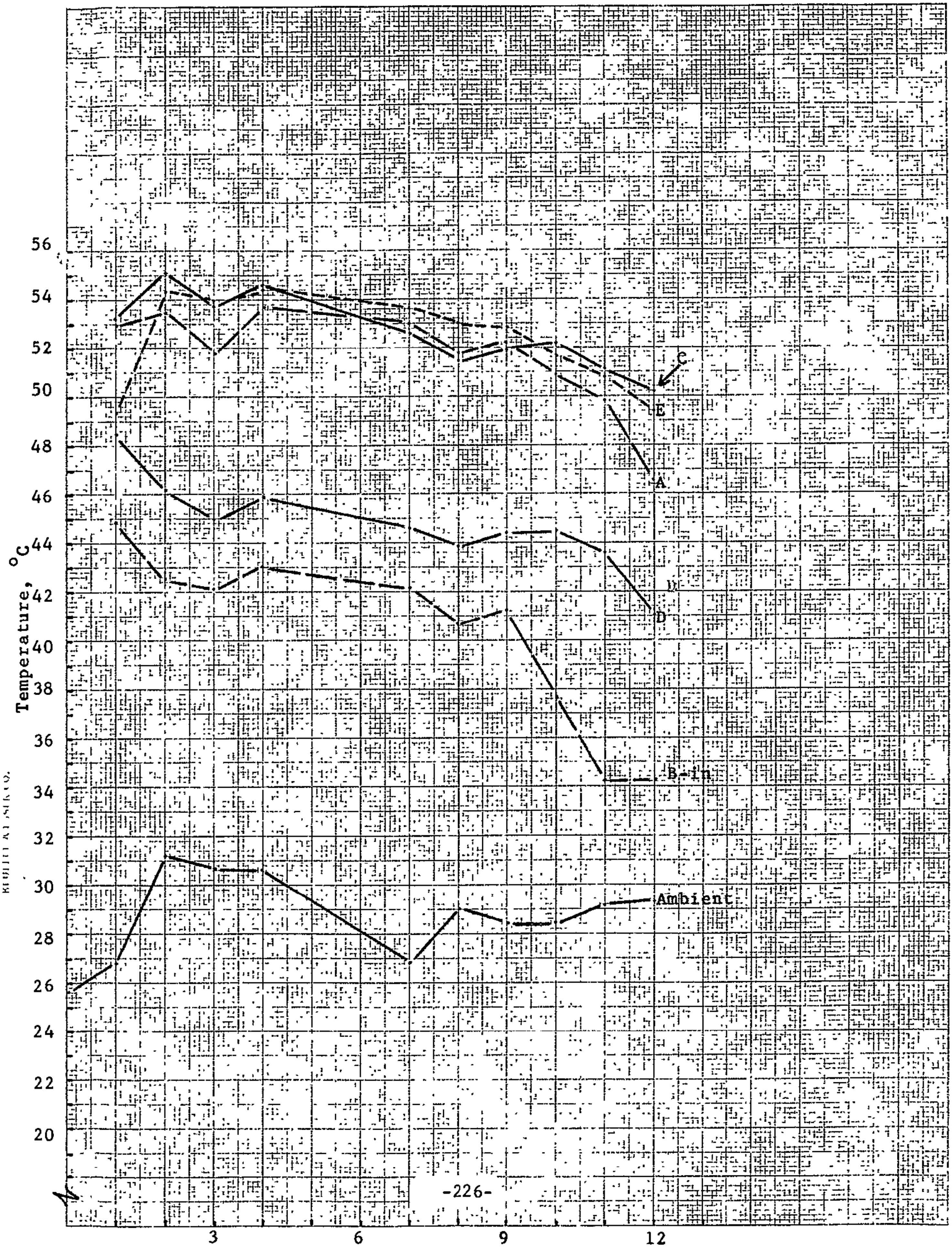

Fig. 3 Average monthly ambient and chip pile temperature

locations of the samples being withdrawn and the set of next samples to be withdrawn 3 months later.

A.2 Rainfall and Moisture Content of the Chips

The outside chip storage pile was located in an area where there is no distinct wet and dry season. There is rainfall throughout the year as shown in Table 1. The 1-year cumulative rainfall during the duration of the outside chip storage experiment was 4,178 mm. The 3-month totals gradually increased from 495 mm during the first 3 months to 1,886 mm during the fourth 3-month period of chip storage.

The moisture contents of the chip samples are given in Table 2. The continuous rainfall undoubtedly caused a gradual increase of the moisture content, from the initial 49.8 percent to 62.5 - 69.0 percent, on the total weight basis at the end of the 12-month chip storage period, despite the elevated temperatures within the chip pile for the duration of the experiment.

The moisture content of the stored chips was higher than that of the control chips. The moisture content tended to increase with the duration of storage. Moisture content tended to increase, the higher the location of the sample within the pile.

The two uppermost positions, A and B (refer to Figs. 1-2) had the highest 12-month average moisture contents, 63.0 - 64.5 percent while the three lower positions had distinctly lower moisture contents, 55.8 - 57.6 percent. However, on a 3-month basis, the difference between the maximum and minimum moisture contents of the individual samples gradually decreased from 20.2 percentage points at the end of 3 months' storage and then to 6.5 percentage points at the end of 12 months' storage.

During the first 3-month chip storage period, moisture content actually decreased for the three lower positions (C, D, E) from the initial 49.8 percent down to 40.4 - 44.0 percent. The upper two positions (A, B) had higher moisture contents, 54.4 - 60.6 percent, than the initial 49.8 percent. By the end of the 6-month storage period, however, the moisture content of even the three lower positions had increased further. By the ninth month, the maximum moisture content exceeded 60 percent for all positions.

Undoubtedly, there existed an upward convection current due to the heat produced, which brought up moisture from the lower portion of the chip pile upwards through the pile (1). This resulted in the drying occurring in the lower portion of the pile and increasing the moisture content of the upper portion. However, with continuing rain, even the lower portion of the pile had higher moisture contents which exceeded the initial moisture content of the fresh chips. It was apparent that by the sixth month the rain had already penetrated down to the lower layer, 7.6 m. below the top of the chip pile.

The New Guinea experimental site, like the PICOP site, is a location with rainfall throughout the year. However, the mean annual rainfall of 2,542 mm of the New Guinea site is 37 percent less than that received by the Bislig area's 4,178 mm during the duration of the chip experiment (5).

In 3 months' chip storage, the PICOP pile already had relatively higher moisture contents than either the 2- or 4-month-old New Guinea piles. At 4 - 5 months, the two upper layers of the PICOP chip pile had probably already attained 60 percent moisture content which is almost the same as the so-called "wet zone" moisture contents, 61 percent, attained in the New Guinea pile (5). By 7 - 8 months, all PICOP samples had already probably attained the "wet zone" moisture contents.

A.3 Specific Gravity of the Chips

Data on chip specific gravity are shown in Table 3. The average specific gravity for all positions decreased from the initial 0.421 down to 0.401 by the third month and to 0.370 by the end of the 12-month storage period.

Chip storage caused a statistically highly significant decrease in specific gravity compared to that of the control chips. The longer the duration, the greater the decrease. Height of the sample in the chip pile did not have any significant effect on the specific gravity.

A.4 Weight Loss in the Chips

From the specific gravity data, the weight losses in the chips were estimated and are shown in Table 4. At 3 months storage, there was already an average weight loss of 4.79 percent, increasing to 12.11 percent at the end of 12 months storage. The average weight loss for the 12-month period was 1.01 percent per month but the weight loss rate was greatest during the first 3-month period when it averaged 1.60 percent per month. This contrasts with the experience in New Guinea where it was about 1 percent per month for the first two months increasing to about 2 percent per month with storage of four months (5, 7).

The loss of wood material is the net result of a combination of biological activity and chemical reactions. Generally, half of this loss, which may be about 1 - 5% of the wood, during the first month consists of constituents such as low-molecular weight carbohydrates, resins, acetic acids, etc., that would be removed anyway during pulping. The rest of the loss, amounting to about 0.5 to 2.5% of the original wood is "valuable" material (1). This refers, of course, to the cellulose and pentosans.

Microbiological deterioration in the chip pile was caused mainly by soft-rotting fungi which could tolerate the high temperature and high moisture content within the pile. Wood-rotting Basidiomycetes caused decay only on the outer surface of the pile up to a depth of about 60 cm. Microbiological activity was greatest near the surface of the chip pile, decreasing proportionately towards the center of the pile. Twenty-seven of the microorganisms found in the chip pile are capable of cellulolytic activity (12).

The significant increase in the moisture content, after the first three months, of the wood chips within the pile could have caused a proportionate decline in the average monthly wood substance loss. The high temperature eventually killed or inactivated the wood-decaying Basidiomycetous fungi and the non-thermotolerant and nonthermophilic soft-rotting fungi, thus contributing to the decline of the average monthly loss of wood substance (12).

B. Chemical Composition of the Chips

B.1 Lignin

The results on the chemical analyses of the chips are given in Tables 5-15. The lignin content increased from an initial 30.6% gradually to a maximum average of 32.2 percent in 9 months, and thereafter decreased to an average of 30.4 percent at 12 months storage. However, no significant difference was noted between lignin values of the control and the stored samples or between the different positions.

In the New Guinea study, the lignin contents were similar for the control and stored chips (6).

B.2 Carbohydrates

The carbohydrates represent the total of the cellulose and hemicellulose of the raw material, reported as glucose. The carbohydrate content increased from an initial 59.1 percent to an average of 61.0 percent at 3 months' storage to a maximum average of 62.2 percent at the end of 12 months' storage. This increase is statistically significant. However, position within the chip pile had no significant effect on carbohydrate content.

The difference between carbohydrate content of fresh and stored chips was not significant. In the New Guinea study, Cross and Bevan cellulose was found to be similar for both control and 2- and 4-month stored chips (6).

B.3 Pentosans

The pentosan content, an indication of the hemicelluloses in the chips, was significantly higher for the stored chips. The position of the chips in the pile did not significantly affect pentosan content. On the other hand, the average pentosan content at 9 months of storage, 11.0 percent, was significantly higher than at other periods of storage.

B.4 1% Caustic Soda Solubility

There was no significant difference between the caustic soda solubility of the stored and the fresh chips despite the fact that this test indicates the degree of fungus decay in wood. There was a trend for decreasing caustic soda solubility with longer chip storage. The annual average value was lowest at the C-position, 13.2 percent, and the highest at the B-out position, 15.9 percent in the pile.

The New Guinea study showed a slight increase in alkali solubles at 4 months storage (6) which parallels the PICOP study for at least up to 6 months of storage. Thereafter, the alkali solubles in the PICOP samples decreased.

B.5 Hot-Water Solubles

The hot-water solubility of the control chips was significantly lower than those of the stored chips. The chip stored for 6 months had the highest average hot-water solubles, 2.96 percent. The D-position chips had the least 12-month average hot-water solubles, 1.43 percent, while the maximum was at the B-in position, 3.50 percent.

B.6 Ash

The control chips had significantly higher ash content than the stored chips. The lowest sample position, E, had the highest annual average ash content, 0.38 percent, while the B-out position had the lowest, 0.26 percent. The chips stored for 9 months had the highest average ash content, 0.40 percent.

B.7 Alcohol-Benzene Solubles

The alcohol-benzene extract is an indication of the amount of resin in the wood. The control chips had significantly higher alcohol-benzene extract than the stored chips. The amount of extract significantly decreased with increasing duration of storage. The effect of position in the chip pile was also significant with the C-position having the lowest annual average extractive content, 1.65 percent, and the D-position, the highest, 2.18 percent.

B.8 Fatty Acids

The fatty acid content was significantly lower in the stored chips than in the control chips. The amount tended to decrease with increased storage time, but the trend was not significant, indicating that a 3-month storage time is sufficient for reducing the fatty acid content. Variation in fatty acid content according to position in the pile also was not significant.

B.9 Combined Acids

The combined acids in the control chips was significantly higher than that in the stored chips. Like the fatty acid content, length of storage or position in the pile did not significantly affect the combined acid content of the chips.

B.10 Resin Acids

Stored chips had significantly reduced resin acid content compared with that in the control chips. The longer the duration of storage, the greater the reduction in resin acid content. The B-in position had the highest annual average resin acid content, 0.17 percent, and positions A, C, D, and E, the least, 0.11 percent.

B.11 Unsaponifiables

The control chips had significantly higher unsaponifiable content than the stored chips. Reduction of unsaponifiable content was greater, the longer the storage period, with 9-month storage giving the minimum average, 0.24 percent. Variation of position in the pile had no significant effect on unsaponifiable content.

The alcohol-benzene extract, an indication of the resin content in the wood, decreased with storage. The seasoning of the resin occurs at much greater rates during chip storage than in roundwood storage (1).

The non-volatile resin consists of the major fractions: Resin acids, free fatty acids, combined fatty acids (esters), and unsaponifiables (10). The major component of hardwood resin is fat, present either as free fatty acids or neutral fatty esters (11).

Biochemical and organic chemical reactions modify the resin composition during OCS. Esters or fats and waxes are hydrolyzed to fatty acids, and alcohols. Respiration metabolizes the fatty acids and, to some extent, higher alcohols to carbon dioxide and water (1). The major change in the seasoning of Betula papyrifera, a hardwood, is the conversion of fatty esters to fatty acids and, under certain conditions, further degradation of fatty materials (13). The fatty acids are metabolized faster than other resin constituents during OCS (1).

In a review concerning pitch-causing agents, the evidence seems to indicate that the pitch-causing agents include fatty acids and possibly unsaponifiable (10). Since the fatty acids, unsaponifiables, and the combined acids in the PICOP chips decreased during storage, the stored chips should cause less pitch problems than fresh chips during pulp and paper manufacture. Mill experience with the pulping of store chips confirms that relatively lesser pitch problems are experienced with stored chips.

C. Sulfate Pulping

C.1 Chemical Consumption

Chemical consumption during pulping was significantly lower for the stored chips than for the control chips, tending to decrease as the storage time was increased to 9 months. Chips in the C, D, and B-in positions had significantly lower annual average chemical consumption, 14.2 - 14.3 percent as Na_2O on o.d. chips, than the chips at the other locations.

C.2 Screened Pulp Yield

Based on the digester charge, pulp yield was not significantly different for both stored and fresh chips. Height of the chips in the pile had no effect on the chemical consumption. Average pulp yield was maximum at 3 and 9 months, 49.1 percent, and was lowest at 12 months, 44.6 percent.

Based on the fresh chips, pulp yield was significantly decreased by storage; the longer the duration of storage, the lower the pulp yield. After 3 months of chip storage, pulp yield loss was 2.1 percentage points and after 12 months storage, it was 9.7 percentage points. Chips at the A-position gave the highest annual average pulp yield, 45.1 percent; and the D-position gave the lowest, 41.6 percent.

C.3 Kappa Number

Kappa number was significantly lower for the stored chips than for the fresh chips, being lowest at 12 months storage, 25.2. It was highest at the B-position, 27.9 - 28.0, and lowest at the bottom E-position, 24.9 percent.

C.4 Burst Factor

There was no significant difference in the burst strength of the sulfate pulps from the fresh chips compared with those from the stored chips. Duration of storage or position of the chips in the pile had no significant effect on the strength.

C.5 Tear Factor

There was no significant difference in the tearing strength of the pulps from the fresh chips and those from stored chips. Position of the chips in the pile also had no effect on the strength. Tear of the pulps from the stored chips tended to decrease with increasing chip storage time.

C.6 Tensile Strength

There was no significant difference between the tensile strength of pulps from the control and the stored chips. Position in the chip pile had no significant effect on the strength. However, tensile strength tended to decrease with increasing storage time.

C.7 Folding Endurance

Folding endurance was not significantly affected by chip storage, duration of storage, or position in the chip pile. This property had the highest coefficient of variation, 29.7%, indicating its great variation.

The Kappa numbers increased for the stored chips in the New Guinea study, due to the increase in the relative amount of lignin in the stored wood (6). The opposite trend was noted in the PICOP chips even for the 3-month-old chips.

The New Guinea study had similar chemical consumption with 3-month-old chips but higher consumption for the 4-month-old chips (6). Chemical consumption, as Na_2O on the o.d. stored PICOP chips, increased slightly over that for the control or fresh chips. The 12-month averages for the various positions showed that position D had the least chemical consumption (14.17%) while the position E had the maximum chemical consumption (14.60%).

The New Guinea study had slightly higher pulp yields on o.d. stored chips than on the control chips but about the same, based on original fresh chips. Alkali consumption on 2 months storage was higher but at 4 months, it was the same as the control (6).

In the New Guinea study, the papermaking properties were similar for the control and the 2- and 4-months stored chips, except that the tearing strength of the pulps from the "wet zone" stored chips were lower and the pulp from stored chips had slightly lower breaking length, bursting strength, and folding endurance.

At least, up to about 9 months chip storage, strength properties of the PICOP chips, except folds, were comparable to that of the control. Folding endurance, even at 3 months, was already lower than that of the control.

D. NSSC Pulping

D.1 Pulp Yield

The pulp yield of the control chips based on the o.d. digester charge was not significantly different from those from the stored chips. Duration of storage and position in the chip pile significantly affected the pulp yield. The maximum pulp yield, based on the digester charge, was attained at 6 months storage, 83.9 percent, the lowest, at 12 months storage, 76.5 percent. Position B-in gave the least annual average pulp yield, 78.6 percent; position D, the highest, 83.4 percent.

The pulp yield, based on the o.d. fresh chips, was significantly higher for the fresh chips than for the stored chips. Pulp yield decreased with increasing duration of storage. The chips at position B-out gave the lowest annual average pulp yield, 71.4 percent, while the highest pulp yield, 75.8 percent, was obtained from position E.

D.2 Kappa Number

There was no significant difference in the Kappa numbers between the pulps from the fresh and the stored chips. However, the duration of storage and position in chip pile affected the values of the Kappa numbers.

D.3 Burst Factor

The burst strengths of the pulps from the stored chips were significantly lower than those from the control chips. The annual average burst factor of the pulps from the chips from the E-position was the lowest, 25, while those of the A-position were the maximum, 35.

D.4 Tear Strength

The pulp from the control samples had significantly higher strength than those made from the stored chips. The pulps from the chips stored at the E-position had significantly the least annual average tear factor, 40, while the pulps from the chips at the C-position had the highest, 50.

D.5 Breaking Length

The control pulp had significantly higher tensile strength than those made from the stored chips. The duration of storage did not result in significantly different tensile strengths of the pulps from the stored chips. Variation of position of the chips in the pile, however, resulted in significantly different strengths. The pulps at the A-position had the highest annual tensile strength, 6.2 km, and the pulps from chips at D and E had the least, 4.5 km.

D.6 Folds

Pulp from the stored chips had significantly lower strengths than from the fresh chips. Pulps from position A had the highest annual average, 18 double folds, while those from position D had the lowest, 5 folds.

The results for NSSC pulping in the New Guinea (6) study are similar to those obtained in this study on PICOP chips concerning pulp yield up to 9 months storage, based on original fresh chips and on the digester charge of stored chips. However, unlike the New Guinea study (6), burst, tear, and folding endurance were adversely affected by chip storage. Pile position affected strength with the chips in the upper portions (positions A, B, C) of the pile, giving NSSC pulps with the maximum burst, tear, tensile, and folds and the lower portions (D, E) giving NSSC pulps of lower strength.

CONCLUSIONS

1. Contrary to the experience in other OCS sites, the moisture content of the chip pile even in the lower most portions actually increased in 6 months, over that of the original moisture content in the fresh chips. In 3 months, the moisture content of the pile down to three meters from the top already had up to 10.8 percentage points higher moisture content than the freshly chipped wood. In 12 months of storage, the average moisture content was 15.3 percentage points higher or 65.1 percent.

2. Weight-loss rate of the chips was greatest during the first 3 months of storage at 1.36% per month. The lowest monthly loss rate was experienced during the 9 months of storage where the loss averaged only 0.99% per month.

3. Sulfate pulp yields from the stored chips, based on the digester charge, were higher than from the control chips. Based on the original chips, pulp yield was significantly higher for the control chips than for the stored chips. Up to 9 months storage, the burst, tear, and tensile strengths of the pulp were not adversely affected. Even the lower folding endurance of the stored chips was not statistically significant. Kappa numbers decreased with chip storage, even at three months.

4. NSSC pulp strengths from the stored chips were relatively lower than from the control chips. Kappa numbers increased for the pulps from the stored chips. Pulp yields on the stored chips, based on the digester charge, increased for up to 9 months storage. However, based on the fresh, original chips, pulp yields from the stored chips decreased.

5. It is expected that storage of the chips, even for 3 months, should reduce pitch troubles during pulp and paper manufacture since unsaponifiables

decreased by 52%, fatty acids by 42%, and combined acids by 20 percent. The combined acids are converted into fatty acids during chip storage. Fatty acids and unsaponifiables are possible pitch-causing agents.

6. Due to the high moisture content and the relatively low temperatures attained in the chip pile, far below temperatures causing combustion, there is no danger from fires in the chip pile in the area of Bislig, Surigao del Sur or any similar area with well-distributed and relatively high rainfall.

7. On the overall, it seems that chips could be stored up to 9 months with no serious loss in pulp strength properties, under the conditions obtained in the experimental site.

ACKNOWLEDGEMENTS

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Table 1. Rainfall, mm

	Chip storage, months											
	1	2	3	4	5	6	7	8	9	10	11	12
Monthly	218	119	158	130	337	150	259	399	522	540	877	470
3-month total			495			617			1180			1886
Cumulative total			495			1112			2292			4178

Table 2. Moisture Content of Chips*

Chip pile position	0	Chip storage, months 3	6	9	12
	49.8				
A		57.8	63.1	66.1	65.2
B-out		54.4	65.8	68.8	69.0
B-in		60.6	63.9	67.6	65.6
C		44.0	59.8	64.0	62.8
D		40.4	54.8	65.6	65.3
E		42.5	55.5	62.7	62.5

*% total weight basis

Table 3. Specific Gravity of Chips*

Chip pile position	0	Chip storage, months			
		3	6	9	12
	0.421				
A		0.403	0.390	0.392	0.386
B-out		0.391	0.384	0.375	0.357
B-in		0.399	0.397	0.368	0.385
C		0.405	0.392	0.390	0.389
D		0.403	0.380	0.390	0.321
E		0.404	0.386	0.384	0.382

*S.g. based on o.d. stored chips

Table 4. Weight Loss of Stored Chips*

Chip pile position	0	Chip storage, months			
		3	6	9	12
	-				
A		4.28	7.36	6.89	8.31
B-out		7.12	8.79	10.93	15.20
B-in		5.22	5.70	12.59	8.55
C		3.80	6.89	7.36	7.60
D		4.28	9.74	7.36	23.75
E		4.04	8.31	8.29	9.26

*% on o.d. fresh chips

Table 5. Lignin*

Chip pile position	Chip storage, months				
	0	3	6	9	12
	30.6	29.0	32.4	31.8	29.2
A		31.3	32.3	33.4	31.4
B-out		31.4	32.4	32.0	30.0
C		30.6	29.4	32.1	31.0
D		31.1	31.7	31.4	30.8
E		30.4	30.4	32.2	30.3

*% od o.d. stored chips

Table 6. Carbohydrates*

Chip pile position	Chip storage, months				
	0	3	6	9	12
	59.1				
A		61.3	53.0	58.7	63.8
B-out		61.3	54.5	57.6	63.4
B-in		62.6	56.9	57.5	65.0
C		60.6	58.2	59.6	61.8
D		60.7	60.3	60.7	60.5
E		59.2	60.4	59.8	59.0

*% of o.d. stored chips

Table 7. Pentosans*

Chip pile position	0	Chip storage, months			
		3	6	9	12
	8.6				
A		7.4	9.1	11.4	8.4
B-out		8.5	9.4	11.1	7.9
B-in		9.0	8.8	11.1	8.4
C		8.3	9.2	11.1	8.1
D		9.3	8.4	11.1	7.8
E		8.4	8.4	10.6	8.1

*% of o.d. stored chips

Table 8. Hot-water Solubility*

Chip pile position	0	Chip storage, months			
		3	6	9	12
	0.80				
A		2.09	2.36	3.99	2.53
B-out		4.96	1.53	1.94	1.62
B-in		3.62	4.97	2.88	2.52
C		0.82	4.60	0.52	1.22
D		0.79	1.54	0.83	2.55
E		3.04	2.78	0.39	2.95

*% of o.d. stored chips

Table 9. 1% Caustic Soda Solubility*

Chip pile position	Chip storage, months				
	0	3	6	9	12
	14.80				
A		18.3	15.5	14.4	13.1
B-out		19.9	14.2	14.3	15.2
B-in		16.5	14.6	14.5	13.3
C		13.0	11.1	15.0	13.8
D		16.9	18.7	13.7	14.1
E		15.7	16.2	14.9	13.3

*% of o.d. stored chips

Table 10. Alcohol-Benzene Solubility*

Chip pile position	Chip storage, months				
	0	3	6	9	12
	2.90				
A		2.42	2.46	2.26	1.01
B-out		2.91	2.57	1.85	1.38
B-in		2.96	2.34	1.75	1.12
C		2.09	1.51	1.64	1.36
D		3.26	2.71	1.29	1.59
E		2.72	2.66	1.88	1.37

*% of o.d. stored chips

Table 11. Ash*

Chip pile position	0	Chip storage, months 3	6	9	12
	0.33				
A		0.34	0.27	0.30	0.27
B-out		0.34	0.20	0.33	0.15
B-in		0.28	0.35	0.40	0.10
C		0.12	0.24	0.47	0.32
D		0.33	0.36	0.43	0.30
E		0.25	0.36	0.49	0.42

*% of o.d. stored chips

Table 12. Fatty Acids*

Chip pile position	0	Chip storage, months 3	6	9	12
	0.26				
A		0.15	0.11	0.10	0.10
B-out		0.12	0.12	0.14	0.14
B-in		0.17	0.16	0.13	0.10
C		0.15	0.15	0.10	0.12
D		0.18	0.16	0.16	0.12
E		0.12	0.15	0.12	0.12

*% of o.d. stored chips

Table 13. Combined Acids*

Chip pile position	0	Chip storage, months			
		3	6	9	12
	0.20				
A		0.19	0.11	0.12	0.14
B-out		0.13	0.16	0.15	0.16
B-in		0.15	0.15	0.14	0.15
C		0.17	0.14	0.15	0.11
D		0.15	0.15	0.17	0.11
E		0.16	0.12	0.11	0.12

*% of o.d. stored chips

Table 14. Resin Acids*

Chip pile position	0	Chip storage, months			
		3	6	9	12
	0.5				
A		0.03	0.03	0.01	0.04
B-out		0.02	0.06	0.03	0.02
B-in		0.03	0.08	0.03	0.03
C		0.04	0.04	0.02	0.01
D		0.01	0.05	0.03	0.02
E		0.03	0.03	0.03	0.02

*% of o.d. stored chips

Table 15. Unsaponifiables*

Chip pile position	Chip storage, months				
	0	3	6	9	12
	0.94				
A		0.48	0.29	0.19	0.26
B-out		0.47	0.28	0.29	0.41
B-in		0.27	0.44	0.23	0.31
C		0.37	0.58	0.22	0.30
D		0.72	0.47	0.27	0.27
E		0.38	0.55	0.25	0.08

*% on o.d. stored chips

Table 16. Sulfate Pulp Kappa Nos.

Chip pile position	Chip storage, months				
	0	3	6	9	12
	30.9				
A		24.3	28.2	28.2	23.2
B-out		31.2	25.0	27.6	28.4
B-in		28.9	29.1	25.9	27.7
C		27.6	29.4	22.4	24.7
D		30.6	24.7	24.2	24.1
E		29.2	23.6	23.2	23.5

Table 17. Sulfate Screened Pulp Yield*

Chip pile position	0	Chip storage, months 3	6	9	12
	48.8				
A		49.4	46.9	50.1	46.7
B-out		53.0	45.4	50.5	45.3
B-in		49.5	46.8	47.3	42.8
C		47.7	47.1	44.6	42.4
D		50.9	44.9	48.5	42.5
E		44.2	46.5	48.6	47.5

*based on o.d. stored chips

Table 18. Sulfate Screened Pulp Yield*

Chip pile position	0	Chip storage, months 3	6	9	12
	48.8				
A		47.3	43.4	46.6	42.8
B-out		49.2	41.4	45.0	38.4
B-in		46.9	44.1	41.3	39.1
C		45.9	43.8	41.3	39.2
D		48.7	40.5	44.9	32.4
E		42.4	42.6	44.3	43.1

*% on o.d. fresh chips

Table 19. Sulfate Pulping Chemical Consumption*

Chip pile position	Chip storage, months				
	0	3	6	9	12
	13.96				
A		15.17	14.74	13.97	14.04
B-out		15.17	14.34	14.60	14.07
B-in		14.95	14.58	13.70	13.68
C		14.89	14.34	13.70	13.96
D		14.86	13.28	13.94	14.61
E		15.04	15.04	14.27	14.07

*% on o.d. stored chips

Table 20. Sulfate Handsheet Burst Factor at 300 ml., CSF

Chip pile position	0	3	6	9	12
	72				
A		77	75	79	76
B-out		82	76	71	61
B-in		76	73	77	75
C		74	77	70	81
D		76	68	70	78
E		80	73	70	76

Table 21. Sulfate Handsheet Tear Factor at 300 ml., CSF

Chip pile position	0	3	6	9	12
	90				
A		95	84	93	90
B-out		92	91	89	90
B-in		94	81	89	72
C		94	97	92	88
D		98	84	94	87
E		92	86	89	84

Table 22. Sulfate Handsheet Breaking Length, m at 300 ml., CSF

Chip pile position	0	Chip storage, months			
		3	6	9	12
	11.2				
A		12.2	10.3	12.1	10.3
B-out		12.0	10.6	11.4	9.7
B-in		11.2	10.4	11.2	9.8
C		10.9	11.0	11.0	11.0
D		11.7	11.1	10.7	10.7
E		11.3	9.0	11.1	10.2

Table 23. Sulfate Handsheet Folds at 300 ml., CSF

Chip pile position	0	Chip storage, months			
		3	6	9	12
	665				
A		760	710	750	349
B-out		670	595	732	435
B-in		762	310	550	634
C		435	600	598	415
D		882	495	392	540
E		336	632	272	478

Table 24. Sulfate Handsheet Density, g/cm^3 at 300 ml., CSF

Chip pile position	Chip storage, months 0	3	6	9	12
	0.71				
A		0.75	0.70	0.71	0.72
B-out		0.71	0.70	0.72	0.72
B-in		0.72	0.72	0.74	0.73
C		0.70	0.70	0.71	0.73
D		0.71	0.71	0.71	0.72
E		0.72	0.71	0.71	0.74

Table 25. NSSC Pulp Kappa Nos.

Chip pile position	Chip storage, months 0	3	6	9	12
	146				
A		160	162	174	155
B-out		136	155	149	151
B-in		152	175	155	153
C		150	156	156	143
D		158	163	157	156
E		147	163	148	151

Table 26. NSSC Pulp Yields*

Chip pile position	Chip storage, months 0	3	6	9	12
	79.4				
A		81.1	78.2	86.6	78.0
B-out		86.0	76.0	85.8	70.8
B-in		80.6	82.5	82.0	67.8
C		82.4	80.3	81.5	81.7
D		84.3	83.8	84.6	81.0
E		79.8	85.0	82.1	80.7

*% on o.d. stored chips

Table 27. NSSC Pulp Yield*

Chip pile position	Chip storage, months				
	0	3	6	9	12
	79.4				
A		77.6	72.4	86.3	71.5
B-out		79.9	69.3	76.4	60.0
B-in		76.4	77.8	71.7	62.0
C		79.3	74.8	75.5	75.5
D		80.7	81.0	78.4	61.8
E		76.6	77.9	74.9	73.2

*% on o.d. fresh chips

Table 28. NSSC Handsheet Burst Factor
at 300 ml., CSF

Chip pile position	Chip storage, months				
	0	3	6	9	12
	32				
A		32	35	33	40
B-out		33	28	30	14
B-in		35	22	31	26
C		29	26	31	35
D		27	27	16	29
E		28	30	9	32

Table 29. NSSC Handsheet Tear Factor

at 300 ml., CSF

Chip pile position	0	Chip storage, months			
		3	6	9	12
	51				
A		41	52	50	48
B-out		58	49	51	40
B-in		53	47	47	44
C		52	44	55	50
D		46	42	30	51
E		46	47	20	49

Table 30. NSSC Handsheet Breaking Length, Km

at 300 ml., CSF

Chip pile position	0	Chip storage, months			
		3	6	9	12
	5.4				
A		6.0	6.3	6.0	6.3
B-out		4.9	4.6	5.5	4.5
B-in		4.5	4.4	5.8	5.6
C		5.8	5.0	5.7	4.8
D		5.0	5.7	3.3	3.9
E		5.4	5.4	1.8	5.4

Table 31. NSSC Handsheet Folds

at 300 ml., CSF

Chip pile position		Chip storage, months			
	0	3	6	9	12
	13				
A		16	20	14	24
B-out		12	5	11	6
B-in		13	4	10	8
C		21	7	10	15
D		5	5	2	7
E		9	10	10	13

Table 32. NSSC Handsheet Density, g/cm^3

at 300 ml., CSF

Chip pile position		Chip storage, months			
	0	3	6	9	12
	0.56				
A		0.54	0.49	0.51	0.58
B-out		0.53	0.46	0.50	0.54
B-in		0.52	0.59	0.56	0.49
C		0.56	0.54	0.56	0.56
D		0.50	0.51	0.44	0.52
E		0.51	0.55	0.39	0.56

Table 33 Analyses of Variance of Chip Properties

Source of variation	Chip moisture content	Chip s.g.
Control vs stored	*	*
Months of storage	**	*
Position in pile	**	NS
Coefficient of variation, %	12.16	3.59

NS - not significant
* - significant at the 5% level
** - significant at the 1% level

Table 34. Analyses of Variance of Chemical Composition of Chips

Source of variation	Carbohydrates	Lignin	Pentosans	Hot water solubles	Alcohol-benzene soluble	1% NaOH solubles	Ash
Control vs stored	NS	NS	*	**	**	NS	**
Months of storage	**	**	**	**	**	**	**
Position in pile	NS	NS	NS	**	**	**	**
Coefficient of variation, %	1.89	3.30	3.29	22.91	6.80	4.76	17.78

Table 35. Analyses of Variance of Ether-Extractives

Source of variation	Fatty acids	Resin acids	Combined acids	Unsaponifiables
Control vs stored	**	**	**	**
Months of storage	NS	**	NS	*
Position in pile	NS	**	NS	NS
Coefficient of variation, %	6.06	16.73	12.37	35.24

Table 36. Analyses of Variance of Sulfate Pulping and Handsheet Properties

Source of variation	Chemical consumption	Screened Pulp Yield		Screen rejects	Kappa no.	Burst	Tear	Tensile	Folds
		fresh chips	stored chips						
Control vs stored	*	*	NS	NS	**	NS	NS	NS	NS
Months of storage	**	**	**	**	**	NS	**	**	NS
Position in pile	*	**	NS	NS	*	NS	NS	NS	NS
Coefficient of variation, %	1.56	2.96	4.55	63.75	7.12	9.88	6.80	6.68	29.73

Table 37. Analyses of Variance of NSSC Pulping and Handsheet Properties

Source of variation	Chemical consumption	Pulp Yield fresh chips	Pulp Yield stored chips	Kappa no.	Burst	Tear	Tensile	Folds
Control vs stored	NS	*	NS	NS	*	**	*	**
Months of storage	**	**	**	*	**	**	NS	**
Position in pile	**	**	**	*	*	**	*	**
Coefficient of variation, %	10.04	3.16	2.92	5.68	0.78	10.25	21.99	37.61

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SECTION IV

WOOD FIBER AND RECONSTITUTED PRODUCTS RESEARCH

SUITABILITY OF TROPICAL FORESTS FOR PULPWOOD:
MIXED HARDWOODS, RESIDUES, AND REFORESTATION SPECIES

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ABSTRACT

As the tropical rainforest assumes greater importance as a source of raw material for the pulp and paper industry, major areas of opportunity for utilization become apparent. However, to preserve future supplies, more efficient utilization of these resources is essential and planned research can be used to achieve an improvement.

The paper gives examples of pulping studies on mixed hardwood species from the rainforests of Papua New Guinea, forest and sawmill residues of Shorea albida from Peat Swamp Forests in Sarawak, Malaysia, and an assessment of the potential of fast-growing hardwood species available for reforestation programmes. The results obtained show the suitability of these materials for various purposes. These research study programmes were developed, in conjunction with forestry authorities, to give practical evidence to assist the planning of forest based industries. Such a coordinated approach is important in obtaining adequate evidence as a basis for efficient planning.

It is suggested that improved utilization depends on an acceptance that:

(i) Tropical forests in different areas are different and must be assessed accordingly

(ii) A total use concept should be applied wherever possible, even in the presence of an apparent abundance of raw material, and

(iii) Reforestation is an essential requirement for providing forest resources for the future.

KEYWORDS: Tropical hardwoods, mixed species, pulping, reforestation species, forest residues, waste wood, pulpwood utilization.

SUITABILITY OF TROPICAL FORESTS FOR PULPWOOD: MIXED HARDWOODS, RESIDUES, AND REFORESTATION SPECIES

By

F. H. Phillips, A. F. Logan, and V. Balodis

As technology advances and as supplies of preferred raw materials diminish, industry accepts other supplies for processing. In the pulp and paper industry this trend has been evident over some 150 years with a movement from the exclusive use of a limited number of coniferous species, through the acceptance of select temperate hardwoods to the utilization of whole trees, forest and mill residues, and increasing numbers of species. Even though there has been considerable resistance to the utilization of mixed tropical hardwoods, those who have been associated with the assessment of tropical forest resources have known that it was only a matter of time before these were also accepted by industry. Some problems in economic utilization remain, but whereas the general view a few years ago was that such materials were unsuitable, this view is not acceptable today. African mixed tropical hardwoods are being used for bleached pulp production, and in India, Thailand, and South America mixed tropical hardwoods are in commercial use, although some selection of species is common practice. Mills in the Philippines and several in Japan are also heavily dependent on tropical hardwoods as a source of pulpwood and these are often mixed with other woods, such as plantation materials or local hardwoods, prior to pulping.

We are now entering a period of rapidly increasing use of tropical timbers for pulpwood and this utilization, together with the demands for additional agricultural land, could result in the destruction of the world's remaining tropical rainforests. Therefore, at the very least it is essential that research programmes are planned to provide evidence which will permit the optimum utilization of these resources and so ensure that the wood supplies are not depleted unnecessarily. Experience indicates that, to be adequate, this planning needs to be based on three factors:

Firstly, an awareness that tropical forest resources vary greatly and that their potential for utilization for commercial pulp and paper production will also vary.

Secondly, an acceptance that as far as possible a total use concept should be followed and that the integration of industries is necessary to reduce waste, both in the forest and in the processing stages.

Thirdly, a determination to pursue a vigorous reforestation programme to assess the potential of fast-growing species which will provide new resources for future operations.

At the Commonwealth Scientific and Industrial Research Organisation (CSIRO) laboratories concerned with the assessment of cellulosic resources for pulping and papermaking, work has been carried out on timbers from Papua New Guinea (PNG) and Malaysia. Less extensive studies have been made on Indonesian, South American, and South Pacific timbers. In the recent major research programmes on such resources we have taken the above-mentioned factors into account. Examples of some of the work will be described in this paper.

MIXED SPECIES FOREST RESOURCES

Forest Areas

Generally it would be expected that efforts to establish a woodchip or pulping industry on natural mixed species forests would result from the initiative of the Forest Department in the area. This was the case in PNG, and laboratory studies were planned so that results could be used for the national scale planning of forest resources by government authorities and provide the evidence for the utilization of the resource to best advantage.

Of the 46 million hectares of total land area in PNG about 40 million hectares is tree covered. A little over one-third of this treed area can be regarded as accessible commercial forest, containing a wide variety of forest types and species mixtures. One area, the Gogol timber area, located towards the eastern end of the Sepik-Ramu forest system and covering approximately 50,000 hectares, is the basis of a woodchip export enterprise. This resource consists mainly of regrowth lowland rainforest, and there is a high volume percentage (ca. 70 percent) of trees less than 50 cm diameter in this area. Intsia spp predominate and the other major genera present include Pometia, Terminalia, Dysoxylum, Teysmanniodendron, Sterculia, Ficus, Pimeleodendron, Canarium, and Myristica (1).

Another timber area in PNG, at Vanimo on the north coast near the Irian Jaya border, covers approximately 300,000 hectares and is the largest single area currently considered for development. The main genera which occur in this area are Intsia, Pometia, Myristica, Celtis, Terminalia, Homalium, Pimeleodendron, Eugenia, Palaquium, Canarium, Planchonella, and Teysmanniodendron (1).

Sample Material

A forest sampling operation involving the major species allowed a limited evaluation of the pulping potential of the Gogol timber resources to be made prior to the establishment of an integrated woodchip and sawn timber industry. The availability of commercial woodchips from this woodchip export operation has now enabled a more extensive investigation to be carried out to determine the pulp quality obtainable from the mixed species, and therefore the value of the raw material, without the need to undertake an extensive forest sampling exercise. The woodchip industry now operating uses waste from the large trees of species selected for saw milling together with all other timber resulting from clear felling. Daily samples of freshly prepared chips were collected over a 3 to 4 week period to form each of three composite mixtures for testing. These three mixtures represented wood harvested from different coupes in the Gogol timber area over a 4 month period.

In the case of the Vanimo timber area, chip mixtures were prepared to represent the different blocks, forest types, and diameter classes available. Possible utilization plans, such as the reservation of large trees of select species for sawmilling, were also investigated. The composite mixtures were prepared following an extensive forest sampling exercise involving the collection of wood from approximately 2,000 trees (2).

The basic density of the three chip samples from the Gogol timber area had an average of 428 kg/m^3 (3) compared with 484 kg/m^3 for samples representing the total wood resources in adjacent blocks of the Vanimo timber area (2) (4). The values are moderately low for pulpwood. Average fibre length of whole fibres was 1.6 mm and ca. 1.5 mm respectively, greater than for many temperate zone hardwoods used in commercial pulping. These results are summarized in table 1.

Pulping Results

The properties of unbleached sulphate pulps prepared at two levels of Kappa number are also given in table 1. The levels chosen were approximately 20, which would provide evidence of suitability for both bleached and unbleached products, and approximately 40 to evaluate suitability for packaging grade products such as linerboard.

Some important physical properties obtained on laboratory handsheets are given in table 2 and show the level of strength developed in the various unbleached and bleached sulphate pulps. Generally it can be concluded that mixed species hardwoods from these two timber areas can be used satisfactorily for the production of sulphate pulps. The unbleached pulp strengths should be adequate for end products such as kraft liner boards, bag and wrapping papers, and multiwall sack papers. The pulps at the higher Kappa number (ca. 40) were produced in higher yields and generally had higher strength properties than those at Kappa number ca. 20. Bleached sulphate pulps were prepared readily from these mixtures of tropical hardwoods using a CEHD bleaching sequence and high brightness was obtained without segregation of any species.

It has been found that satisfactory NSSC pulps can be prepared from the mixed hardwoods from these timber areas in PNG (2) (3) (4) (5). High yields (ca. 73-77 percent) were obtained at Kappa numbers of ca. 130 and the pulps would be suitable for corrugating medium. However, more severe cooking conditions, which substantially lowered the pulp yield, were required to produce NSSC pulps suitable for higher quality products.

Table 1

Wood properties, pulping conditions and properties of sulphate pulps from Papua New Guinea mixed hardwoods

	Gogol Timber Area Samples		Vanimo Timber Area Samples	
Basic density (kg/m^3)	428		484	
Fibre length, whole fibres (mm)	1.6		1.5	
Active alkali* (as Na_2O) (%)	12	15	12	16
Unbleached pulp				
Yield (%) +				
Unscreened	52.2	48.3	51.7	47.7
Screened	47.1	46.8	48.3	46.5
Kappa number (screened pulp)	40.9	21.8	44.4	22.0
Bleached pulp				
Yield (%) +	-	42.2	-	42.9
Brightness (%) (Elrepho)	-	>87	-	85

Pulping conditions:	Charge 1800 g (o.d.)	chips in 20 l rotary digester
	Sulphidity	25%
	Liquor:wood ratio*	3.5:1
	Cooking temperature	170°C
	Time to temperature	1.5 h
	Time at temperature	2 h
	Blow down time	0.3 h

Bleaching sequence: CEHD

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* Based on o.d. wood

\+ o.d. pulp as a percentage of o.d. wood

Source of data Ref. (2)(3)(4)

Table 2

Comparison of papermaking properties of unbleached and bleached sulphate pulps from Papua New Guinea mixed hardwoods

(for pulping conditions see Table 1)

Property	Freeness (Canadian Standard)	Gogol Timber Area		Vanimo Timber Area	
		Kappa No. *ca.* 40	Kappa No. *ca.* 20	Kappa No. *ca.* 40	Kappa No. *ca.* 20
Unbleached Pulp					
Bulk (cm^3/g)	450	1.71	1.72	1.80	1.77
	250	1.54	1.56	1.65	1.60
Tear index ($mN\ m^2/g$)	450	10.7	10.2	11.0	10.9
	250	10.6	9.5	11.3	10.4
Breaking length (km)	450	6.7	6.4	6.4	6.0
	250	8.5	8.3	8.4	7.9
Bleached Pulp					
Bulk (cm^3/g)	450	-	1.69	-	1.79
	250	-	1.52	-	1.60
Tear index ($mN\ m^2/g$)	450	-	10.2	-	9.6
	250	-	9.9	-	9.8
Breaking length (km)	450	-	5.1	-	4.3
	250	-	7.3	-	6.2

Further Implications

As well as indicating suitability for pulping, as discussed above, and establishing a level of quality for the woodchip mixture on which export price negotiations can be centered, the investigations were planned to provide evidence of assistance in forest management and utilization planning. It has been shown that:

(i) Even though there were differences in the wood resources available in the different areas, particularly in regard to forest type, diameter class, and species composition, the pulp properties were not greatly different.

(ii) The exclusion of large trees (>50 cm diameter) of some species for sawmilling, or the exclusion of all small trees (<30 cm diameter), or the exclusive use of hill or lowland species in the Vanimo timber area had little effect on pulp quality.

(iii) The large number of species in the mixture did not create pulping problems, and it was not necessary to segregate species, even for the production of high brightness bleached pulps.

These findings should be of practical significance in future logging operations and in planning the efficient utilization of PNG forest resources. However, it does not necessarily follow that these conclusions will apply to tropical forest resources elsewhere.

RESIDUES FROM FOREST AND SAWMILL OPERATIONS

Extending Pulpwood Resources

The utilization of the whole tree is becoming accepted as desirable practice in the forest products industries of developed countries. It is one way of providing additional material for our future needs. However, other new materials must also be introduced into commercial operations and tropical forest resources are in this category. They must be supplied for use in existing processes, not according to practices based on a concept of an overabundance of raw material, but considered in the same way as temperate zone timbers in limited supply. Optimum use patterns must be developed for each type of material to conserve the limited resources.

As pulpwood is normally of lower quality than that demanded by sawmills, veneer mills, and moulding plants, only the noncommercial timbers and the small and defective trees unsuitable for these purposes should be harvested for chipping. Otherwise residue material, which includes crowns and bark, offcuts, and cores, would be a source of material for pulpwood chips whenever available. Initiatives to produce woodchips from these materials should be important aspects of both Forest Department programmes and timber industry plans for improving the economics of current operations. With this incentive, support should be available for developing realistic study programmes to prove the viability of including such residue materials in raw material supplies.

Shorea albida Residues

In Sarawak, Malaysia the forests cover about three quarters of the total land area and one of the two major forest groups, the Peat Swamp Forests, occupy about 1.5 million hectares, or over 11 percent of the land area. Investigations of the pulping potential of Peat Swamp Forest and residue resources are being undertaken. However, the most abundant species in the peat swamps is Shorea albida sym. and is currently being used for sawmilling, veneer production, and log export. The material available for pulpwood in the form of defective and damaged trees, nonsawlog portions of trees, and crowns was estimated to be approximately 10 million cubic metres and potentially could sustain a chip/pulp industry in the immediate future. The Sibu area, which has an estimated annual supply of 250 thousand cubic metres of Shorea albida residues, was selected as the source of pulpwood test sample.

Shorea albida produces two distinctly different types of timber: Alan batu, a heavy dense wood, and Alan bunga, a light to medium density wood. Both were included in the pulp test composite mixture. According to estimates, this should contain 86 percent Alan batu and the remainder Alan bunga if all the residues available, including crowns, are used for wood chipping. The actual composition was:

		Percentage (by volume)
Alan batu	Stemwood and offcuts	65
	Crowns	21
Alan bunga	Stemwood	8
	Offcuts	0
	Crowns	6
		100

It is doubtful whether Alan bunga sawmill offcuts will be available in practice because Alan bunga is exported, and these were not included in the mixture of chips prepared to represent the raw material supply. Because of the high proportion of Alan batu, which has a basic density of 624 kg/m^3 compared with 482 and 592 kg/m^3 for Alan bunga stemwood and crowns respectively, the basic density of the composite mixture was 618 kg/m^3.

Pulping and papermaking test results shown in table 3 indicate that bonding strengths are low but tearing resistance is quite satisfactory, consistent with the medium-high basic density of the composite sample. Of course, the higher density, compared, for example, with mixed species wood chips from PNG would be an advantage for more economic woodchip transport or higher digester production capacity. Bleached pulp brightness was satisfactory for a CEHD sequence and further tests showed that additional stages produced considerable improvement with only a slight loss in yield.

Table 3

Properties of sulphate pulps from *Shorea albida* residues from Sarawak, Malaysia

(pulping conditions, except active alkali, as for pulps listed in Table 1)

	at 450 Csf	at 250 Csf
Unbleached pulp		
Active alkali* (as Na_2O)(%)	15.5	
Screened yield+ (%)	46.0	
Kappa number	21.2	
Bulk (cm^3/g)	1.99	1.86
Tear index ($mN\ m^2/g$)	9.9	11.7
Breaking length (km)	4.7	5.8
Bleached pulp (CEHD sequence)		
Yield+ (%)	42.0	
Brightness (Elrepho)(%)	84	
Bulk (cm^3/g)	1.91	1.79
Tear index ($mN\ m^2/g$)	8.6	9.8
Breaking length (km)	4.2	5.3

* Based on o.d. wood

\+ o.d. pulp as a percentage of o.d. wood

Table 4

Properties of sulphate pulps from potential reforestation species

Pulping conditions:	Charge	200 to 250 g (o.d.) chips in 2 l. reaction vessels
	Sulphidity	25%
	Liquor to wood*	3.5:1
	Cooking temperature	170°C
	Time to temperature	1.25 h
	Time at temperature	2 h

Sample	Age (yr)	Basic density (kg/m³)	Active alkali* (as Na_2O) (%)	Unbleached pulp								Bleached pulp (CEHD sequence)	
				Screened yield⁺ (%)	Kappa No.	at 450 Csf			at 250 Csf			Yield⁺ (%)	Brightness (Elrepho) (%) (pulp)
						Bulk (cm³/g)	Tear index (mN m²/g)	Break. length (km)	Bulk (cm³/g)	Tear index (mN m²/g)	Break. length (km)		
Acacia auriculiformis	10	497	13	54.7	17.4	1.64	12.0	7.9	1.34	11.6	11.3	-	-
Albizia falcataria	7	238	13	52.6	17.9	-	-	-	1.24	9.0	11.4	-	-
Gmelina arborea	5	346	13	51.7	18.6	1.43	10.9	7.0	1.23	10.7	11.4	-	-
Terminalia brassii	10	287	16.5	48.0	20.9	-	-	-	1.24	9.3	13.9	46.5	89
Eucalyptus deglupta	9	344	13	49.8	20.1	-	-	-	1.34	10.9	11.6	48.2	88
Eucalyptus tereticornis	4	634	16	43.3	24.9	2.02	5.8	4.3	1.67	10.1	7.5	-	-
Melaleuca leucodendron	4	545	13	39.0	36.6	-	-	-	1.49	9.9	7.8	-	-
Eucalyptus regnans	12	398	12	55.2	15.7	-	-	-	1.40	9.9	9.9	-	-
Mixed Species[ø] (Gogol Timber Area, PNG)	-	428	15	45.3	21.8	1.72	10.2	6.4	1.56	9.5	8.3	42.2	>87

* Based on o.d. wood   + o.d. pulp as a percentage of o.d. wood   Source of data Ref (3)(6)(7)(8)(9)

ø Charge 1800 g(o.d.) chips cooked in 20 l rotary digester, 2 h at 170°C

Table 3

Properties of sulphate pulps from *Shorea albida* residues from Sarawak, Malaysia

(pulping conditions, except active alkali, as for pulps listed in Table 1)

Unbleached pulp		
Active alkali* (as Na_2O) (%)	15.5	
Screened yield+ (%)	46.0	
Kappa number	21.2	
	at 450 Csf	at 250 Csf
Bulk (cm^3/g)	1.99	1.86
Tear index ($mN\ m^2/g$)	9.9	11.7
Breaking length (km)	4.7	5.8
Bleached pulp (CEHD sequence)		
Yield+ (%)	42.0	
Brightness (Elrepho) (%)	84	
	at 450 Csf	at 250 Csf
Bulk (cm^3/g)	1.91	1.79
Tear index ($mN\ m^2/g$)	8.6	9.8
Breaking length (km)	4.2	5.3

* Based on o.d. wood

\+ o.d. pulp as a percentage of o.d. wood

Table 4

Properties of sulphate pulps from potential reforestation species

Pulping conditions: Charge 200 to 250 g (o.d.) chips in 2 l. reaction vessels
Sulphidity 25%
Liquor to wood* 3.5:1
Cooking temperature 170°C
Time to temperature 1.25 h
Time at temperature 2 h

Sample	Age (yr)	Basic density (kg/m³)	Active alkali[*] (as Na_2O) (%)	Unbleached pulp								Bleached pulp (CEHD sequence)	
				Screened yield[+] (%)	Kappa No.	at 450 Csf			at 250 Csf			Yield[+] (%)	Brightness (Elrepho) (%) (pulp)
						Bulk (cm³/g)	Tear index (mN m²/g)	Break. length (km)	Bulk (cm³/g)	Tear index (mN m²/g)	Break. length (km)		
Acacia auriculiformis	10	497	13	54.7	17.4	1.64	12.0	7.9	1.34	11.6	11.3	-	-
Albizia falcataria	7	238	13	52.6	17.9	-	-	-	1.24	9.0	11.4	-	-
Gmelina arborea	5	346	13	51.7	18.6	1.43	10.9	7.0	1.23	10.7	11.4	-	-
Terminalia brassii	10	287	16.5	48.0	20.9	-	-	-	1.24	9.3	13.9	46.5	89
Eucalyptus deglupta	9	344	13	49.8	20.1	-	-	-	1.34	10.9	11.6	48.2	88
Eucalyptus tereticornis	4	634	16	43.3	24.9	2.02	5.8	4.3	1.67	10.1	7.5	-	-
Melaleuca leucodendron	4	545	13	39.0	36.6	-	-	-	1.49	9.9	7.8	-	-
Eucalyptus regnans	12	398	12	55.2	15.7	-	-	-	1.40	9.9	9.9	-	-
Mixed Species[ø] (Gogol Timber Area, PNG)	-	428	15	45.3	21.8	1.72	10.2	6.4	1.56	9.5	8.3	42.2	>87

[*] Based on o.d. wood [+] o.d. pulp as a percentage of o.d. wood Source of data Ref (3)(6)(7)(8)(9)

[ø] Charge 1800 g(o.d.) chips cooked in 20 l rotary digester, 2 h at 170°C

The results obtained on the composite mixture were greatly influenced by the high proportion of Alan batu stemwood. Tests on individual samples of stemwood, offcuts, and crowns of both Alan batu and Alan bunga showed that wood components of Alan bunga require less alkali and produced higher yields of sulphate pulps at the same Kappa number. Bonding strengths were also higher for the Alan bunga samples. Crown material was the least desirable component although the properties of pulps from Alan bunga crowns were more satisfactory than from any of the Alan batu components.

It can be concluded that the mixture of Shorea albida residues would be satisfactory for use in bleached sulphate pulp production and subsequently for writing and printing papers. Use in the manufacture of packaging materials which do not require high strengths may also be possible. Tests indicated that some packaging materials could also be produced from the high yield (>70 percent) NSSC pulp.

The Shorea albida residues consist of various components from natural tropical forests. The wood properties and the pulping properties are quite different from those of the mixed hardwood species, available from PNG forest areas, which were considered above. Even though both supplies could be termed 'tropical forest resources,' 'mixed tropical hardwoods,' or 'pulpwood from tropical species' it is obvious that both need to be assessed independently and utilized according to their potential, which apparently is rather different.

HARDWOOD SPECIES FOR REFORESTATION

Tropical rainforest must be regarded as a renewable resource, but natural regeneration within clear felled areas will produce a species mixture with characteristics different from those of the virgin forest, and the secondary regrowth is often of doubtful value to the pulp and paper industry, at least in the short term. Irrespective of the general forestry policies adopted, it appears certain that young fast-grown hardwoods will have an important role in the industry in the future, and the eventual supply of pulpwood must come from plantations or reforested areas. The evaluation of species with potential for reforestation purposes is an urgent necessity.

Pulping investigations on several plantation species from PNG and Northern Australia have been carried out at our laboratory. Fortunately the PNG Department of Forests had realized the need for silvicultural research studies on potential fast-growing plantation hardwoods and had earlier established plots of a variety of species in many different locations. In Northern Australia studies are also being carried out to find species which produce rapid growth under irrigation and subsequently to determine their potentialities as pulpwood. A wide range of material, already proved silviculturally, was therefore available for laboratory pulping studies. The results obtained are interesting and have already proved valuable in guiding forestry authorities engaged in plantation establishment.

Papua New Guinea Species

The main species studied include Eucalyptus deglupta, Terminalia brassii, Acacia auriculiformis, Albizia falcataria, Gmelina arborea, Eucalyptus tereticornis, and Melaleuca leucadendron. The investigations are continuing, but it has been established that some of these fast-growing woods possess very good pulping and papermaking properties (6).

Results of some of these tests, on both unbleached and bleached sulphate pulps, are given in table 4. For comparison, results on a sample of young temperate zone Eucalyptus regnans and on the mixed species hardwoods from the Gogol timber area, PNG are included. The former material is regarded as extremely acceptable for commercial pulping operations. Results of NSSC pulping tests on some of the wood species are given in table 5.

Unfortunately the plantation samples are not all the same age, but the variation does not preclude a useful comparison of their properties. Generally, the plantation species required less alkali to pulp to a similar Kappa number, generally produced higher yields of pulp, and had superior strength properties to mixed tropical hardwoods from the virgin forests. Acacia auriculiformis, Albizia falcataria, and Gmelina arborea gave high yields of unbleached sulphate pulps, but Terminalia brassii needed a relatively high concentration of alkali and therefore the yield was slightly low. The bonding strengths of these four pulps were excellent, and tearing resistance was also high in some cases. Bleached sulphate pulps of high brightness were prepared from Eucalyptus deglupta and Terminalia brassii. Eucalyptus tereticornis and Melaleuca leucadendron, both 4 years, showed inferior sulphate pulping properties compared with the other species listed. The NSSC pulps shown in table 5 would be suitable for corrugating medium and similar coarse products, if cooked to the higher yield-higher Kappa number level, and in some cases, if cooked to a lower Kappa number, could also be used as a replacement for sulphate pulps.

Because it is necessary, even with plantation-grown woods, to ensure efficient utilization of the available material the CSIRO laboratory pulping studies have also included tests on Eucalyptus deglupta samples covering an age range of 3 to 20 years to show the optimum age for harvesting this plantation grown pulpwood (7). Spacing trial samples having considerably different growth rates have been tested to determine whether the wood produced in considerably greater volume was as satisfactory for pulping as slower growing wood. Defective wood of Eucalyptus deglupta, caused by soft rot or decay or brittle heart as well as stained heartwood, were investigated also to decide whether such materials were suitable for pulping and bleaching (10). As mentioned earlier, more attention is being given to pulping parts of the tree other than the wood of the merchantable bole. With young plantation-woods especially, it would be an advantage to be able to pulp the material without removal of bark, both because of the gain of additional fibrous material and the difficulty of economic removal from small diameter stems. Results of sulphate pulping and bleaching tests, on unbarked wood of plantation-grown

Table 5

Properties of NSSC pulps from potential reforestation species

				At 250 Csf		
	Age (yr)	Screened yield$^+$ (%)	Kappa number	Tear index (mN m^2/g)	Breaking length (km)	Crush$^{\varnothing}$ resistance (CMT) (N)
Acacia auriculiformis	10	76.2(i)	119	9.1	9.2	345
		65.6(ii)	78	10.2	10.7	395
Albizia falcataria	7	74.5(i)	126	6.6	9.6	360
		64.4(ii)	84	7.7	11.3	375
Eucalyptus deglupta	11	78.7(i) US	148	7.5	8.1	395
		65.4(ii) US	98	9.9	9.4	386
Eucalyptus tereticornis	4	63.9(i)	152	6.0	4.7	305
		56.2(ii)	111	7.6	5.4	315
Gmelina arborea	5	76.4(i)	141	7.4	7.1	320
Terminalia brassii	9	72.0(i)	138	6.9	11.5	390
		61.2(ii)	100	6.8	13.2	430

(i) Chips cooked with 15% Na_2SO_3* at 170°C for 2 h

(ii) Chips cooked with 25% Na_2SO_3* at 180°C for 3 h

* Based on o.d. wood

\+ o.d. pulp as a percentage of o.d. wood

ø Tests made on 120 g/m^2 handsheet

US = unscreened pulp

Source of data Ref (7)(8)(9)

Eucalyptus deglupta and Terminalia brassii, showed that it should be possible to pulp these plantation species on a commercial scale, without removing the bark and without any substantial change to the normal pulping and bleaching conditions used for unbarked wood (8) (10).

Northern Australian Species

The pulping potential of two species from Northern Australia, Anthocephalus chinensis (2-1/2 years) and Sesbania grandiflora (4-1/2 years) have also been examined (11). Anthocephalus chinensis should be suitable, in either the unbarked or debarked state, for sulphate pulp production and subsequent use for both unbleached and bleached papers. Sesbania grandiflora, pulped after bark removal, produced moderately low yields of sulphate pulp suitable for a limited range of end products. The NSSC pulping and papermaking properties of Anthocephalus chinensis (without bark) were considered adequate for various end products, but NSSC pulp from Sesbania grandiflora could probably be used only for corrugating medium.

Suitability for End Products

An assessment of the suitability of Eucalyptus deglupta, Terminalia brassii, Acacia auriculiformis, Gmelina arborea, Albizia falcataria, Anthocephalus chinensis, and Sesbania grandiflora for unbleached kraft and NSSC pulp production has been attempted. Considering these species generally on the basis of pulp yield, pulp strength, and basic density, an approximate ranking in order of decreasing suitability is given in table 6. Eucalyptus tereticornis and Melaleuca leucadendron pulps were not included in the ranking. The Anthocephalus chinensis and Sesbania grandiflora samples evaluated were very young. As it has been shown recently that plantation-grown Eucalyptus deglupta (7) and Eucalyptus globulus (12) pulping and papermaking properties improve over the first few years, then it is probable that older wood of Anthocephalus and Sesbania, up to say 8 or 10 years, would produce pulp of better quality. It is interesting to note that Acacia auriculiformis appears at the top of each list. This species was found to be extremely suitable for both sulphate and NSSC pulps. However, all of the species on this list should be suitable for sulphate and NSSC pulp production, irrespective of ranking.

Wood yield has not been taken into consideration in the listing because reliable data were not available, but this important factor should not be overlooked in pulpwood assessment. Frequently, species which have high growth rates have quite low basic density. Although such wood can generally be readily pulped to produce high yields of pulp from a given weight of chips, these low density woods may not provide a satisfactory pulp yield per hectare of plantation on a weight basis. Low basic density also increases wood and chip handling costs and reduces digester production capacity. Consequently, the final choice of species will probably be related to the economics of a particular situation.

The importance of ensuring that the species considered suitable for planting in a particular tropical forest area will produce pulp with

Table 6

Suitability of tropical hardwood plantation species for pulp and paper products

	Unbleached kraft pulp (Bag and wrapping papers, linerboards)		NSSC pulp (Corrugating medium and higher grade products)
1.	*Acacia auriculiformis*	1.	*Acacia auriculiformis*
2.	*Gmelina arborea*	2.	*Eucalyptus deglupta*
3.	*Eucalyptus deglupta*	3.	*Terminalia brassii*
	Terminalia brassii		*Albizia falcataria*
	Albizia falcataria	5.	*Gmelina arborea*
6.	*Anthocephalus chinensis*	6.	*Anthocephalus chinensis*
7.	*Sesbania grandiflora*	7.	*Sesbania grandiflora* (corrugating medium only)

satisfactory properties for the specific needs of the industry must be stressed. However, no matter what advantages plantation-grown trees may have over the natural resource, it is unlikely that any one species will provide all the desired properties for a range of pulp and paper products. Thus, for maximum benefit, it may prove advisable to replant with a number of species. Optimum quality for different end uses can then be attained by mixing, before pulping. This allows the various components to compensate for any deficiency in the individuals. The shortcomings of certain fast-grown species with respect to growing conditions, the effect of certain wood properties such as density, vessel size, and frequency, and the inherent dangers of a monoculture, also favour the establishment of a range of species. Recent tests at our laboratory, on many of the above species, have shown that it is possible to predict the properties of two and three component mixtures from the pulping and papermaking results on individual samples (13).

In the immediate future our work on reforestation species will be concentrated on mechanical pulping. The suitability of fast-growing hardwood species for the production of groundwood from impregnated billets, refiner mechanical, cold soda semichemical, and thermomechanical pulps will be investigated, and the prospects for the use of these species in newsprint manufacture will be assessed.

DISCUSSION

Even though it is natural that industry should prefer even-aged, fast-growing plantation material for their operations, the natural growth mixed species forests must not be exploited merely to make way for plantation schemes. Furthermore, felling carried out merely to clear the area, even to provide land for agriculture, should not be tolerated. In such circumstances, the natural resources could, at the very least, be chipped and exported for utilization elsewhere.

The mixed tropical hardwoods from many areas have already been proved suitable for pulping and papermaking and planned research can provide answers to further improve the utilization of the existing tropical forests. With greater effort the current level of wastage of raw materials can be reduced and the life of the remaining tropical rainforests can be extended.

Some examples of how planned research can provide a basis for improved utilization have been given. However, the requirements in various areas will vary greatly. For example, in the timber areas under review in PNG, it had been decided that clear felling would be the most suitable procedure to provide material for integrated sawmilling, veneer, and pulping industries. Reforestation would then contribute a continuous timber supply through the establishment of fast-growing hardwood plantations. The high volume production from such plantations would allow some areas of previously forested land to be used for agriculture. If we consider other situations, different circumstances may prevail which would require different utilization programmes. Such situations could include: Forests containing slow growing tropical hardwoods which may be growing on poor soils where regeneration of any timber resource could be a problem; forest operations where selective logging is practiced followed by enrichment planting as necessary; utilization of mixed dipterocarps that may cause production problems because some of the timbers have a high resin content. Furthermore, in countries where wood using industries are well established quantities of waste wood are available for use. Land clearing schemes for agricultural use are also producing enormous quantities of residue material in some areas, and this material needs to be considered for utilization, perhaps for woodchips for export, as suggested earlier, or for local pulp production.

Reforestation is a requirement common to every country, but an acceptable programme will be greatly dependent on the forestry practices which vary so widely in each. Establishment of coniferous or hardwood plantations, enrichment planting, natural regeneration, or even coppice production from existing stock are among the options possible. The decisions are more difficult when they must be made in conjunction with environmental constraints applied for safeguarding the natural or existing resources.

Thus if the utilization of mixed tropical forest resources is to be improved, close attention must be given to the situation existing in each area. As pointed out by Grant (14), with tropical forests no two sets of conditions, no two regions, and no two types of forest are alike, and each project should be considered separately and assessed on its own merits. In temperate zone forests we have accepted the fact of extremes of quality when different species, regions, or growth conditions occur. The same must be accepted for tropical forest resources. In achieving improved utilization of these resources there is a continuing need for adequate sampling operations and testing programmes, a need for liaison with local authorities in determining future utilization programmes, a need to realize the importance of reducing waste in both the forest and industry, in spite of an apparent local abundance of raw material in many tropical countries and, finally, a need to acknowledge the necessity for reforestation to maintain forest resources for the future.

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BLEACHED KRAFT PULP FROM MIXED HARDWOODS FROM IVORY COAST FORESTS

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ABSTRACT

By means of a modified central composite statistical design, the effects on yield, viscosity, Kappa number, and brightness of three variables--% sulphidity, % active alkali, and "H" factor--were tested in the kraft pulping of a mixture of 74 species of Ivory Coast hardwoods. From 10 cooks, it was determined that sulphidity was the variable with least effect, and it was accordingly held constant, at 27%, in a subsequent series of experiments, based on an orthogonal (2-factor: % active alkali and "H" factor) composite design aimed at optimizing the conditions. The most significant effects of variations in the two factors were on total pulp yield, screen rejects, viscosity, and tensile breaking length, and the optimum values were: active alkali, 15.5%; "H" factor, 1700. A five-stage D/CEDED bleaching sequence gave pulp of 88.9% (Elrepho) brightness, with breaking length 9.4 km, tear index 13.8 $mN \cdot m^2/g$, burst index 6.5 $kPa \cdot m^2/g$, and folding endurance (MIT) of 688--all at 300 ml CSF.

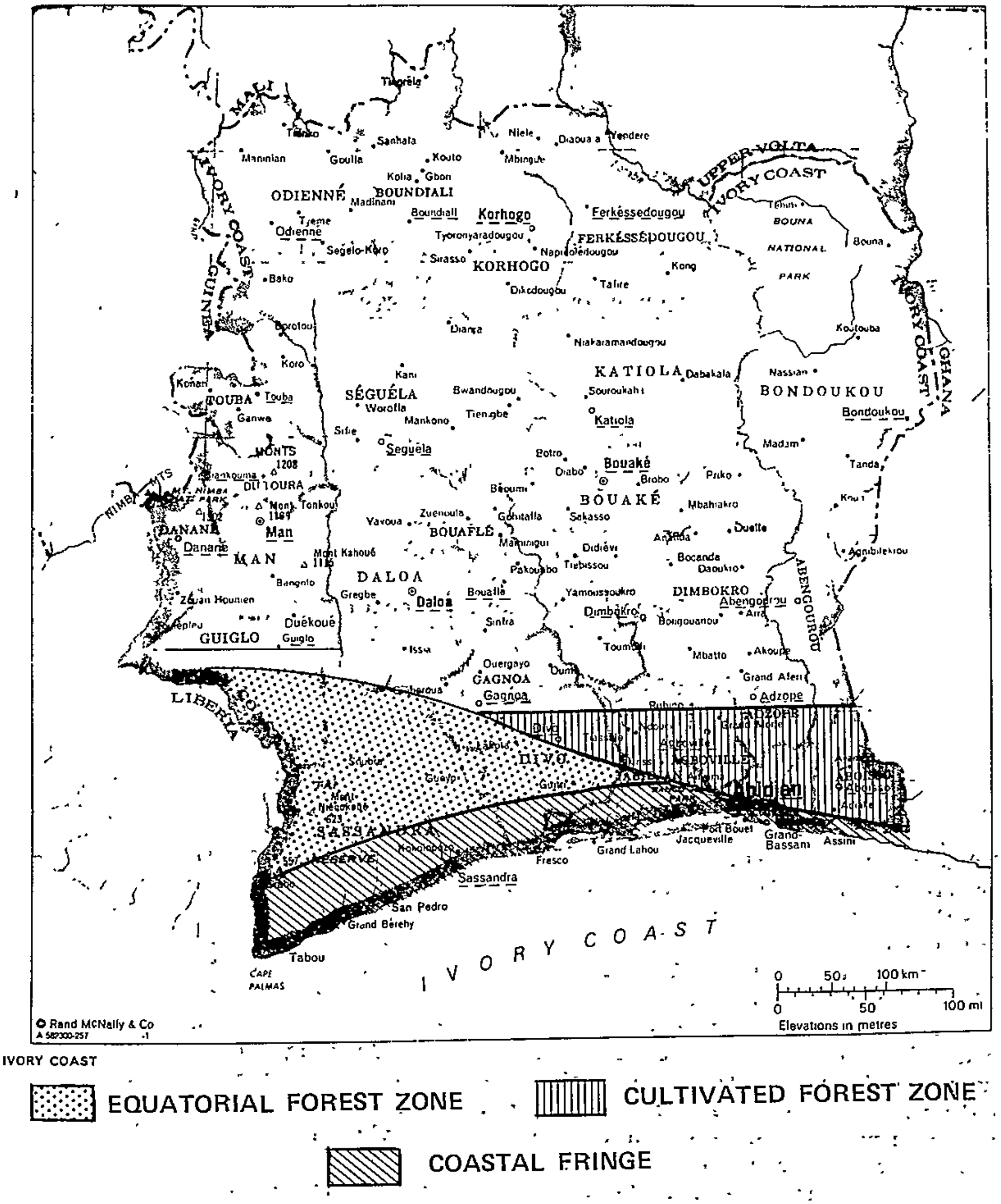

Figure 1.--Map of the Ivory Coast showing the location of the utilizable forest (1).

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By

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INTRODUCTION

The Ivory Coast, or, more properly, La Republique de Côte d'Ivoire, is an equatorial country, 326,000 km^2 in area. Its southern boundary runs almost due east-west along the shore of the Gulf of Guinea at about 5° N latitude, and its northern border meanders about the tenth parallel. An equatorial forest zone (fig. 1) lies north of a coastal fringe, and is never more than 65 km, and sometimes only 7 km, from the sea. A hundred years ago, the equatorial forest zone formed a continuous band more than 200 km wide. Now only the western region is natural forest, while the eastern region has been partly cleared for plantations (1).

The forests of the Ivory Coast constitute its primary natural resource, and a timber industry was established there while the country was still a French colony. Since Independence, in 1960, the Ivory Coast has become first in Africa and second in the world as an exporter of tropical wood (1).

Given the timber industry as a base, it was logical to contemplate expansion into pulp manufacture as a vehicle for further industrialization. Steps to this end were first taken nearly 30 years ago, when the French government financed the construction and operation (1951-4) of a 3,000-5,000 tonne/y pilot pulp and paper mill at Bimbresso, near Abidjan (2,3). The mill made paper that was said to be of higher quality than the paper made at that time from European hardwoods, and equal to paper made from Maritime pine (2). The internal market was not large enough to permit consideration of a full-size, economic-scale mill. Nevertheless, the Bimbresso project constituted a demonstration that there were significant future possibilities for making pulp, not only in the Ivory Coast, but also in many other tropical areas.

Beginning in 1965, various schemes were considered for building a pulp mill of commercial size in the Ivory Coast. At the same time, the port of San Pedro, 320 km west of Abidjan, was being planned and built; it was opened in 1971 (1). Since there are 2.5 million hectares of natural forest (2) in the vicinity of San Pedro, the idea was conceived, in 1970, of building a pulp mill there. It would have a capacity (3) of 250-300,000 t/y of bleached kraft market pulp aimed, not at the domestic, or even the African market, but at the world market (primarily Europe).

From the technical point of view, a complicating factor in this plan is the complexity of the mixture of available species in the San Pedro forest—some 100 of them, rather uniformly distributed. According to the forest inventory, no species constitutes more than 13% of the mixture, and only six species contribute more than 3% each to the mixture. Forty-five species each contribute less than 1%, with the rest in between. Examined individually, these species show a broad range of responses to kraft pulping conditions. Therefore, beginning in 1971, the behaviour of the heterogeneous wood mixture was investigated by the C.T.F.T. (Centre Technique Forestier Tropical, in France) in a programme that included papermaking trials as well as pilot-plant cooking. It was concluded (3) that mixed hardwoods from the San Pedro region could be used to make marketable pulp despite three disadvantages relative to temperate hardwoods: (a) 2-4% more alkali required for cooking; (b) somewhat lower yield; and (c) the need for an extra stage of bleaching.

In accordance with recommendations made by the scientists at C.T.F.T., a kraft pulping trial was conducted in October 1974, at Hualien in Taiwan, at the mill of the Chung Hwa Pulp Corporation which already processes tropical hardwood and has a capacity of about 100,000 t/y. Nearly 5,000 t of a mixture of 76 species of Ivorian wood was pulped and bleached (CEHDED) over the course of 12 days. The unbleached yield was 48%, and the shrinkage on bleaching was 10%. The properties of the pulp are shown in table 6.

At about the time of the trial at Hualien, we undertook, in our laboratories, some preliminary studies on the pulping and bleaching of the mixture of Ivorian hardwoods. The results, taken together with those of the mill trial, suggested that the properties of the pulp might be improved by optimizing some of the parameters of the pulping and bleaching processes. This optimization, then, was the objective of the work described in the present paper. Optimization was approached by conducting two series of statistically designed experiments. In this way, conditions have been found which improved brightness, tear index, burst index, and tensile breaking length.

MATERIALS AND METHODS

Analysis

All chemical analyses and physical tests were performed according to the CPPA (Technical Section) standards.

Preparation of Wood

A total of 77 species of wood was collected in the Ivory Coast, carefully identified, and sprayed on the bark with Cryptogyl DCG, a preservative meant to protect the wood against biological deterioration during prolonged storage. When the wood was received in the laboratory, each log was barked (thus removing the preservative), chipped, and screened. Then the chips of 74 of the species (excluding those known as Dobotou, Kotibe, and Sougue) were combined in the weight proportions closely representing their distribution in the natural forest, and the mixture was homogenized. The moisture content of the mixture was determined, and then 30 charges, each of 2 kg (O.D. basis), were weighed, wrapped in individual air-tight heavy duty polyethylene bags, and stored in a cold-storage room (4° C) until required for pulping.

Pulping

All the pulping experiments were performed in a 20-ℓ experimental digester. The constant conditions of operation are shown in table 1. The variables in the first statistically designed series were sulphidity, active alkali, and final H-factor (see "Statistical Design," below). In the second series, sulphidity was held constant at 27.0%. In both series, the final H-factor determined the total cooking time.

Statistical Design

Stage 1

Preliminary experiments indicated that optimization of pulp properties (the dependent variables) might be achieved by manipulating only three of the independent variables within the following ranges: sulphidity, 24.5-29.5%; active alkali, 15.5-18.5%; and final H-factor, 1400-2000. Their effects were investigated by applying the modified composite design (4) shown in figure 2. Ten cooks were done in the random order indicated on the diagram, with the cook at the centre of the cube being done in duplicate in order to permit evaluation of experimental error. The results were analyzed graphically.

Stage 2

Since the results of Stage 1 eliminated sulphidity as a variable, it was held at 27.0%, and only two independent variables were tested in Stage 2 in the following ranges: active alkali, 14.0-17.0%; final H-factor, 1400-2000. An orthogonal composite design was used (fig. 3), requiring 10 cooks, including duplicates at the centre, performed in the random order indicated on the diagram.

Bleaching

Only pulps prepared under the optimum conditions were bleached. Their Kappa numbers were 25.3 and 28.7. Four bleaching sequences were tested, CED, CEDED, CEHDED, and D/CEDED. The procedures have been described elsewhere (5). Conditions for each stage are given in table 2.

RESULTS AND DISCUSSION

Pulping

In the first statistically designed series of 10 cooks, sulphidity, active alkali, and final H-factor were varied (fig. 2) while all other

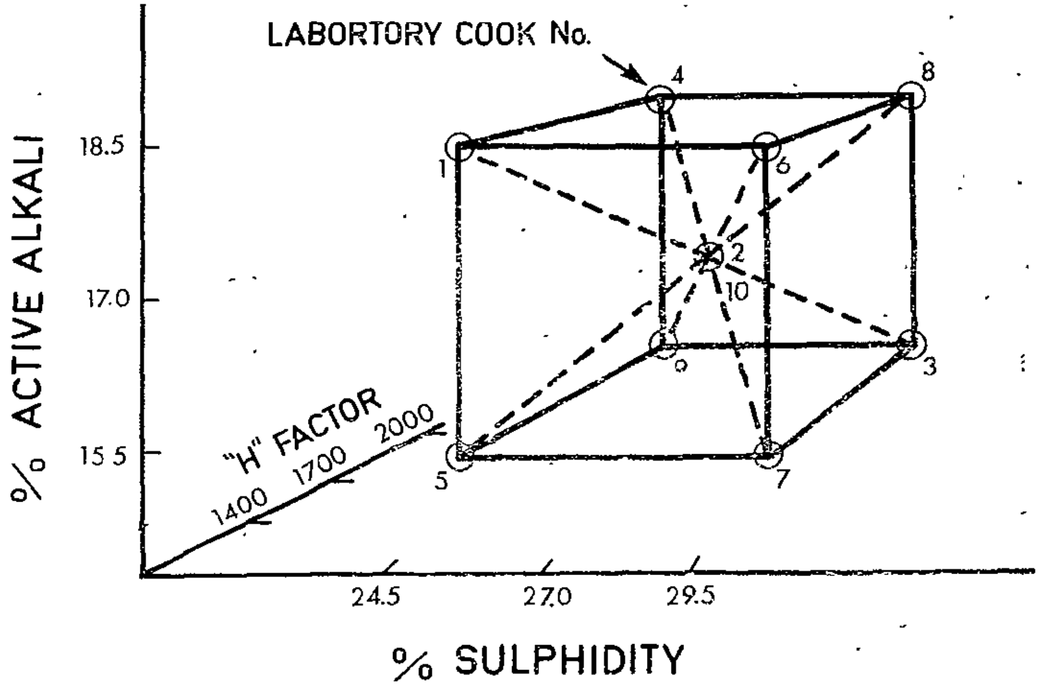


Figure 2.--Central composite design, stage 1. The numbers at each point show the order in which the cooks were done.

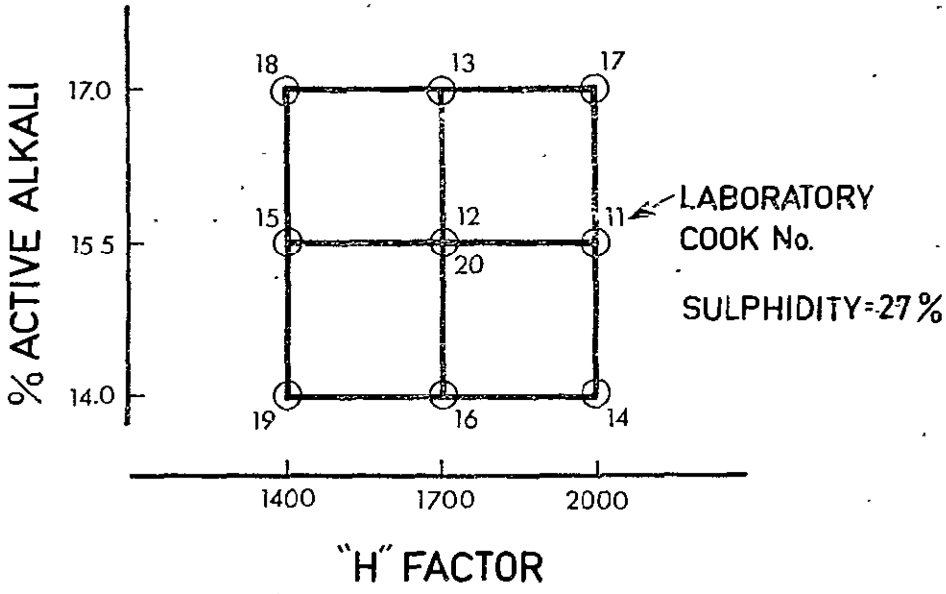


Figure 3.--Orthogonal composite design, stage 2. The numbers at each point show the order in which the cooks were done.

variables were held constant (table 1). The yield, Kappa number, and viscosity of each pulp were determined, as well as all the strength properties. The results of the two cooks at the centre of the design showed that the range of experimental error was probably quite small: total pulp yield, 46.2% and 46.5%; Kappa number, 24.7 and 24.6; and viscosity, 24.9 mPa·s and 26.2 mPa·s.

When the results were plotted as graphs of the dependent variables versus the independent variables, it was apparent that formal analysis of variance was not needed, since inspection alone provided the following observations (applicable within the ranges of variables tested):

Kappa number--Even under the mildest cooking conditions tested, 15.5% active alkali and 1400 H-factor, the Kappa numbers of the pulps were never above 30, which was the upper limit specified for good bleachability; the variation of sulphidity had no significant effect on Kappa numbers.

Viscosity--At 15.5% active alkali, the viscosities of the pulps were nearly the same and in the range of 30 mPa·s independent of H-factor; at 18.5% active alkali, viscosity at 1400 H-factor was 19-23 mPa·s, and decreased (to 14-17 mPa·s) when the H-factor was increased; variation of sulphidity had no significant effect.

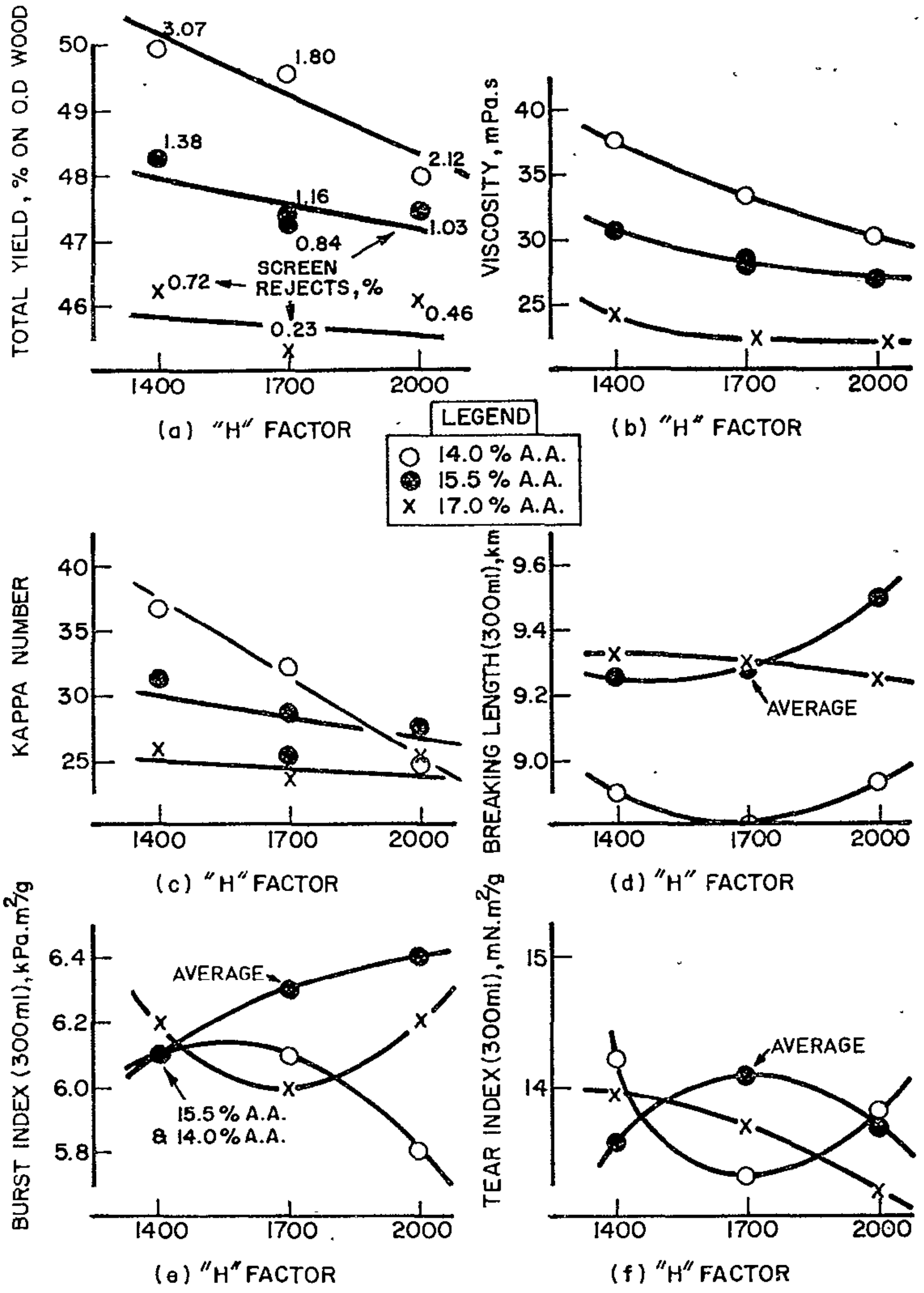
Total yield--The highest yield was obtained at the lowest level of active alkali (15.5%); variation of sulphidity had no significant effect.

Breaking length--Two sets of conditions gave the highest breaking lengths: (i) low sulphidity, high active alkali, and high H-factor; and (ii) high sulphidity, low active alkali, and high H-factor.

Burst index--Two sets of conditions gave the best burst index: (i) low sulphidity, high active alkali, and low H-factor; and (ii) high sulphidity, low active alkali, and high H-factor; at the high level of active alkali, the burst index varied inversely with the H-factor.

Tear index--The tear index was generally highest at the low level of H-factor and the lowest sulphidity, and exhibited only a small, possibly insignificant, dependence on active alkali.

Taking all these observations together, it was concluded that a second series of cooks was required to explore the effects of a lower range of active alkali within the same range of H-factors. In the light of the negligible effect of sulphidity on yield, Kappa number, and viscosity, its value in the second series was fixed at 27.0%, as a compromise level around which breaking length, tear index, and burst index could be optimized.



(a) "H" FACTOR

(b) "H" FACTOR

(c) "H" FACTOR

(d) "H" FACTOR

(e) "H" FACTOR

(f) "H" FACTOR

Figure 4.--Properties of pulps obtained in stage 2.

Since there were only two variables in the second series, an orthogonal composite design, requiring 10 cooks, was used (fig. 3). The duplication of results at the centre of the design was good with respect to total pulp yield (47.2 and 47.4%) and viscosity (28.3 and 27.7 mPa·s), but the difference in Kappa numbers (25.3 and 28.7; Δ3.4) was larger than expected. The experimental error can be neglected, however, as judged from the graphic presentation of the results in figure 4. Some of the scatter in points representing strength properties was no doubt due to the fact that 2-kg samples of a mixture of 74 species could not be completely homogeneous. Inspection of figure 4 gives the following observations:

Kappa number--At a low charge of active alkali (14%), the H-factor had to be greater than 1700 to produce a pulp with a Kappa number below the target of 30; at 15.5% or more of active alkali and H-factors no less than 1500 (corresponding to about 87 minutes at the maximum cooking temperature of 170° C), bleachable pulps were readily obtained; 17.0% of active alkali gave soft, bleachable pulps even at an H-factor of 1400.

Viscosity--The charge of active alkali had a significant effect on viscosity, but viscosities of 30 mPa·s, or more, were obtained at any level of H-factor (within the range tested) if the charge was 15.5% or less.

Total yield--Since more than 1% of rejects was considered unacceptable, the results of the second series ruled out the use of 14.0% of active alkali, but showed that at 15.5%, the highest possible yield of acceptable pulp, with respect to both rejects and Kappa number, might be obtained by cooking to about 1700 H-factor.

Breaking length--Despite some scatter in the results, it appeared that the best breaking lengths were achievable by using 15.5% of active alkali, and cooking to an H-factor of 1700-2000.

Burst index--Despite some scatter (within a small range) it appeared that 15.5% of active alkali, at H-factors of 1700 and 2000 gave the highest burst index.

Tear index--The range of variation in tear index was not great, but it appeared that, at 15.5% active alkali, cooking to an H-factor of 1700 would give a maximum value of about 14 mN·m^2/g.

Together, all these results point to the centre of the second design (15.5% active alkali; 1700 H-factor) as representing, as it should, the optimum pulping conditions. The results also suggest that a total yield of about 47.5% cannot be exceeded, if screen rejects are to be kept below 1%. The conditions in table 3 show how to pulp this mixture of wood to the level of 47.5% yield, while optimizing the physical and chemical properties of the pulp. Representative properties are shown in table 4.

Table 4 also shows the effect of adding Dobotou, Kotibe, and Sougue chips, in the proportion 3.16, 0.74, and 0.67%, respectively, to the 74 species, and then pulping the whole mixture under the conditions determined as optimum for the 74 species alone. Unpublished, preliminary work done elsewhere on the pulping of the species individually had suggested that the three species were difficult to pulp, and should be omitted from the trials on the mixed woods. In fact, perhaps because the three "troublesome" species constituted only 4.57% of the total, no difficulty was encountered in pulping the mixture that contained them. The main differences associated with their presence appeared to be a decrease both in total yield (by 1%) and in viscosity (by 7-8 mPa·s), but all the strength properties after beating fell within or close to the range of experimental error. It is possible that a slight adjustment in cooking conditions is required when the three "troublesome" species are included in the wood mixture, but the important point is that their presence does not make the mixture unpulpable.

Bleaching

Pulps containing the "troublesome" species were not used in the bleaching trials, of which the objective was to find a sequence or sequences which would give bleached pulps of the highest possible quality at the lowest possible cost in chemicals. Pulp from Cook No. 12 (table 4) was used to evaluate three sequences: CED, CEDED, and CEHDED. Pulp from Cook No. 20 was used to evaluate two variations of a D/CEDED sequence.

A single large batch of pulp No. 12 was taken for chlorination and extraction (conditions in table 2), which gave a product with Kappa number 4.0 and viscosity 21.3 mPa·s. This product was then divided into two parts, one twice as large as the other. The larger part was oxidized with chlorine dioxide, thus providing on the one hand the pulp that would be tested as the CED-bleached pulp, and on the other hand, a portion that could be further bleached to the CEDED level. The remaining third of the chlorinated and extracted pulp was bleached with hypochlorite before the DED sequence was applied. Unbleached pulp No. 20 was divided into two portions in order to test two variations of the D/CEDED sequence; in one, the D/C stage was done at 40° C, and in the other at 20° C. The difference between the latter two sequences was apparent immediately after the first extraction. The $(D/C)_{40°}$ E-treated pulp had a Kappa number of 4.5, which indicated adequate chlorination (cf. the CE-treated pulp with Kappa = 4.0), while the $(D/C)_{20°}$ E-treated pulp had a Kappa number of 7.9. The difference was reflected, of course, not only in the final properties of the pulps, but also in the consumption of ClO_2 in the subsequent bleaching stages.

Although the CEHDED sequence gave a slightly higher final brightness than the CEDED sequence, and, as expected, required less ClO_2 in the later stages, the loss in viscosity caused by the H-stage is reflected in the somewhat poorer strength properties of the final pulp.

The results given in table 5 suggest that, with respect to final brightness, viscosity, and shrinkage, the D/CEDED sequence (D/C at 40° C) was the best of those tested. It was, however, only slightly better than the CEDED sequence, which gave a bleached pulp that, despite a measurably lower viscosity, had nearly the same strength properties as the pulp from the D/CEDED sequence.

CONCLUSIONS

Table 6 shows the properties of the best bleached pulps produced in the course of the present research compared with those of Ivorian pulps made elsewhere, and of some other bleached hardwood pulps. The properties shown for the other pulps are not necessarily the best available, but are those that were published in a previous report (3) on Ivorian pulps. A striking feature of our bleached pulps is their exceptionally high tear strength, which may enhance their marketability.

A sequence of improvement is evident from properties shown in table 6, because, while the pulp from the C.T.F.T. laboratory studies was generally comparable in properties to the run-of-the-mill pulp from the Hualien mill, the mill-scale pulping of the Ivorian wood gave an improvement in properties. Optimization of pulping conditions, by means of a statistically designed series of experiments, gave a further improvement. This technique bears further application in examining the potential of new species for pulping.

As to the Ivorian hardwood itself, clearly a pulp of more than adequate quality, even relative to commercial market pulps (table 6), could be made in a 20-ℓ digester under optimized conditions. If these conditions can be duplicated at reasonable cost in a mill of commercial size, the product will be competitive in the market place.

ACKNOWLEDGEMENTS

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TABLE 1

CONSTANT CONDITIONS IN PULPING EXPERIMENTS

Charge of wood chips, kg (O.D.)	2.0
Presteaming with 1.4 atm saturated steam:	
No. of purges	3
Time of each purge, min.	3
Liquor-to-wood ratio (excluding wood moisture)	4:1
Initial liquor temperature, °C	80
Maximum cooking temperature, °C	170
Time to maximum cooking temperature, min.	90

TABLE 2

BLEACHING CONDITIONS

Stage	Symbol	Chemicals	Chemical charge, % on pulp	Consistency, %	Time, minutes	Temperature, °C
Chlorination	C	Cl_2	5.6	3.5	45	24
Chlorine dioxide - chlorine mixture	D/C	ClO_2 Cl_2	4.5 1) 1.9	3.5	45	40
Extraction	E_1	NaOH	3.0 2) 3.5 3)	10.0	90	70
Hypochlorite	H	NaOCl NaOH	1.5 0.6	10.0	120	40
Chlorine dioxide	D_1	ClO_2 NaOH	1.0 0.4	10.0	180	60
Extraction	E_2	NaOH	1.0	10.0	60	60
Chlorine dioxide	D_2	ClO_2 NaOH	0.5 0.2	10.0	180	60

1) as available chlorine.
2) amount added in CE stage.
3) amount added in D/CE stage.

TABLE 3

OPTIMUM KRAFT PULPING CONDITIONS FOR MIXED TROPICAL HARDWOODS

Sulphidity, %	27.0
Active alkali (as Na_2O), % on O.D. wood	15.5
Active alkali (as Na_2O), gm/ℓ	38.8
Liquor-to-wood ratio (excluding moisture)	4:1
Maximum cooking temperature, °C	170
Time to maximum cooking temperature, minutes	90
Time at maximum cooking temperature, minutes	100
H-factor	1700

TABLE 4

PROPERTIES[1] OF UNBLEACHED PULPS PREPARED FROM MIXED TROPICAL HARDWOODS UNDER OPTIMUM CONDITIONS[2].

	A Cook No. 12[3]	B Cook No. 20[3]	Average of A & B	Cooks of mixture including Dobotou, Kotibe, and Sougue[4]
Total yield, % of O.D. wood	47.2	47.4	47.3	46.0
Screen rejects, % of O.D. wood	0.84	1.16	1.00	0.88
Kappa number	25.3	28.7	27.0	27.6
Viscosity, mPa·s	28.3	27.7	28.0	20.3
Brightness, % absolute	23.5	23.4	23.5	23.1
Tear index, $mN{\cdot}m^2/g$	13.6	14.6	14.1	12.7
Burst index, $kPa{\cdot}m^2/g$	6.3	6.3	6.3	6.0
Breaking length, km	9.5	9.1	9.3	9.4
MIT double fold	541	606	574	606
Stretch, %	3.27	3.20	3.24	3.17
Toughness index, mJ	174	170	172	169
Bulk, cm^3/g	1.79	1.82	1.81	1.78
Beating time, PFI revs.	7,900	8,470	8,185	7,100

1) Beating time, bulk, and strength properties are all expressed at 300 CSF.
2) Conditions in Table 3.
3) Blend of 74 species, excluding Dobotou, Kotibe, and Sougue; cook numbers correspond to those in Figure 3.
4) % in O.D. wood blend: Dobotou, 3.16; Kotibe, 0.74; and Sougue, 0.67.

TABLE 5

COMPARISON OF EFFECTS OF FIVE BLEACHING SEQUENCES APPLIED TO TROPICAL HARDWOOD KRAFT PULPS

Sequence	Brightness, % absolute	Viscosity, mPa·s	Total shrinkage, %[1]
CED	82.5	20.1	7.6
CEDED	88.3	16.8	7.8
CEHDED	88.8	11.3	7.9
$(D/C)_{40}$°EDED	88.9	20.4	6.6
$(D/C)_{20}$°EDED[2]	85.8	22.4	–[3]

[1] calculated as % of unbleached pulp (O.D. basis).
[2] D_1 stage at 9% consistency.
[3] not determined.

TABLE 6

PROPERTIES OF BLEACHED PULPS AT 300 CSF (40°SR) a)

	Mixture of Ivorian hardwoods			Hualien tropical hardwoods run-of-mill	Beechwood	Canadian mixed hardwoods	Scandinavian birchwood
	This work b)	C.T.F.T. laboratory	Hualien mill-trial				
Brightness, % c)	88.9	88	86	86	91	90	90
Opacity (TAPPI), %	~70	64	76	73	69	65	56
Tear index, mN·m^2/g	13.8	8.4	9.7	8.0	6.4	7.0	7.5
Burst index, kPa·m^2/g	6.5	4.0	5.0	4.2	3.8	4.1	6.1
Breaking length, km	9.4	6.1	7.5	6.0	6.0	6.9	8.0
Stretch, %	3.7	-	3.5	3.7	-	2.9	-
MIT double folds	688	20	150	32	15	300	180
Bulk, cm^3/g	1.60	1.4	1.7	1.5	1.4	1.4	1.4

a) The results in the last 6 columns were all adapted from ref. [3] with some interpolation and rounding. Other values for Canadian and Swedish pulps can be found elsewhere, e.g., ref. [6].

b) This pulp was unbleached pulp No. 20, bleached in the D/CEDED sequence (40° D/C); its beating time to 300 CSF was 6,770 PFI revolutions.

c) Brightness was measured by various methods, some of them non-standard; hence results are not always comparable.

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SUITABILITY OF SOME FAST-GROWING HARDWOODS AND LONG-FIBERED SPECIES OF THE PHILIPPINES FOR VARIOUS PRODUCTS

By

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SUITABILITY OF SOME FAST-GROWING HARDWOODS AND LONG-FIBERED SPECIES OF THE PHILIPPINES FOR VARIOUS PRODUCTS

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INTRODUCTION

Over the last ten years or so, considerable interest has developed among foresters, wood technologists, and wood industry people in the Philippines in the production and utilization of two species of hardwoods that have been observed to exhibit fast rates of growth under plantation conditions. These species are Albizia falcataria and Eucalyptus deglupta, which are locally known as Moluccan sau and bagras, respectively. According to an estimate made by the Paper Industries Corporation of the Philippines (PICOP), the largest pulp and paper firm in the country, A. falcataria can easily produce 350 to 400 m^3 per hectare in 8 years, while bagras can proudce 200 to 300 m^3 per hectare in 12 years (Tagudar, 1975). More than 75% of the total area of forest plantations that have been developed so far by various wood industrial establishments in the country are planted to these two species (Source: 1975 Philippine Forestry Statistics).

In the 1960's, species like Anthocephalus chinensis and Gmelina arborea have been reported by a number of researchers to exhibit fast rates of growth. However, field trials conducted by firms engaged in the development of industrial forest plantations have failed to confirm these reports. As a consequence, research interest in the utilization of these species has considerably diminished and so has their use as plantation crops. These species will not be discussed in this paper.

Another species that has been reported to exhibit a phenomenal rate of growth in the Philippines is Leucaena leucocephala or giant ipil-ipil. Because of the adaptability of this species to a wide variety of site conditions, it is now being extensively used for reforestation in various parts of the country. This species was introduced in the Philippines only recently so we know very little so far regarding its wood properties and uses. Its excellent quality as a fuelwood, however, is widely acknowledged in the country.

Aside from A. falcataria and E. deglupta the other species that are discussed in this paper are Pinus kesiya and some native species of hardwoods that have been found to possess long fibers. Interest in these species has developed in recent years as a result of the increasing need of the country for long-fibered pulp. Future expansion of the local pulp and paper industry is expected and this would undoubtedly increase the need for long-fibered pulp.

A. FALCATARIA

A. falcataria is a large-sized tree that reaches a height of 46 m and a diameter at breast height of 127 cm. It is known to be short-lived; after reaching the age of 25-30 years it starts to die back.

A native of the Moluccas, the species was introduced in the Philippines in 1951 when an Italian quinine seed seller who came to the country gave a handful of seeds of the species to the Cinchona Project in Kaatoan, Bukidnon of what is now known as the Bureau of Forest Development. It is believed that all stands of A. falcataria in the Philippines originated from the trees that grew out of those seeds.

The wood of A. falcataria is whitish to pinkish with the heartwood often not clearly demarcated from the sapwood. It is moderately coarse in testure and soft and light in weight. Our study of the wood of 10-year-old trees grown in Mt. Makiling in the province of Laguna (Lantican and Madamba, 1977) gave an average specific gravity of 0.27 and an average fiber length of 1.06 mm. In this study specific gravity varied from tree to tree within the range of 0.23 to 0.29 and showed a tendency to increase quadratically with increasing distance from the pith at different height levels. Fiber length varied only slightly from tree to tree (1.03 to 1.07 mm) but showed a marked quadratic increase with increasing distance from the pith at various height levels.

The wood of A. falcataria has been found suitable for a number of uses, the more important of which are lumber and pulp and paper. In this paper, however, the pulp and paper making characteristics of the species will not be discussed as this topic is already covered in one of the other papers in this symposium.

Despite its low density, A. falcataria wood has turned out to be difficult to saw. This is probably due to interlocked nature of the grain which causes the pinching of the saw teeth during the cutting process. To solve this problem, the use of carbide-tipped saws has been recommended (Burgess, 1966).

In the form of lumber, A. falcataria wood has found increasing use in furniture manufacture and others in which strength is not a primary concern. Foreign demand for A. falcataria lumber has increased significantly in recent years so that one company in the Philippines has started exporting this product. If this trend continues, it appears likely that in the future A. falcataria may be raised primarily for lumber.

The suitability of A. falcataria for veneer and plywood has also been looked at by investigators in the Philippines (Saraos, 1960; Inawat and Eala, 1970). These investigators have found A. falcataria wood unsuitable for this purpose because of its low resistance to indentation, susceptability to stain and the fact that the veneer produced tends to have fuzzy surfaces. Moreover, exposure to the air changes the original color of the veneers to tan which is undesirable.

Studies at FORPRIDECOM have shown that A. falcataria wood can be manufactured into particleboard that satisfactorily meets commercial standards at a resin content level of 8% using urea formaldehyde.

According to Domingo (1966), A. falcataria had been used as matchwood in Sarawak, Brunei, and in other parts of Malaysia, in Indonesia, and in the Netherlands Indies. However, tests made by the Philippine Match Co., Ltd. in Manila have shown that the wood of the species is too soft and brittle when struck against the matchbox.

The suitability of A. falcataria for fiberboard manufacture has been mentioned by Cariño (1975) in a symposium paper but he did not cite the source information. I understand that the FORPRIDECOM has undertaken research on this but the results have not yet been published.

E. DEGLUPTA

Although this species is of natural occurrence in the Philippines, only a limited amount of research has been carried out so far regarding its properties and uses. This is so because the species caught the attention of forest products researchers in the country only recently when it was discovered that the species is capable of very rapid growth under plantation conditions. In fact much more is known about the wood properties and uses of A. falcataria, an introduced species, than E. deglupta. Moreover, most of the information available in the literature regarding this latter species is based on materials from natural stands.

The wood of E. deglupta according to Reyes (1938) is suitable for interior finish, furniture, framings, beams, joists, studs, and all the uses for which red lauan (Shorea negrosensis) is suitable.

It has been reported that the timber is relatively difficult to season (Kukachka, 1959). It has a pronounced tendency to check during seasoning and the cracks may become very deep in thick pieces. Collapse is rather prevalent.

According to Cariño (1975),the wood is fairly hard to work in machines and difficult to cut with hand tools. With its silica inclusions, it dulls tool edges quite easily.

In a study of ten 6-year-old trees grown in a PICOP plantation in Bislig, Surigao, Madamba and Lantican (1978) found that the wood of this species is pinkish in color, with slightly crossed-grain, of moderately coarse texture, and of moderate hardness. The trees which ranged in diameter from 20 to 30 cm in diameter gave an average specific gravity of 0.39 and an average fiber length of 1.34 mm. In these trees fiber length increased in a quadratic manner with increasing distance from the pith regardless of height level while specific gravity showed a slight decreasing trend.

Villaflor (1978) examined the gluability of the wood of the same trees into 3-ply, 4-mm plywood using urea formaldehyde and phenol formaldehyde adhesives. His results showed the suitability of the species for exterior and interior types of plywood.

There have been no reports yet regarding the suitability of these species for fiberboards and particleboards. A study dealing with the suitability of the species for pulp and paper manufacture has been carried out but this is not discussed in this paper.

LONG-FIBERED WOODS

An adequate and continuous supply of long-fibered pulp is vital to the survival and growth of the local pulp and paper industry. The country imports a large volume of long-fibered pulp yearly. For 1975 the import figure for this commodity was 26.9 million kilograms valued at 8.7 million U.S. dollars. Higher figures are expected in the future unless large quantities of suitable local substitutes can be found.

The best known long-fibered tree species in the Philippines is Benguet pine (Pinus kesiya Royle ex. Gord.). The species forms the natural vegetative cover of approximately 262,000 hectares of highlands in Northern Luzon, particularly in the Central Cordillera Mountain ranges at elevations ranging from 1000 to 2700 m. The species also accurs in Zambales, a province in the eastern part of Central Luzon, but it is not abundant. According to a recent estimate made by the Bureau of Forest Development, the total standing timber volume of the species in Luzon is about 18.6 million m^3.

Benguet pine is commonly used as a reforestation species in many parts of the country. Plantations of the species have been successfully developed in Cebu, Iloilo, Bukidnon, Agusan, and Surigao. Although the natural altitudinal range of the species is above 1000 meters, it has been demonstrated that the species also thrives well at lower elevations, like for instance in Cebu where plantations have been successfully established at elevations ranging from 500 to 650 m.

At present the wood of Benguet pine is used largely for the manufacture of lumber for construction, furniture and other purposes. In the Mountain provinces, the species is used extensively for mine timber and occasionally for poles, and guitar backs and sides.

Pulping studies at the FORPRIDECOM have shown that Benguet pine wood is amenable to the kraft process but less so to the semi-chemical process (Zerrudo, 1977).

At the UPLB College of Forestry, we have been investigating the influence of tree age on the pulping characteristics of Benguet pine. In this study, bolts from 4-, 8-, 16-, and 32-year-old trees were pulped using the following conditions which were found suitable for the species by FORPRIDECOM:

Chemical charge (based on moisture-free chips)	
NaOH	15%
Na_2S	5%
Cook Schedule	
Time from room temperature to maximum temperature (170°C)	1.5 hours
Time at 170°C	1.5 hours
Liquor to wood ratio	4.1 liter/kg.

The chips from the 32-year-old trees gave the lowest screened pulp yield (41%) while the highest (46.41%) was obtained for the 8-year-old trees (Table 1). The low pulp yield exhibited by the 32-year-old trees is attributable to the high percentage of rejects which is probably due to the presence of heartwood. The rejects consisted of chips which were obviously not completely penetrated by the cooking chemicals.

Examination of handsheet properties showed that burst factor and strength in double folds increased from the 4-year-old trees to the 8-year-old trees and then decreased with increasing tree age at 300 CSF (Table 2). At the same CSF level, tear factor increased with increasing tree age while breaking length showed a decreasing pattern (Table 2). Similar patterns were obtained for 400 and 500 CSF levels.

The observed variation in pulp yield and handsheet properties with respect to tree age is very likely due to differences in wood characteristics such as specific gravity, tracheid dimensions, and extractive content. It has been observed that specific gravity and tracheid length and diameter in Benguet pine increase quadratically with increasing ring number from the pith (Lantican, 1977); hence, the mean values of these properties will tend to change with increasing tree age. Insofar as extractive content is concerned, it is well known that younger trees contain a lesser amount of extractives than older trees of the same species.

Mindoro pine (<u>Pinus merkusii</u> Jungh and de Vr.) is another long-fibered species that occurs naturally in the Philippines. The species, however, is not available in commercial quantity and attempts to grow it in plantations have not been too successful so far. It is thus unlikely that

Table 1. Pulp Yield Data and Permanganate Number of Benguet Pine of Various Ages*

TREE		% PULP		
Age (Yrs.)	Total	Screened	Reject	Permanganate
4	47.06	42.47	4.59	22.7
8	49.37	46.41	2.96	23.7
16	51.57	44.20	7.37	23.6
32	47.49	41.02	6.47	23.9

*Average values

Table 2. Pulp Variation of Benguet Pine of Various Ages Interpolated at 300CSF*

TREE			STRENGTH PROPERTIES		
Age (Yrs.)	Density gm/cc	Burst Factor	Tear Factor	Breaking Length (M)	Double Folds
4	0.786	75.65	88.5	11475	1125
8	0.76	82.25	98.83	11250	1130
16	0.714	77.7	111.05	9730	936
32	0.676	59.4	114.3	8875	650

*Average values

this species will become a major source of long-fibered pulp in the Philippines in the near future. The kraft pulp from Mindoro pine is comparable to that of Benguet pine, although in terms of tearing resistance it is better than the latter species (Escolano and Bawagan, 1975). According to Escolano and Bawagan (1975) kraft and bag papers from Mindoro pine pulp have high tear with moderate bursting, folding and tensile strength.

One significant result of investigations concerning fiber dimensions of Philippine woods is the discovery that some native hardwoods are long-fibered, following the definition of terms of the International Association of Wood Anatomists (1937). Of particular interest in this connection are the species with fibers longer than 2 mm. Examples of these species are agosip (Symplocos) anonggo (Turpinia ovalifolia), apanit (Mastixia philippinensis), balikbikan (Drypetes bordenii), gubas (Endospermum peltatum), katmon (Dillenia philippinensis), mabunot (Stemonurus luzonensis), and tuai (Bischofia javanica). Table 3 gives the fiber length, Runkel ratio, and wood specific gravity of these species.

In a preliminary study conducted by Zerrudo and Visperas (1976) apanit, balikbikan, katmon, and mabunot gave pulp yields of 45.7%, 41.0%, 37.6%, and 34.8%, respectively, using the pulping conditions given earlier for Benguet pine. The permanganate numbers obtained were 11.3 for apanit, 25.6 for balikbikan, 16.8 for katmon, and 34.8 for mabunot. According to the authors, the strength properties of pulps from the four species may be considered moderate but indicated that they all had good tearing resistance.

Go and Villaflor (1978) also used the kraft process in a study dealing with the suitability of agosip for pulp and paper making. For this species the pulp yield obtained was about 40% and the permanganate number was 19.2. Agosip pulps developed better quality papers than those of Moluccan sau in terms of folding endurance, tensile strength, tearing resistance, and bursting strength.

RESEARCH PROGRAMS ON FAST-GROWING SPECIES AND LONG-FIBERED HARDWOODS

Realizing the potentials of fast-growing species and long-fibered hardwoods as sources of raw materials for the wood-based industries, particularly the pulp and paper industry, the UPLB College of Forestry, in cooperation with FORPRIDECOM and the recently established Forest Research Institute (FORI) has developed two research programs; namely:

1. National Integrated Research Program on
   Industrial Forest Plantation Species; and

Table 3. Fiber length, Runkel ratio and wood specific gravity of some long-fibered hardwoods of the Philippines

Species	Fiber length (mm)	Runkel Ratio	Specific Gravity
Agosip (*Symplocos* sp.)	2.74	1.00	
Anonggo (*Turpinia ovalifolia*)	2.72	0.69	0.40
Apanit (*Mastixia philippinensis*)	3.47	1.13	0.49
Balikbikan (*Drypetes bordenii*)	2.43	2.86	0.75
Gubas (*Endospermum peltatum*)	2.33	0.38	
Katmon (*Dillenia philippinensis*)	2.73	1.00	0.62
Mabunot (*Stemonurus luzonensis*)	3.32	2.18	0.34
Tusi (*Bischofia javanica*)	2.16		

2. Integrated Research Program on Long-Fibered Hardwoods

The research program on industrial forest plantation species is concerned with four species: Albizia falcataria, Anthocephalus chinensis, Endospermum peltatum, Eucalyptus deglupta, and Gmelina arborea. The program on long-fibered hardwoods deals with 19 native species (Table 4) which are mostly non-commercial at present.

Both programs are rather comprehensive in scope. They include studies dealing not only with the suitability of the different species for pulp and paper making, but also with the biology, silviculture, protection, management, and wood structure and properties of the different species.

The program on industrial plantation species is now being implemented partially. The program on long-fibered hardwoods, on the other hand, is still being evaluated by the National Science Development Board for possible funding. Needless to say, these programs could yield information that would be of utmost value to the growing pulp and paper industry in the Philippines.

Table 4. List of species included in research program on long-fibered hardwoods

Common Name	Scientific Name	Family
Agosip	*Symplocos villarii*	Symplocaceae
Agosip puti	*S. ahernii*	Symplocaceae
Dulangon	*S. confusa*	Symplocaceae
Himmaliu	*S. floridissima*	Symplocaceae
Ditaman	*S. pulgarensis*	Symplocaceae
Balakbakan	*S. polyandra*	Symplocaceae
Kolalabang	*Saurauia latibractea*	Saurauiacaceae
Pangi	*Pangium edule*	Flacourtiaceae
Sanglai	*Ahernia glandulosa*	Flacourtiaceae
Mangoi	*Gomphandra cumingiana*	Icacinaceae
Mabunot	*Stemonurus luzonensis*	Rubiaceae
Southern Bangkal	*Nauclea junghuhnii*	Sterculiaceae
Mountain Tapinag	*Sterculia montana*	Sterculiaceae
Malabulak	*Salmalia malabarica*	Bombacaceae
Putian	*Alangium meyeri*	Alangiaceae
Apanit	*Mastixia philippinensis*	Cornaceae
Tuai	*Bischofia javanica*	Euphorbiaceae
Balikbikan	*Drypetes bordenii*	Euphorbiaceae
Gubas	*Endospermum peltatum*	Euphorbiaceae
Anonggo	*Turpinia ovalifolia*	Staphyleaceae

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USE OF MIXED TROPICAL HARDWOODS FOR PULP MANUFACTURE

By

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USE OF MIXED TROPICAL HARDWOODS FOR PULP MANUFACTURE

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As you well know, it is possible to produce excellent quality pulp from some individual wood species. Sometimes, like in Scandinavia, these species form the bulk of the wood volume in the forest. Under such circumstances it becomes quite feasible to separate each of the species on felling and to keep them separate throughout the logging, transport, and pulping operations, especially if the number of such species is very low.

This classical method of pulpwood harvesting can no longer be applied when the number of species in a forest area increases to 200 or 300, like in the tropical hardwood forests. Even if 20 species represent about 75 percent of the total wood volume, separating single species and keeping them separate throughout the operations makes the pulpwood extremely expensive. The only possible approach to extraction of pulpwood from tropical hardwood forests is evidently to accept whatever can be used, avoiding species which are obviously detrimental to the pulping process or the pulp quality and even that only when they are present in the mix in substantial quantities.

Taking this as a starting point, the object of research into mixed tropical hardwood pulping is determination of the suitability of a forest area as a source of pulpwood rather than determination of the suitability of individual wood species. Such an approach brings about two main problem areas which are specific for the use of mixed tropical hardwood in pulping and papermaking. These are:

Uniformity of pulp quality which is of particular importance for an export market pulp mill.

The extent to which the natural pulpwood mix has to be modified in order to suit the pulping process.

The purpose of this paper is to present a short summary of the present thinking at FAO with regard to these two problem areas.

The quality of the product of a market pulp mill is important because otherwise the mill will not be able to penetrate and maintain its share of the market. However, there are many aspects of quality; although the pulp may compare badly in some respects with competing pulps, it may have other characteristics which are outstanding. One of these outstanding characteristics may even be the price. However, what is more important than the actual overall quality level as such is the uniformity of quality, within shipments and between shipments. Once a buyer is accustomed to a brand of pulp, he wants the pulp from different shipments to behave in the same way in the papermaking process. The variations in pulp quality must accordingly, in the case of a market pulp mill, be kept at a minimum. The requirements in this regard may be less stringent in an integrated operation.

There are basically two types of quality variation in a pulp mill which uses tropical hardwoods as a raw material, that is, short-term and long-term variations. The short-term variations arise from either variations in the process variables or from non-uniformity of the wood raw material fed into the process. This type of variation can usually be avoided by careful process control and adequate mixing of the wood in the woodyard and especially in the chip pile.

If the tropical forest used as the pulpwood supply area is uniformly heterogeneous, the only variations in the pulp quality will be of the short-term type. However, if the forest is truly heterogeneous, (with varying composition in different parts of the area), there will be long-term variations in pulp quality as well, as the wood harvesting proceeds through the forest. As the source of the variation is in the forest itself, the obvious action to be taken is to employ quality control on the source.

A uniform feed of pulpwood to the pulp mill could be achieved--in a rather tedious way--by selective extraction of species by volume from the area and making sure that the percentage of each species in the pulpwood supply is constant on a long-term basis. Although this would eliminate the long-term variations completely, such a procedure would be completely uneconomical to adopt. However, what is of interest from the pulping point of view is not so much the composition by species as the overall pulping and papermaking characteristics of the mixture used.

Assume that, on the basis of photo-interpretation and topography studies, a forest area has been found to consist of a number of sectors of different types of vegetation which is uniformly heterogeneous within each sector. The basic approach for reduction of long-term variations would then be to mix pulpwood from several of these sectors, selected and combined in order to maintain a constant quality level. This of course presumes that the pulping and papermaking characteristics of the natural pulpwood mix from each of the sectors are known. Before this is achieved a lot of exploratory work has to be done.

The first task to be undertaken, once the sectors of uniform vegetation have been identified, is a forest inventory of each of the sectors and sampling for pulping and papermaking trials. The object of the pulping studies is then to determine the pulping and papermaking characteristics of natural pulpwood mixes which can be obtained from each of the sectors.

In addition, information is required of the variation in the selected characteristics within each of the sectors. If this information were to be collected on the basis of pulping of several representative samples of wood mixtures from each sector, the size of each sample and the number of cooks to be carried out would render the exercise extremely difficult and time-consuming.

However, a study carried out under FAO's Andre Mayer fellowship by Jaime Navarro from the Philippines at CTFT in France from 1974 to 1975 shows that it is possible to mathematically predict the pulping and papermaking characteristics of a wood mixture from the characteristics and relative quantities of the species which are included in the mixture. It is thus possible to carry out pulping tests on a small scale with individual species and to calculate the characteristics of natural wood mixtures which can be obtained from the different sectors on the basis of the inventory data. The testing may even be carried out in a field laboratory concurrent with the inventory work.

Once all the tests and calculations have been carried out, a map can be drawn of the forest area showing the characteristics of the pulp which can be obtained from wood from different parts of the forest. This map is used for planning of the logging operations so that wood from 4 to 8 different sectors are extracted at the same time and mixed to give pulp of a predetermined constant quality level. I shall not go into details here of how adequate mixing is achieved or of the statistical mathematics used to calculate the final confidence limits for the quality variations. This is all described in a FAO document which can be made available to those interested.

The methodology which I have outlined briefly here is mainly designed for an export pulp mill which produces chemical pulp. In such a case the number of species which have to be left out of the pulpwood mix are comparatively few--mainly species which are high in silica or latex content and those which are extremely hard. The necessity of excluding such species of course also depends on the quantities involved. If the total volume of these species correspond to only a few percent, the need may not arise for excluding them.

If the tropical forest is to form the raw material supply for an integrated mechanical pulp and paper mill which produces newsprint and printing and writing papers, the range of wood which can be used is far more restricted than in the case of a chemical pulp mill. The chemi-mechanical pulping process would probably be able to cope with the widest range of wood characteristics for the production of these papers. Even then, the wood should be of low to medium density, and it should be light-colored to avoid extensive costs of bleaching. This means that, for instance, as much as 80 percent of the total available wood volume may have to be excluded from the pulpwood mix and utilized for other purposes, such as fuelwood, charcoal, or for chemical pulping.

Separation of the pulpwood species by identification in the forest in the same manner as is done for sawlogs and peeler logs is evidently not economically feasible. One possibility of course, if there are a sufficient number of sawmills in the area, is to use selected sawmill waste as raw material for the pulp mill. On the other hand, some preliminary results obtained by FAO for one forest area show that separation of pulpwood on the basis of lightness of color is about 75 percent effective in separating the light-to-medium density woods as well. This essentially means that perhaps a handful of light-colored high-density species have to be identified before felling to increase the effectiveness of the separation system. The effectiveness may also be improved by discarding wood of a diameter below a certain critical value. The actual effectiveness of course depends ultimately on distribution of species in the forest area. In some forests the effectiveness of such a system has been shown to be 100 percent, as in the Philippines where all wood is of low to medium density; in others it may be entirely unsatisfactory. In the latter case the obvious conclusion is that such a forest is not a suitable wood supply for a pulp and paper mill based on mechanical-type pulping.

It is obvious that, regardless of whether the planned mill is going to produce market pulp or wood-containing paper for domestic consumption, an appropriate forest inventory is a must. Unfortunately the forest inventory data which are available usually refer to species used as sawlogs and peeler logs, whereas the rest of the wood volume is given as a lump sum total, sometimes with a list of the most common species attached. Such inventory data are of course meaningless as a base for planning a pulp and paper industry.

The inadequacy of the forest inventories from a pulping technologist's point of view is not the fault of the foresters who try to supply information asked from them. The pulp and paper experts accordingly have to inform the foresters what information they want from each forest area to be studied, and the foresters have to adapt their plans for the inventory and accessibility studies to provide this information.

However, the dialogue between the foresters and the pulp and paper experts should not end once the information is obtained for the virgin forest. It should continue with the aim of establishing plantations of species which are well adapted to the future requirements of the pulp and paper mill.

FAST-GROWING PLANTATION HARDWOODS FOR PULP AND PAPER PRODUCTION

By

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ABSTRACT

The following fast-growing woods: bagras (Eucalyptus deglupta Blume), giant ipil-ipil (Leucaena leucocephala (Lam.) de Wit), Kaatoan bangkal (Anthocephalus chinensis (Lamk.) Rich. ex. Walp.), Moluccan sau (Albizia falcataria (L.) Fosb.)and yemane (Gmelina arborea Roxb.) were characterized with respect to the chemical composition, fiber morphology, sulfate pulping and handsheet properties, and growth rates.

FAST-GROWING PLANTATION HARDWOODS FOR PULP AND PAPER PRODUCTION

By

José A. Semana

INTRODUCTION

Increasingly, the conflicting requirements of growing population with their correspondingly expanding needs for food, construction materials, pulp and paper, fuelwood, and other products are straining our finite land areas.

The overall result has been the irreversible decrease in the land area devoted to forests, especially where the area has been transformed into farms and communities, since land requirements for food and for communities appear to have higher priority over other considerations. On the other hand, a certain proportion of the irreversible reduction in the forest areas appears to have been caused by shifting agriculture and/or lack of proper forestry practices.

Eckholm has well described the importance of the crucial ecological roles of forests (1). Forests influence the wind, temperature, humidity, soil, and water in ways often discovered only after the trees are cut, and these usually beneficial functions are sabotaged. Forests assist in the essential global recycling of water, oxygen, carbon, and nitrogen. Rainwater falling on tree-covered land tends to soak into the ground rather than to rush off, reducing erosion and flooding; and more water is likely to seep into underground pools and springs (1).

Growing shortages of trees for fuel, lumber, newsprint, and ecological protection have compelled many governments to recognize the need for reforestation. The past few decades have seen ambitious national forestry plans unfulfilled by governments either unwilling or incapable of backing their schemes with sufficient money and political commitment (1).

It has been estimated that the forests of the Philippines are decreasing at the rate of 203,905 ha. annually due to reclassification of forest areas into agricultural areas and forest denudation caused by illegal logging and shifting cultivation. The government was able to reforest at an annual rate of only 9,773 ha. for Fiscal Years 1960 - 61 to 1973 - 74. By Fiscal Year 1974 - 75 to 1975 - 76, the net annual reforestation rate was already 15,685 ha. (2). Further intensification of the rate of reforestation rate will be required if the present forested area is to be maintained or even increased.

No area in the Philippines has yet attained the situation in some Himalayan foothills where formerly firewood gathering was a one- or two-hour job daily and now it is an entire day's task due to the scarcity of wood (1). Nevertheless, the status of Philippine forests is still a critical one.

The total area available for long-range forestry development is as follows (3):

1. Public forest lands	
a. Open lands (barren, denuded, etc.)	2.6 million ha.
b. Reproduction brushlands	2.3 million ha.
c. Degraded logged-over areas	3.0 million ha.
d. Government reforestation projects	0.8 million ha.
Total	8.7 million ha.
2. Privately owned lands (idle lands, marginal lands, etc.)	2.0 million ha.

The area classified as public forest land in 1974, 14,083 million ha., comprised 57.3 percent of the total land area of 30 million ha., of which 8.7 million ha. was considered available for long-range forestry development and constituted 50.9 percent of the public forest land (4).

With this huge task before it, the government attempted to increase the reforestation rate by a combination of incentives to those going into large-scale industrial plantations, financing assistance, and compulsion. By itself, the government cannot accomplish reforestation single-handedly and private firms or individuals could engage in large-scale reforestation if there were economic incentives.

Such incentives are in the form of grants of leases for at least 25 years to a maximum of 50 years for the establishment of industrial tree plantations, with nominal filing fees, rental charges, the maximum of which is ₱1.00 (US $0.13) per ha., forest charges of six percent of the current value of the wood harvested, and various reduced tax benefits (5).

Additional benefits are available from the Investment Incentives Act (6) regarding deductions from taxable income regarding certain expenses. Financing, under certain conditions, for an amount of ₱1300 to ₱2000 (US $173-267) per ha. are available to qualified planters from Government financing institutions. A recent law now requires every citizen of at least 10 years of age to plant one tree every month for five consecutive years or a total of 60 trees beginning June 1977 (7). The element of compulsory tree planting, besides hastening reforestation, would perhaps make the population realize that forestry is everybody's job, not only those of the forestry agencies; a failure in forestry ultimately adversely affects the lives of even those living in areas remote from the forests.

PROPERTIES OF AN IDEAL PULPWOOD SPECIES

The urgent need for reforestation, the requirement for employment opportunities, and the demand for wood products, particularly for pulp and paper, has virtually created a need for wood species which would have the desirable properties for wood products.

Since we are concerned with pulp and paper we set forth the specifications most of which have been described by Dadswell (8,9):

1. A growth rate as rapid as the economics of plantation management will allow.
2. Higher than average fiber length for the species.
3. Cell wall thickness such that the Runkel ratio (twice the cell wall thickness/lumen diameter) is less than 1.
4. Basic density lower than average for the species (this is correlated with (3) above).
5. Higher than average cellulose content.
6. Suitable pentosan content in the pulp, which has to be determined for each species.
7. Low extractive content.

To the above, we add the following requirements:

8. Low lignin content and
9. Low ash content.

Another desirable characteristic in an ideal pulpwood would be that no product more expensive than pulp and paper could be made from the pulpwood.

THE FAST-GROWING HARDWOODS

Characteristics

Bagras

Bagras is the only native Philippine eucalypt species and is one of the largest and tallest trees in the Philippines, attaining a height of 20-30 m. and a maximum diameter of 200 cm (10).

Its bole is tall and straight. It thrives in places with a non-seasonal rainfall of about 3000 mm, is tolerant of wet sites associated with river beds, and requires full overhead light for development. It is considered an all-purpose wood. In about 10 years, it is big enough for pulpwood and in 20-30 years, it can be made into lumber or plywood (11).

Giant ipil-ipil

Leucaena is a Central American genus of the family Mimosaceae which has 10 species which are considered to be of unquestioned validity. Of these species, Leucaena leuccocephala (Lam.) de Wit formerly known as Leucaena glauca (L.) Benth., has the greatest geographical distribution (12).

While it originated in Mexico, it is now found in other countries in Central and South America, in a few states of the United States, the West Indies, Asia, the Pacific Islands, Africa, and Australia (13).

The common ipil-ipil found in the Philippines is a 5-8 m. tall shrub while the giant strains attain up to 20 m. height (14). The giant Hawaiian strains were introduced sometime in 1964 into the Philippines (15) but the first relatively large-scale plantings were undertaken in 1970-71 in the southern Philippines (16). It is one of the fast-growing species adopted by the government in its reforestation program. In addition, large-scale planting by private firms and individuals is going on for use for forage, fuelwood, and for charcoal.

Ipil-ipil has certain characteristics which have contributed to its widespread distribution and to its suitability for multiple uses such as its adaptability to wide ranges in climate and soil conditions, ease and rapidity of reproduction, gregarious and rapid growth, deep root system, and tolerance of hazards and pests.

Kaatoan bangkal

This species attains up to 15-30 m. height and a dbh of 40-60 cm. It is a prolific seeder and can produce by coppice growth. It has been grown in altitudes of 100-1000 m. (17).

Moluccan sau

Moluccan sau is indigenous to Indonesia (19). It is a large, fast-growing tree which may reach a height of 45 m. Dominant trees may reach a height of 13.6-18.3 m. in three years on good sites. This species prefers a reasonably fertile soil and responds well to fertilizers (19).

Planting of this species was pioneered on a large scale by two forestry companies in the southern Philippines. About 13,000 ha. of private tree farms of this species have also been established to supply the pulpwood demands of one of the firms, in addition to the company plantations (20). However, it is not as suited for the northern Philippines where strong typhoon winds easily break the low-density trunks.

Yemane

This species requires a moderately fertile soil free from competition at an early age until its crown has closed. It has a straight bole and may attain a height of about 20 m. It is resistant to fire and strong winds. The average dbh in a 3-year plantation was 19.4 cm. It has been reported to produce a greater volume from coppice growths than from planted seedlings (19).

Growth Rates

The term "fast-growing" is relative. "Fast-growing" trees should show substantially greater growth compared with the usual rate expected from the Dipterocarps which comprise the principal portion of Philippine forests.

The Dipterocarps, in well managed, selectively logged stands, can yield only 100 to 150 m.^{3}/ha. in 35 years or 2.9 to 4.3 m.^{3}/ha. per year (21) or about 1.3 to 1.9 bone dry metric tons (bdt) per ha. per year.

Table 1 gives the mean annual increments of the fast-growing wood species in the Philippines (16,19,21-23). The growth rates in bdt per ha. per year were calculated from the volumetric rate using their specific gravities (16,24). The growth rates vary from 16.7 to 311.9 m.^{3}/ha. per year or 7.2-149.5 bdt per ha. per year. Whether the between-species

Table 1. Mean Annual Increments of Some Fast-Growing Woods in the Philippines

Species	m^3/ha/year	Mean annual increment bdt/ha/year
Bagras	16.7-25.0	7.2-10.8
Giant ipil-ipil		
Peruvian, 1.5 yrs.	123.1	66.5
K - 8 , 2 yrs.	30.7	16.3
K - 28 , 2 yrs.	23.8	12.6
K - 8 , 2.5 yrs.	236.7	110.8
K - 28 , 2.5 yrs.	311.9	149.5
K - 28 , 7 yrs.	45.7	25.8
Kaatoan bangkal	36	11.9
Moluccan sau	25-50	10.8-12.5
Yemane	36	11.9

Table 2. Annual Increments of Foreign Fast-Growing Woods

Species	Increment m^3/ha/year	Location
Eucalyptus	50	Africa
Eucalyptus	20-30	South America
Eucalyptus	15-25	Tropical Africa
Pinus and *Cuppressus* species	12-17	
Teak	Not greater than 10	
Gmelina and *Maesopsis eminii*	10-15	

differences are significant is not yet known in the absence of more extensive data. Variables which affect the growth rate are site quality, spacing or number of stems per ha., age, etc.

Observations by Chinte indicate that the growth rate tends to decrease with age (19,21). The better the site quality, the greater the growth rate. For example, giant ipil-ipil has given the higher yields on agricultural lands while lower growth rates, as low as three bdt per ha. per year, have been obtained on former forested areas which have been logged-over several years previous to planting with ipil-ipil.

Reported growth rates for eucalyptus ranged from 15 up to 50 $m.^3$/ha. per year in Africa, South America, and Tropical Africa, 12 to 17 bdt per ha. per year while Gmelina and Maesopsis eminii showed growth rates of 10-15 bdt per ha. per year (25,26).

Such high growth rates make possible short rotations, minimize land area requirements compared with conventional wood species, make possible clear-felling practices which reduce logging costs, and other advantages, all of which reduce wood costs; of all forest industries, per unit wood costs of the pulp industry must be the cheapest. Pulpwood, as a rule, is generally of such a diameter, length, or shape as to be unsuitable for such higher cost (on the wood volume basis) products as lumber, plywood, or veneer. Moreover, a preferably low-density pulpwood conflicts with the need of higher wood density (for higher strength) wood for lumber.

Basic Density

The basic densities of the fast-growing species are shown in Table 3. Three species--Kaatoan bangkal, Moluccan sau, and Yemane--have relatively lower densities than the other species.

There are several advantages for low-density woods. The pulp yields and strengths of eucalypts from Tasmania, Australia, were observed to decrease while pulping chemical consumption increased with increasing basic density of the wood (27,28). Density has a direct relationship with the age of the wood. Young eucalypt trees have lower densities than older wood (29). Pulping times for low-density woods can be shorter since impregnation with chemicals is relatively easier.

Morphology of the Fibers

Fiber length

The fiber dimensions and derived values of most of the wood species given here have been reported previously by Tamolang et al and Zamuco (33).

Table 3. Fiber Dimensions and Basic Densities of Some Philippine Woods

Species	Length (L) mm	Width (D) mm	Lumen (1) mm	Cell-wall thickness(t) mm	Slenderness ratio (1/D)	Flexibility ratio (1/D)x100)	Runkel ratio 2xt/1	Basic density
Bagras	1.04	0.025	0.017	0.004	42	68	0.47	0.44
Giant ipil-ipil								
Copil, 1 year	0.87	0.028	0.020	0.004	31	71	0.40	0.44
K-8, 1 year	1.11	0.026	0.016	0.006	43	62	0.75	0.51
K-28, 1 year	0.96	0.027	0.018	0.004	36	67	0.44	0.42
K-28, 1.5 years	1.04	0.026	0.016	0.005	40	62	0.62	0.52
K-28, trunk, 6 years	1.20	0.025	0.015	0.005	48	60	0.67	0.52
K-28, branches, 6 years	1.09	0.024	0.014	0.005	45	58	0.71	0.49
Kaatoan bangkal	1.43	0.034	0.024	0.005	42	71	0.42	0.33
Moluccan sau	1.04	0.027	0.018	0.0045	39	67	0.50	0.25
Yemane	1.30	0.031	0.024	0.0035	42	77	0.29	0.33

They are also shown in Table 3. As expected, the fiber lengths are relatively short, typical of hardwoods. The direct relationship of fiber length to the tearing strength of paper has already been shown (8,34). However, the stiffness, or lack of flexibility of fibers due to relatively thick cell walls, also contribute to tearing strength in fibers (34). With the relatively short fibers of these hardwoods compared with the 3 mm or more fiber length for softwoods, the tearing resistance would be expected to be relatively low. Tearing resistance is an essential property for such papers as bag and wrapping papers, and for linerboard. In many cases, it is possible to use hardwood pulps provided a certain amount of long-fibered pulp is added to impart the required tearing resistance.

Fibers formed during the early years of the development of a tree are shorter than those laid down later in its life (29). Hence, the older the tree, the longer would be the average fiber length. This appears to be true in the case of the 1-, 1.5-, and 6-year-old K-28 strains of giant ipil-ipil. The basic densities appear to be higher for the 1.5- and 6-year-old trees than the 1-year-old trees.

Cell Wall Thickness

Dinwoodie considers that, although fiber length or the ratio of fiber length to diameter is important, fiber density is likewise important (34). Fiber density may be expressed as density *per se*, cell wall thickness, as the Runkel ratio, or as flexibility coefficient.

The Runkel ratios of the various species all pass Runkel's criteria for good papermaking fibers, all being less than 1. Runkel showed that, provided the fiber length was average, hardwood species would be suitable if the ratio of twice the cell wall thickness/lumen diameter was less than 1 (35). Thus, low Runkel ratios are desirable.

The flexibility coefficient or ratio (lumen diameter/fiber diameter) is an inverse measure of fiber density, being higher the lower the fiber density.

These ratios are measures of the ability of the fibers to conform to each other in the paper sheet. Low Runkel ratios (or high flexibility ratios or coefficients) characterize thin-walled fibers which after beating and subsequent drying collapse readily to form a flat ribbonlike structure which provides relatively large areas for bonding with other adjacent fibers. The greater the conformability of the fibers, the better the fiber-to-fiber bonds. The paper will have relatively low tearing strength compared with sheets made from coniferous pulps, but will have excellent bursting strength and tensile strength. Dense papers will be produced with low opacity if the pulp is beaten to a low freeness (Canadian Standard).

Beaten thick-walled fibers, on the other hand, tend to retain their rounded shape instead of collapsing and thus remain stiff. Consequently, the bonding with adjacent similar fibers is relatively low, resulting in a relatively weaker paper sheet. However, their stiffness results in greater tearing resistance. Papers made from such fibers also tend to have higher opacity (8). This is a desirable property for printing papers.

Dadswell noted a direct relationship between basic density and cell wall thickness in both hardwoods and softwoods which is quite definite within a given species (8). Comparisons between species may be obscured, however, by other factors that affect basic density. Excessive extractives may result in higher basic density, or a too-high percentage of short thin-walled parenchyma could cause low basic density (9).

Chemical Composition

The morphological features of the fibers are generally considered to be much more important than the chemical composition in determining strength, especially in coniferous sulfate pulps. In hardwood chemical and semichemical pulp, however, the pentosans and other hemicelluloses often contribute greatly to paper strength because these are contained in larger percentages in hardwoods compared with the softwoods.

The proximate chemical composition data of these fast-growing woods, as determined at FORPRIDECOM using TAPPI methods (36), except for holocellulose, are given in Table 4. Holocellulose was calculated as follows: % Holocellulose = (100 - % lignin - % Ash - % hot water solubles - % alcohol-benzene soluble).

Holocellulose

Holocellulose, the total carbohydrate content (cellulose and hemicellulose) of wood, is directly related to chemical and semichemical pulp yield. The fast-growing woods show satisfactorily high holocellulose contents.

Pentosans

The pentosans are the more resistant of the hemicelluloses to pulping chemicals. The amount of hemicellulose influences the interfiber bonds. An increasing hemicellulose content makes the pulp more easily beaten and makes the resulting paper denser and more transparent (37). However, Dadswell's work indicates an optimum pentosan content of 5 to 7 percent for *Eucalyptus regnans* pulp for maximum burst and tear strength (8).

Table 4. Proximate Chemical Composition of Some Fast-Growing Wood in the Philippines

Sample	Holocellulose	Pentosans	Lignin	Solubilities in: Alcohol-benzene	Solubilities in: Hot-water	Ash
	%	%	%	%	%	%
Bagras	69.8	17.0	27.0	1.2	1.4	0.6
Giant ipi-ipil						
Peruvian, 0.5 year	69.8	8.9	25.4	1.4	2.5	0.9
Peruvian, 2 yrs.	69.9	16.0	26.0	1.5	1.9	0.7
Copil, 1 year	61.6	16.7	29.2	3.4	4.2	1.6
K-8, 1 year	72.6	15.9	17.5	4.2	4.22	1.5
K-28, 1 year	70.4	17.1	21.4	2.8	3.6	1.7
K-28, 1.5 yrs.	72.6	20.1	22.7	1.7	2.0	0.9
K-28, 5 yrs.	71.0	13.6	23.3	2.6	2.3	0.8
Kaatoan bangkal	70.2	19.6	22.5	3.2	3.2	0.9
Moluccan sau	70.8	16.9	25.0	2.6	1.1	0.5
Yemane	71.7	18.4	21.8	3.2	2.3	1.0

The 0.5-year-old Peruvian ipil-ipil has much lower pentosan content than the other strains of ipil-ipil or other species.

SULFATE PULPING OF FAST-GROWING HARDWOODS

Tables 5 and 6 show the results of pulping and beater tests on the fast-growing hardwoods. The 7-year-old K-28 ipil-ipil trunk and branch, Moluccan sau (38) and yemane (38) showed high pulp yields of 51.6 to 55.7 percent. Bagras had relatively much lower pulp yield, 44.1 percent. The equivalent Kappa numbers of the giant ipil-ipil pulps would appear to be somewhat higher than that of the other species.

Tensile strength and folding endurance of the Kaatoan bangkal, Moluccan sau, and yemane pulps appear to be better than those of the other species but, except for 1-year Copil and K-28, the ipil-ipil pulps have better tear strength and comparable and better burst strength. Bagras seems to be inferior to the other pulps in most respects.

CONCLUSION

Of the fast-growing woods studied, bagras appears to produce sulfate pulp inferior to those from other species. Seven-year-old K-28 ipil-ipil, Kaatoan bangkal, Moluccan sau, and yemane sulfate pulps had good strength properties.

Table 5. Sulfate Pulping Data on Fast-growing Hardwoods*.

Species	Chemical charged on o.d. chips		Pulp yield		K or Kappa No.
	NaOh	Na_2S	Accepts	Rejects	
	%	%	%	%	
Bagras	15.0	5.0	44.1	0.1	15.0 K no.
Giant Ipil-ipil					
Copil, 1 year	15.0	5.0	49.1	0.4	19.0 Kappa no.
K-8, 1 year	15.0	5.0	48.4	2.0	25.2 Kappa no.
K-28, 1 year	15.0	5.0	46.7	0.8	22.1 "
K-28, trunk, 7 years	15.0	5.0	52.4	0.4	26.9 "
K-28, branch, 7 years	15.0	5.0	51.6	1.11	29.6 "
Kaatoan bangkal	15.0	5.0	47.3	0.2	15.9 K no.
Moluccan sau	13.3	6.7	53.8	0.02	10.9 "
Yemane	15.0	5.0	55.7	0.05	11.4 "

*Unless otherwise specified, all percentages are based on moisture-free weight of wood.

The following pulping conditions were applied in all cases:

a. Liquor-to-material ratio 4:1
b. Maximum cooking temperature . . . . 170°C
c. Pulping schedule:
    1. Time from room to maximum temperature 170
       170°C . . . . 90 min.
    2. Time at maximum temperature 170°C . . . 90 min.

Table 6. Properties of Unbleached Sulfate Pulps of Some Fast-Growing Hardwoods at 300 cm^3, CSF

Species	Burst Factor	Tear Factor	Folds (double) M.I.T.	Tensile breaking length in m	Density g/cm^3
Bagras	54	53	187	10.110	0.76
Giant ipil-ipil					
Copil, 1 year	64	62	658	9.8	0.81
K-8, 1 year	72	75	598	10.8	0.78
K-28, 1 year	60	58	680	9.4	0.84
K-28, trunk, 7 years	77	86	950	11.0	0.76
K-28, branch, 7 years	75	77	776	11.8	0.72
Kaatoan bangkal	72	82	825	13.0	0.79
Moluccan sau	69	67	1080	10.8	0.79
Yemane	68	68	1450	12.8	0.88

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SECTION V

WOOD FIBER AND RECONSTITUTED PRODUCTS RESEARCH

KRAFT AND NSSC PULPING OF MIXED TROPICAL HARDWOODS

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KRAFT AND NSSC PULPING
OF MIXED TROPICAL HARDWOODS

By

James F. Laundrie

SUMMARY

Samples of tropical hardwoods with wide ranges of properties were obtained from the Philippines, Ghana, and Colombia. Three different mixtures were made with the woods from each country--one with uniform-density distribution, the second favoring the higher densities, and the third with a preponderance of the medium-density woods. Three kinds of kraft digestions were made using all nine mixtures to produce fully cooked, high-screenings, and semichemical pulps. Neutral sulfite semichemical (NSSC) digestions were also made using all nine mixtures. Results indicate that mixed tropical hardwoods, regardless of source, would be suitable for the production of kraft and NSSC pulps, with properties as good as similar pulps made from temperate zone hardwoods.

INTRODUCTION

Traditionally, forest industries have been based on the "difference approach." Forests have been surveyed and screened to find species that could perform best for specific end uses. Recently, however, there has been increased interest in species-tolerant processes and products. For the heterogeneous tropical forests, more intensive application of nontaxonomic or nonspecific systems could permit more flexible harvest of the timber resource and more effective management of the forest.

As mixed as the tropical forests are, similarities may appear in composition and form between widely dispersed timber stands. Holdridge [1/] has quantified the forest shape or physiognomy based on life zones defined by rainfall, temperature, and evapotranspiration. Recent studies at the Forest Products Laboratory[2/] show wood specific gravity distribution patterns for tropical American species are indeed unique to certain Holdridge life zones. Specific gravity was chosen for the first probe because it correlates well with many important wood characteristics and pulp quality. If it can be demonstrated that the total wood resource, as well as the forest form, reflects the environmental conditions of a life zone, then processes can be developed based on this particular wood

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mix, regardless of species composition. Results would be applicable to large forest tracts, wherever located, that have the same life zone classification.

With these opportunities in mind, the Forest Products Laboratory, under agreement and with the assistance of the U.S. Agency for International Development, investigated the feasibility of producing forest products--pulp, paper, hardboard, and particleboard--from raw material representing a wide mix of tree species. To augment and provide a suitable frame of reference in applying the results of those technical feasibility studies, supplementary studies of silvicultural and environmental implications and of the implications of governmental policies in developing nations were also undertaken. Benefits to the developing tropical countries expected from these investigations include (1) new jobs for both skilled and unskilled workers, (2) production of forest products useful in developing local markets and competitive in world markets, (3) stimulation of ancillary industries, and (4) sizable savings in foreign currency exchange.

This paper, however, is concerned only with determining the pulping characteristics of mixed species of secondary tropical hardwoods by the kraft and NSSC processes.

EXPERIMENTAL

Research Materials and Sampling

Three countries representing three geographical areas were selected for sampling the wood resource. These were, in the order sampled, the Philippines (representing Southeast Asia), Ghana (Africa), and Colombia (South America). The method of sampling for each location was essentially the same. From the literature, species with preselected values for density, silica content, and extractives were designated as potential samples; thus various density distribution mixtures could be simulated, low and high contents of silica and extractives would be available, and a range of color from light to dark would be present. Some freedom of substitution was allowed where local conditions made it difficult to harvest a preferred species.

Fifty species were sampled in the Philippines, 22 in Ghana, and 18 in Colombia (see tables 1, 2, and 3). The greater sampling in the Philippines was due to the broader range of effort scheduled for the first sample and the plan to use subsequent samples primarily for verification of the first results.

The wood was airfreighted to the Forest Products Laboratory where it was debarked and sampled for determining specific gravity, moisture content, and fiber morphology. After chipping, the wood was stored in a cold room (+2° C) for subsequent use. Representative chip samples of each species were analyzed to determine the amounts of ash and silica.

Table 1.--Specific gravity, ash, and silica content of 50 Philippine hardwoods

No.	Species		Specific gravity[1/]	Ash[2/]	Silica[2/]
	Common name	Botanical name			
				Pct	Pct
1	Tangisang-bayauak	Ficus variegata	0.24	3.64	0.02
2	Binuang	Octomeles sumatrana	.24	1.32	< .01
3	Kapok	Ceiba pentandra	.24	4.45	< .01
4	Balilang-uak	Meliosma macrophylla	.26	1.34	.04
5	Rarang	Erythrina subumbrans	.26	1.61	< .01
6	Kaitana	Zanthoxylum rhetsa	.30	.75	< .01
7	Ilang-ilang	Cananga odorata	.31	1.46	.02
8	Gubas	Endosperum peltatum	.32	.62	< .01
9	Dita	Alstonia scholaris	.32	1.08	.01
10	Anabiong	Trema orientalis	.32	1.00	< .01
11	Hamindang	Macaranga bicolor	.32	1.46	.02
12	Balanti	Homalanthus populneus	.36	1.17	< .01
13	Mayapis	Shorea squamata	.37	.36	.04
14	Matang-arau	Melicope triphylla	.38	1.05	.43
15	Malasantol	Sandoricum vidalii	.39	.61	.01
16	White lauan	Pentacme contorta	.40	.72	.06
17	Tulo	Alphitonia philippinensis	.42	.47	< .01
18	Tangile	Shorea polysperma	.43	.20	.08
19	Pahutan	Mangifera altissima	.44	2.91	.02
20	Apanit	Mastixia philippinensis	.45	1.72	.10
21	Lago	Pygeum vulgare	.45	.50	< .01
22	Antipolo	Artocarpus blancoi	.47	5.21	4.55
23	Bagtikan	Parashorea plicata	.48	1.42	< .01
24	Sakat	Terminalia nitens	.49	.68	.10
25	Red lauan	Shorea negrosensis	.51	.09	.03
26	Itangan	Weinmannia luzoniensis	.53	1.52	< .01
27	Piling-liitan	Canarium luzonicum	.55	.73	.21
28	Palosapis	Anisoptera thurifera	.55	1.17	.72
29	Lomarau	Swintonia foxworthyi	.56	1.00	.10
30	Malabetis	Madhuca oblongifolia	.56	3.01	2.19
31	Dangkalan	Calophyllum obliquinervium	.57	.65	< .01
32	Panau	Dipterocarpus gracilis	.58	.93	.43
33	Katmon	Dillenia philippinensis	.59	1.06	.02
34	Batitinan	Lagerstroemia piriformis	.60	3.56	.01
35	Katong-lakihan	Amoora macrocarpa	.61	.84	.03
36	Narig	Vatica mangachapoi	.62	.74	.22
37	Miau	Dysoxylum euphlebium	.62	1.16	.04
38	Apitong	Dipterocarpus grandiflorus	.62	.69	.23
39	Bok-bok	Xanthophyllum excelsum	.64	1.11	< .01
40	Kamatog	Erythrophloeum densiflorum	.65	1.62	.01

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Table 1.--Specific gravity, ash, and silica content of 50 Philippine hardwoods--cont.

No.	Species		Specific gravity[1]	Ash[2]	Silica[2]
	Common name	Botanical name			
				Pct	Pct
41	Dalingdingan	Hopea foxworthyi	0.67	0.70	0.04
42	Katilma	Diospyros nitida	.68	2.51	.02
43	Yakal	Shorea astylosa	.72	.92	.03
44	Kamagong	Diospyros philippinensis	.72	2.98	< .01
45	Katong-matsin	Chistocheton pentandrus	.73	.78	.02
46	Manaring	Lithocarpus soleriana	.74	.79	.02
47	Ipil-ipil	Leucaena leucocephala	.74	.91	.01
48	Bolong-eta	Diospyros philosanthera	.74	1.96	.02
49	Makaasim	Syzygium nitidum	.78	.78	.03
50	Alupag-amo	Litchi philippinensis	.79	1.10	< .01

[1] Dry weight, green volume basis.
[2] Moisture-free wood basis.

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Table 2.--Specific gravity, ash, and silica content of 22 Ghanaian hardwoods

No.	Species		Specific gravity[1]	Ash[2]	Silica[2]
	Common name	Botanical name			
				Pct	Pct
1	Otu	Cleistopholis patens	0.24	1.24	0.02
2	Effeu	Hannoa klaineana	.28	.92	.02
3	African corkwood	Musanga cecropioides	.30	.81	.04
4	Obeche	Triplochiton scleroxylon	.30	2.24	.01
5	Antiaris	Antiaris africana	.31	1.65	.20
6	Canarium	Canarium schweinfurthii	.34	1.11	.30
7	Akoret	Discoglypremna caloneura	.37	1.75	.01
8	African mahogany	Khaya ivorensis	.41	.54	< .01
9	Dahoma	Piptadeniastrum africanum	.44	.75	.02
10	Gedu nohor	Entandrophragma angolense	.45	1.16	< .01
11	Niangon	Tarrietia utilis	.46	.53	< .01
12	Scented guarea	Guarea cedrata	.49	1.27	.11
13	Makore	Tieghemella heckelii	.50	.55	.16
14	Tallow tree	Allanblackia floribunda	.54	1.73	< .01
15	Lokonfi	Celtis adolfi-friderici	.55	1.41	.01
16	Brown sterculia	Sterculia rhinopetala	.55	2.75	< .01
17	Eyong	Sterculia oblonga	.59	2.47	< .01
18	Adjouba	Dacryodes klaineana	.69	1.41	.52
19	Afina	Strombosia glaucescens	.70	1.54	.01
20	Kane	Anogeissus leiocarpus	.71	3.62	.09
21	Kokoti	Anopyxis klaineana	.72	.25	< .01
22	Ekki	Lophira alata	.81	.45	< .01

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[1] Dry weight, green volume basis.

[2] Moisture-free wood basis.

Table 3.--Specific gravity, ash, and silica content of 18 Colombian hardwoods

No.	Species: Common name	Species: Botanical name	Specific gravity[1]	Ash[2]	Silica[2]
				Pct	Pct
1	Peine mono	Apeiba aspera	0.14	3.55	<0.01
2	Ceiba	Ceiba pentandra	.23	3.73	< .01
3	Yarumo	Cecropia sp.	.25	1.71	.02
4	Cirpo	Pourouma sp.	.37	.76	< .01
5	Chingale	Jacaranda copaia	.37	.58	< .01
6	Dormilon	Vochysia ferruginea	.45	.82	.02
7	Sande	Brosimum utile	.49	.51	.01
8	Sangretoro	Virola sebifera	.51	.33	< .01
9	Arenillo	Castostemma alstonii	.54	1.26	< .01
10	Canelo	Nectandra sp.	.55	.18	< .01
11	Perillo negro	Couma macrocarpa	.55	.40	< .01
12	Casaco	Hieronyma sp.	.60	.55	< .01
13	Carbonero	Enterolobium schomburgkii	.63	.75	< .01
14	Chocho	Ormosia paraensis	.67	.29	.01
15	Carreto	Aspidosperma sp.	.69	.62	< .01
16	Lecheperra	Helicostylis tomentosa	.79	1.10	.03
17	Tamarindo	Dialium guianense	.82	1.82	1.48
18	Caimo	Neoxythece sp.	.86	.95	.55

[1] Dry weight, green volume basis.
[2] Moisture-free wood basis.

The woods from each country were divided into six groupings based on our specific gravity measurements. The original intention was to group the woods as follows:

Less than 0.3	0.5 to 0.6
0.3 to 0.4	0.6 to 0.7
0.4 to 0.5	Greater than 0.7

However, in order to have nearly the same number of woods in each grouping and, in some instances, to have more than one species in a group, the actual specific gravity range for each grouping varied slightly from those listed above.

Three chip mixtures were made with the wood from each country. In one, the density distribution was uniform, in the second the higher densities were favored, and in the third the medium densities were dominant. These have been designated as mixtures A, B, and C, respectively (see table 4 for mixture compositions). The average specific gravity of the nine mixtures was calculated and the mixtures were analyzed to determine the amounts of ash, silica, lignin, and extractives.

Separation of Chip Mixtures

A major premise of this study was that the higher specific gravity woods could be separated from the chip mixtures to provide fuel, with an expected improvement in the quality of the pulp made from the remaining lower density chips. One Ghanaian and two Philippine chip mixtures were air classified to obtain two weight fractions from each corresponding to the known compositions of the mixtures. The specific gravity separation point was 0.5 for the Philippine mixtures and 0.45 for the Ghanaian mixture.

Kraft Pulping

Fully cooked kraft pulps having less than 1 percent screenings were made using all nine whole mixtures and the six fractions of the air-separated mixtures. Kraft digestions were also made using the nine whole mixtures to produce pulps having 25 to 30 percent screenings. These digestions were made to indicate the feasibility of using the screened pulp for linerboard and the screenings for corrugating medium. Semichemical kraft pulps were also made from the Colombian A mixture and evaluated for possible use in corrugating medium. The screenings and semichemical pulps were fiberized and refined in a 12-inch-diameter, single-rotating disk mill and made into handsheets having a basis weight of 26 pounds per 1,000 square feet. Strength development of the screened pulps was in a Valley beater, and handsheets were made and evaluated according to standard TAPPI methods.

Table 4.--Composition of tropical hardwood chip mixtures used for kraft and semichemical pulping

Species[1/]			Mixture composition[2/]		
Philippines	Ghana	Colombia	A	B	C
			Pct	Pct	Pct
1-6	1-4	2-3	16.7	2	4
7-15	5-7	4-5	16.7	4	8
16-24	8-10	6-8	16.7	9	20
25-34	11-13	9-11	16.7	15	40
35-42	14-17	12-14	16.7	20	20
43-50	18-22	15-18	16.7	50	8

[1/] Individual species listed by number in tables 1 to 3.

[2/] Moisture-free wood basis.

NSSC Pulping

NSSC pulps with yields of about 75 percent were made from all nine whole mixtures. Additional NSSC digestions of only the Colombian A mixture were made with increasing amounts of sodium sulfite and sodium carbonate and time at cooking temperature in order to obtain lower yield pulps. The effects of adding caustic soda to the NSSC cooking liquor were also determined at the 75 percent yield level. All of these semichemical pulps were fiberized and refined in a 12-inch-diameter, single-rotating disk mill and made into handsheets having a basis weight of 26 pounds per 1,000 square feet.

RESULTS

Chemical Analysis of Individual Species and Chip Mixtures

The amounts of ash and silica in the individual species are given in tables 1, 2, and 3. Ash values ranged from 0.09 to 5.21 percent for the Philippine species, 0.25 to 3.62 percent for the Ghanaian species, and 0.18 to 3.73 percent for the Colombian species. Similarly, silica values ranged from less than 0.01 to 4.55 percent for the Philippine species, 0.52 percent for the Ghanaian species, and 1.48 percent for the Colombian species.

Shown in table 5 are the calculated average specific gravities and chemical analysis of the nine whole chip mixtures. Except for lignin, differences were small between the mixtures with respect to pH, ash, silica, and extractives. The three Philippine mixtures contained the most lignin with an average of 31.4 percent, while the Ghanaian mixtures contained the least with an average of 26.7 percent.

Separation of Chip Mixtures

Samples of chips in both the light and heavy fractions were identified to determine the efficiency of separation, which is defined as the percentage of desirable chips in that particular fraction. The average efficiency for all six fractions was nearly 80 percent. Undoubtedly, this efficiency could have been increased considerably with further drying of the chips prior to air separation. On the other hand, any separation would have been impossible without at least some drying because when freshly cut the range of specific gravity, on the basis of wet weight, wet volume, falls into a very narrow range.

Kraft Pulping

Fully Cooked Pulps

The conditions and results of the kraft digestions made with all nine mixtures to produce fully cooked pulps are given in table 6. Similar results were obtained with all nine mixtures pulped under exactly the same conditions. The pulps from the Philippine mixtures had the

Table 5.--Average specific gravity and chemical analysis of tropical hardwood mixtures used for kraft and semichemical pulping

Mixture	Average specific gravity[1]	pH	Ash[2]	SiO_2[2]	Lignin[2]	Extractives[2] Ethyl ether	Extractives[2] Alcohol benzene	Extractives[2] Hot water
			Pct	Pct	Pct	Pct	Pct	Pct
				PHILIPPINES				
A	0.50	5.4	1.45	0.19	30.80	0.76	4.14	3.45
B	.64	5.1	1.38	.12	31.75	.91	4.05	3.28
C	.54	5.1	1.39	.28	31.60	.75	3.78	3.05
				GHANA				
A	.47	5.6	1.26	.08	26.64	.51	4.07	2.76
B	.60	5.2	1.47	.08	27.72	.10	3.32	2.38
C	.49	5.7	1.16	.06	25.62	.46	4.07	2.50
				COLOMBIA				
A	.51	5.7	.94	.06	28.71	.33	3.84	3.79
B	.67	5.8	.91	.28	28.60	.34	3.15	3.89
C	.54	5.6	.68	.04	29.51	.31	3.66	3.70

[1] Dry weight, green volume basis.
[2] Moisture-free wood basis.

Table 6.--Fully cooked kraft pulping[1] of tropical hardwood mixtures

Mixture	Black liquor		Yield		Kappa No.
	NaOH (Na_2O)	Na_2S (Na_2O)	Total	Screenings	
	G/l	G/l	Pct	Pct	
			PHILIPPINES		
A	2.2	7.2	47.5	0.9	29.6
B	2.1	7.9	47.5	.9	29.1
C	1.5	8.0	48.0	.9	27.8
			GHANA		
A	5.1	5.3	45.8	.6	26.0
B	3.1	7.1	43.5	.6	27.5
C	2.9	7.6	44.6	.4	22.0
			COLOMBIA		
A	4.6	6.9	46.9	1.2	24.5
B	5.3	6.6	47.5	.4	23.3
C	5.1	6.5	46.7	.7	23.4

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[1] 16.0 pct active alkali, 25 pct sulfidity, 4 to 1 water-to-wood ratio, 90 min 80° to 170° C, and 90 min at 170° C.

Table 7.--High screenings kraft pulping[1] of tropical hardwood mixtures

Mixture	Black liquor		Yield		Kappa No.
	NaOH (Na_2O)	Na_2S (Na_2O)	Total	Screenings	
	G/1	G/1	Pct	Pct	
PHILIPPINES					
A	5.1	8.4	52.6	22.6	48.7
B	5.2	9.3	51.1	21.1	47.6
C	4.9	9.1	52.7	24.0	47.3
GHANA					
A	6.1	7.6	50.7	21.0	52.3
B	7.1	7.8	49.6	19.0	54.8
C	6.3	7.6	48.2	17.1	46.3
COLOMBIA					
A	7.7	6.8	54.6	27.6	67.5
B	9.5	7.4	53.6	19.0	56.7
C	8.3	7.2	52.4	21.2	55.3

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[1] 16.0 pct active alkali, 25 pct sulfidity, 4-to-1 water-to-wood ratio, 90 min 80° to 170° C, 15 min at 170° C.

highest yields with an average of 47.7 percent and also the highest kappa numbers with an average of 28.8. The lowest yield pulps came from the Ghanaian mixtures with an average of 44.6 percent, while the lowest kappa number pulps were those from the Colombian mixtures within an average of 23.7. The differences within the mixtures from each resource were even smaller.

High Screenings Pulps

Shown in table 7 are the conditions and results of the digestions made with all nine mixtures. As with the fully cooked pulps, similar results were again obtained with all nine mixtures pulped under exactly the same conditions. However, the relative spread of yield and kappa number increased between the mixtures from the different resources. The pulps made from the Colombian mixtures had the highest total yields, averaging 53.5 percent, and also the highest kappa numbers, averaging 59.9. The lowest total yield pulps came again from the Ghanaian mixtures with an average of 49.5 percent, while the lowest kappa number pulps came from the Philippine mixtures with an average of 47.9. Between and within the mixtures from both the Philippine and Ghanaian hardwoods differences were again very small in both yield and kappa number. However, within the mixtures from Colombian hardwoods, the ranges expanded for yield and kappa number. Colombian A mixture had a yield of 54.6 percent and a kappa number of 67.5, while the Colombian C mixture had a yield of 52.4 percent and a kappa number of 55.3.

NSSC Pulping

The conditions and results of the NSSC digestions made with all nine mixtures to produce 75 percent yield pulps are given in table 8. While the three Philippine and three Ghanaian mixtures all responded similarly under the same pulping conditions, the A and B mixtures of Colombian hardwoods required additional time at cooking temperature to obtain 75 percent yield; furthermore, all three Colombian mixtures consumed more sodium sulfite than either the Philippine or the Ghanaian mixtures.

Handsheet Properties

Fully Cooked Kraft Pulps from Whole Mixtures

Handsheet properties of the fully cooked kraft pulps are given in table 9. The differences in pulp properties between the three mixtures from each of the three resources were surprisingly small. Nevertheless the A and C mixtures from all three resources appeared to have slightly higher bursting and tensile strengths. While it was expected that the B mixtures might have superior tearing resistance because of the thicker walled fibers, this trend was not evident except at lower freeness levels for the pulps made from the Philippine and Ghanaian mixtures.

All nine of the fully cooked kraft pulps were as good as similar pulps made from temperate zone hardwoods, thus indicating that mixed tropical

Table 8.--NSSC pulping[1] of tropical hardwood mixtures.

Mixture	Spent liquor		Yield
	Na_2SO_3	pH	
	G/1		Pct
	PHILIPPINES		
A	18.7	8.7	74.9
B	21.7	8.7	77.1
C	19.8	8.6	76.4
	GHANA		
A	21.9	8.1	72.5
B	24.1	8.0	74.0
C	23.4	8.0	72.3
	COLOMBIA		
A	15.0	8.5	74.0
B	14.6	8.6	[2] 75.2
C	13.8	--	[3] 74.3

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[1] 16 pct Na_2SO_3, 4 pct Na_2CO_3, 15 min steaming at 15 psig, 3.5-to-1 water-to-wood ratio, 120 min 80° to 175° C, and 60 min at 175° C unless otherwise noted.

[2] 120 min at 175° C.

[3] 105 min at 175° C.

Table 9.--Properties of fully cooked kraft pulps made from tropical hardwood mixtures

Mixture	Kappa No.	Handsheet properties				
		Freeness (Canadian Standard)	Burst factor	Tear factor	Breaking length	Apparent density
		Ml			Km	G/cc
		PHILIPPINES				
A	29.6	645	22.9	133.6	5.9	0.51
		550	52.5	136.5	9.3	.59
		350	72.5	131.0	11.8	.67
B	29.1	675	14.7	88.5	4.5	.46
		550	46.0	134.0	8.7	.57
		350	66.5	139.0	10.8	.65
C	27.8	675	21.5	114.8	6.0	.52
		550	57.5	139.0	9.9	.61
		350	73.0	136.0	11.5	.66
		GHANA				
A	26.0	640	25.3	125.1	5.8	.54
		550	50.0	129.5	8.8	.60
		350	82.0	118.5	12.2	.69
B	27.5	690	16.9	115.1	4.6	.49
		550	47.0	148.0	8.2	.53
		350	67.0	138.0	10.3	.60
C	22.0	620	33.8	156.4	6.8	.56
		550	62.0	139.5	9.5	.62
		350	91.0	112.5	12.5	.70
		COLOMBIA				
A	24.5	670	22.0	124.0	5.6	.52
		550	48.5	125.0	8.8	.58
		350	68.0	124.5	11.0	.66
B	23.3	690	14.6	85.6	4.1	.45
		550	55.0	133.0	7.3	.55
		350	61.0	140.5	9.2	.61
C	23.4	675	20.0	113.8	5.1	.51
		550	47.0	143.0	8.4	.58
		350	65.0	140.0	10.4	.64

hardwoods should be suitable for the production of bleached, market grades of pulp.

Fully Cooked Kraft Pulps from Separated Fractions

Given in table 10 are the handsheet properties of the fully cooked kraft pulps made from the air-separated fractions of the whole mixtures. The pulps made from the lighter fractions had 10 to 20 percent higher bursting and tensile strengths compared to the pulps made from the heavier fractions. Thus air separation appears to be one viable means of improving the quality of pulps made from mixed tropical hardwoods.

Screened High-Yield Kraft Pulps

Handsheet properties of the screened high-yield kraft pulps are given in table 11. These pulps, again regardless of source or mixture, had bursting and tensile strengths only slightly less than those of the fully cooked kraft pulps, but had a loss in tearing resistance of about 10 percent.

Pulps for Corrugating Medium

Given in table 12 are the handsheet properties of the NSSC pulps and in table 13 are the handsheet properties of the high-yield kraft screenings. Based on these results it appears that acceptable quality corrugating medium could be made from any of the mixtures of tropical hardwoods cooked by either the NSSC or the kraft processes. Subsequent pilot-scale digestions, and paper machine trials not reported here, confirmed that mixed tropical hardwoods are acceptable for producing corrugating medium with good properties. However, with some of these mediums, there were problems with runnability through the corrugator.

The effects of caustic soda addition to the NSSC pulping liquor and lowering yields of both NSSC and kraft semichemical pulps to obtain improved properties are given in table 14. At the same yield, caustic addition increased the ring crush from 55.4 to 63.8 pounds and the Conçora from 56.8 to 66.0 pounds. Lowering the NSSC pulp yield from 74.0 to 66.1 percent increased the ring crush from 55.4 to 68.6 pounds and the Concora from 56.8 to 75.6 pounds. Thus improved strength properties can be obtained either through the addition of caustic soda to the NSSC pulping liquor or by reducing NSSC pulp yield. Lowering kraft semichemical pulp yield from 72.6 to 58.8 percent increased the ring crush only slightly, from 41.0 to 44.4 pounds, and the Concora from 38.8 to 69.4 pounds.

Based on these results it appears that NSSC pulps are superior to kraft semichemical pulps for corrugating medium from the viewpoint of both yield and properties of the handsheets.

Table 10.--Properties of kraft pulps made from air-separated fractions of tropical hardwood mixtures

Mixture	Kappa No.	Handsheet properties				
		Freeness (Canadian Standard)	Burst factor	Tear factor	Breaking length	Apparent density
		Ml			Km	G/cc
			PHILIPPINES			
A Lights	23.3	645	28.9	125.6	6.3	0.55
		550	63.5	124.5	10.4	.64
		350	86.0	116.0	12.5	.72
A Heavies	24.9	675	21.0	128.6	4.6	.50
		550	57.0	136.0	9.1	.58
		350	71.5	130.0	11.0	.65
B Lights	22.5	660	24.8	128.6	6.0	.54
		550	52.0	126.0	9.4	.63
		350	75.0	120.0	11.4	.68
B Heavies	24.9	680	19.8	80.8	4.8	.48
		550	47.5	131.5	8.3	.58
		350	66.0	137.0	10.2	.64
			GHANA			
A Lights	23.8	625	34.6	151.5	6.6	.57
		550	60.0	140.0	8.8	.62
		350	85.5	118.0	12.8	.70
A Heavies	26.3	660	22.6	136.3	5.3	.51
		550	45.5	143.5	8.4	.56
		350	69.5	139.0	10.5	.63

Table 11.--Properties of screened high yield kraft pulps made from tropical hardwood mixtures

Mixture	Kappa No.	Freeness (Canadian Standard)	Burst factor	Tear factor	Breaking length	Apparent density
		Ml			Km	G/cc
			PHILIPPINES			
A	48.7	700	16.6	82.0	4.2	0.49
		550	49.5	114.0	9.2	.57
		350	68.0	116.5	11.0	.66
B	47.6	710	11.3	65.0	3.6	.46
		550	43.0	124.0	8.7	.56
		350	59.0	129.0	10.3	.61
C	47.3	740	7.6	50.7	2.1	.40
		550	47.0	114.0	8.0	.59
		350	64.0	116.0	9.8	.64
			GHANA			
A	52.3	690	17.2	115.1	4.2	.52
		550	60.0	129.0	9.9	.64
		350	77.0	116.0	12.0	.67
B	54.8	705	13.1	92.1	3.7	.47
		550	48.0	128.0	8.2	.56
		350	64.0	124.0	10.0	.61
C	46.3	675	22.0	124.0	5.6	.52
		550	48.5	125.0	8.8	.58
		350	68.0	124.5	11.0	.66
			COLOMBIA			
A	67.5	725	11.5	65.5	3.7	.47
		550	40.0	88.5	11.3	.59
		350	55.0	103.0	11.0	.62
B	56.7	730	8.5	61.5	2.5	.45
		550	31.0	118.0	6.5	.51
		350	49.0	129.0	8.0	.55
C	55.3	730	12.5	80.5	3.4	.47
		550	45.0	133.0	8.4	.57
		350	61.0	127.5	9.7	.61

Table 12.--Handsheet properties of NSSC pulps made from mixed tropical hardwoods

Mixture	Yield	Freeness (Canadian Standard)	Basis weight	Thickness	Burst factor	Tear factor	Breaking length	Apparent density	Ring crush	Concora
	Pct	Ml	Lb/1,000 ft^2	Mils			M	G/cc	Lb	Lb
					PHILIPPINES					
A	74.9	255	26.4	9.5	29.4	72.0	5,490	0.48	63.8	68.6
B	77.1	250	26.3	10.6	27.9	73.5	5,015	.43	52.6	60.8
C	76.4	265	26.8	10.7	25.2	71.8	5,015	.43	56.8	58.8
					GHANA					
A	72.5	340	27.0	9.9	30.1	70.9	6,260	.47	70.4	63.0
B	74.0	335	26.3	9.7	22.1	64.8	4,870	.47	56.6	57.4
C	72.3	340	26.0	9.2	30.3	81.2	6,695	.49	51.4	66.4
					COLOMBIA					
A	74.0	350	26.0	10.6	21.5	60.6	4,785	.42	55.4	56.8
B	75.2	370	26.2	11.2	19.1	59.7	4,380	.40	50.0	46.6
C	74.3	325	26.3	10.7	20.8	56.6	4,540	.43	57.8	58.4

Table 13.--Handsheet properties of high-yield kraft screenings made from tropical hardwood mixtures

Mixture	Freeness (Canadian Standard)	Basis weight (air-dry basis)	Thickness	Burst factor	Tear factor	Breaking length	Apparent density	Ring crush	Concora
	Ml	Lb/1,000 ft^2	Mils			M	G/cm^3	Lb	Lb
				PHILIPPINES					
A	250	26.4	8.9	40.5	112.4	6,745	0.51	55.0	61.6
B	250	25.5	9.5	34.1	97.4	5,875	.46	47.4	58.8
C	265	26.2	8.5	37.1	101.0	6,395	.53	51.6	62.4
				GHANA					
A	335	26.1	8.5	45.8	123.7	8,040	.53	66.4	60.8
B	355	26.4	9.9	30.7	117.7	6,135	.46	58.0	56.4
C	345	23.9	7.9	57.4	149.1	9,145	.58	73.4	74.2
				COLOMBIA					
A	345	27.2	9.6	37.6	97.0	7,060	.49	66.2	71.2
B	375	26.9	10.2	28.9	71.5	5,580	.46	58.4	59.8
C	360	26.8	8.4	38.6	109.6	6,810	.55	70.8	67.2

Table 14.--Effects of caustic addition to NSSC pulping and lowering yields of NSSC and kraft pulps for corrugating medium from mixed Colombian tropical hardwoods

Pulp yield	Freeness (Canadian Standard)	Basis weight	Thickness	Burst factor	Tear factor	Breaking length	Apparent density	Ring crush	Concora
Pct	Ml	Lb/1,000 ft^2	Mils			M	G/cm^3	Lb	Lb
				NSSC					
74.0	350	26.0	10.6	21.5	60.6	4,785	0.42	55.4	56.8
1/73.2	340	26.5	9.5	29.2	67.4	5,895	.48	63.8	66.0
69.2	345	27.3	9.8	27.2	78.0	5,925	.48	67.0	67.6
66.1	350	28.2	10.1	30.1	70.4	6,140	.48	68.6	75.6
				KRAFT					
72.6	365	26.5	11.7	13.9	42.6	3,325	.39	41.0	38.8
69.0	340	26.3	10.9	16.9	59.5	4,115	.42	44.4	47.0
65.8	350	26.2	10.5	22.6	75.6	5,080	.43	39.6	55.0
58.8	340	25.9	9.6	34.8	111.2	6,795	.47	44.4	69.4

1/ 3 pct NaOH (moisture-free wood basis) in pulping liquor.

CONCLUSIONS

(1) Within the wood specific gravity ranges studied, the differences in both the NSSC and kraft pulpability of all nine mixtures are relatively small.

(2) The strength properties of the fully cooked kraft pulps from all nine mixtures were as good as those made from temperate zone hardwoods. Thus mixed tropical hardwoods, regardless of source, should be suitable for the production of bleached, market-type pulps.

(3) The screened portions of high-yield kraft pulps were nearly as good as fully cooked kraft pulps. The screenings portion was found to be acceptable for corrugating medium. Thus it may be possible to produce both a pulp for linerboard and one for corrugating medium using a single pulping process.

(4) Handsheet properties of both NSSC pulps and kraft semichemical pulps indicate that either process could be used to produce pulps for use in corrugating medium. However, NSSC pulps offer a yield advantage and improved properties.

(5) Improved semichemical pulp properties can be obtained by adding caustic soda to the NSSC pulping liquor or by reducing yields of either NSSC or kraft pulps.

MARKET PULP AND WHITE PAPERS FROM MIXED TROPICAL HARDWOODS

By

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and

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SUMMARY

Market-type, bleached kraft pulps with quality as good or better than commercial North American hardwood kraft market pulps were made from mixtures of tropical hardwoods grown in the Philippines, Ghana, or Colombia. The lowest density, lightest colored species selected from two of these three wood resources produced good-quality thermomechanical pulps suitable for use in a variety of white papers.

Acceptable quality newsprint for local markets was made from: (1) 100 percent Philippine hardwoods consisting of 70 percent thermomechanical pulp and 30 percent bleached hardwood kraft pulp, and (2) 90 percent Philippine hardwoods consisting of 70 percent thermomechanical pulp and 20 percent bleached hardwood kraft pulp, with the remainder being 10 percent long-fibered kraft or sulfite pulp. These results were verified by making similar newsprint from the Ghanaian hardwoods.

Furnishes containing 80 percent bleached Philippine hardwood kraft pulp and 20 percent commercial long-fibered pulp produced acceptable quality tissue and toweling papers. Replacing half the hardwood kraft pulp with thermomechanical pulp caused no significant changes in quality of these papers.

Acceptable quality tablet paper was made from a furnish containing 60 percent Philippine hardwood kraft pulp and 20 percent each of thermomechanical pulp and commercial long-fibered pulp. Increasing the amount of thermomechanical pulp decreased all properties except opacity.

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INTRODUCTION

The demand for pulp and paper continues to grow with the greatest increases projected to occur in the developing countries. Many of these developing countries are in the tropics and have an abundance of hardwood forests which are presently underutilized or misused through highly selective logging of prime timber species. These studies were made in order to assist these developing countries in establishing manufacturing facilities for conversion of their remaining secondary species into exportable bleached market-type kraft pulps and newsprint, tissue and toweling, and tablet papers for either domestic consumption or export. These studies were part of a larger program in which the Forest Products Laboratory, under a contract with the U.S. Agency for International Development, investigated the feasibility of producing a variety of forest products from a wide mix of tropical hardwood species.

EXPERIMENTAL

Wood Resource

Three geographical areas were selected for obtaining the wood resource. These were the Philippines (representing Southeast Asia), Ghana (Africa), and Colombia (Latin America). The method of sampling for each location was essentially the same. From the literature, species with specified values for density, silica content, and extractives were designated as potential samples. Thus mixtures with various density distributions could be simulated, low and high contents of silica and extractives would be available, and a range of color from light to dark would be present. Some freedom of substitution was allowed where local conditions made it difficult to harvest a preferred species. The logs were shipped to Forest Products Laboratory for processing.

Table 1.--Names and specific gravities of 24 Philippine hardwoods used to make mixtures for both kraft and thermomechanical pulping

Common name	Botanical name	Specific gravity[1]
Tangisang-bayauak	Ficus variegata	0.236
Binuang	Octomeles sumatrana	.242
Balilang-uak	Meliosma macrophylla	.260
Kaitana	Zanthoxylum rhetsa	.296
Ilang-ilang	Cananga odorata	.308
Anabiong	Trema orientalis	.319
Hamindang	Macaranga bicolor	.324
Balanti	Homolanthus populneus	.356
Mayapis	Shorea squamata	.366
Malansantol	Sandoricum vidalii	.394
White lauan	Pentacme contorta	.401
Tulo	Alphitonia philippinensis	.422
Tangile	Shorea polysperma	.429
Pahutan	Mangifera altissima	.435
Apanit	Mastixia philippinensis	.447
Lago	Pygeum vulgare	.451
Bagtikan	Parashorea plicata	.478
Sakat	Terminalia nitens	.485
Red lauan	Shorea negroensis	.510
Itangan	Weinmannia luzoniensis	.526
Piling-liitan	Canarium luzonicum	.549
Lomarau	Switonia foxworthyi	.559
Malabetis	Madhuca oblongifolia	.560
Dangkalan	Calophyllum obliquinervium	.568

1/ Dry weight, green volume basis.

Chip Mixtures

Forty-seven species of Philippine hardwoods, 22 species of Ghanaian hardwoods, and 17 species of Colombian hardwoods were used to make chip mixtures for kraft pulping.[1] The chips were made from bark-free logs in a commercial size four-knife chipper. The nominal length of the chips was 5/8 inch, and the fines and oversize were removed prior to blending of the individual species.

Four chip mixtures were made for kraft pulping:

(a) Equal amounts of the 47 Philippine species.[1]
(b) Equal amounts of 24 Philippine species listed in table 1.
(c) Equal amounts of the 22 Ghanaian species.[1]
(d) Equal amounts of the 17 Colombian species.[1]

The mixture of 24 Philippine species was also used for producing thermomechanical pulp. Three special chip mixtures were made of only the lowest density, lightest colored species for producing thermomechanical pulps. One mixture contained three species and another contained five species of Philippine hardwoods. The third mixture contained four species of Ghanaian hardwoods. The names and specific gravities of the species used in these special mixtures are given in table 2.

Kraft Pulping

Based on the results of preliminary small-scale digestions of all the mixtures, the pilot-scale digestions providing pulp for bleaching and subsequent papermaking were all made under the following conditions regardless of wood source:

(1) 16.0 percent active alkali
(2) 25.0 percent sulfidity
(3) 4 to 1 water-to-wood ratio
(4) 90 minutes to raise the temperature to 170° C
(5) 90 minutes at 170° C

At the end of the cooking period the digester was blown, and the resulting pulps were washed with hot water, screened through a 0.012-inch slotted flat screen, and wet lapped prior to bleaching.

1/ The general groups of species are described by J. F. Laundrie in "Kraft and NSSC Pulping of Mixed Tropical Hardwoods."

Table 2.--Names and specific gravities of the hardwoods used to make mixtures for thermomechanical pulping

Common name	Botanical name	Specific gravity[1]
	PHILIPPINE 3-SPECIES MIXTURE	
Rarang	Erythrina subumbrans	0.264
Gubas	Endospermum peltatum	.316
Dita	Alstonia scholaris	.316
	PHILIPPINE 5-SPECIES MIXTURE	
Binuang	Octomeles sumatrana	.242
Kapok	Ceiba pentandra	.244
Balilang-uak	Meliosma macrophylla	.260
Kaitana	Zanthoxylum rhetsa	.296
Ilang-ilang	Cananga odorata	.308
	GHANAIAN 4-SPECIES MIXTURE	
Otu	Cleistopholis patens	.241
Effeu	Hannoa kleineana	.283
African corkwood	Musanga cecropioides	.301
Obeche	Triplochiton scleroxylon	.302

1/ Dry weight, green volume basis.

Bleaching

Kraft pulps made from the two mixtures of Philippine hardwoods and the mixture of Ghanaian hardwoods were semibleached to 75 to 85 percent brightness in a three-stage bleach consisting of chlorination, caustic soda extraction, and hypochlorite. These semibleached pulps were used as part of the furnish in the production of newsprint.

Fully bleached kraft pulps were made from all the mixtures except the Philippine mixture containing 24 species. These pulps were bleached to 88 to 90 percent brightness in a five-stage bleach consisting of chlorination, caustic soda extraction, chlorine dioxide, caustic soda extraction, and chlorine dioxide. These fully bleached pulps were subsequently used as part of the furnish in the production of tablet, tissue, and toweling papers. Quantities of these fully bleached pulps were also dried on the paper machine in order to provide samples of a market-type pulp sheet.

Thermomechanical Pulping

The 3-, 5-, and 24-species mixtures of Philippine hardwoods and the 4-species mixture of Ghanaian hardwoods were converted into thermomechanical pulps at the pilot plant of C. E. Bauer, Springfield, Ohio. These mixtures were given an initial 2-minute steaming at 30 pounds per square inch gage and then fiberized to about 400 Canadian Standard freeness in a 418 pressurized refiner. These high-freeness pulps were returned to the Forest Products Laboratory after the initial fiberizing to allow better control and more flexibility in developing optimum properties of these pulps.

Preliminary atmospheric refining trials made with these high-freeness pulps in a 36-inch-diameter disk mill indicated that it was necessary to lower the freeness to about 125 Canadian Standard freeness to develop optimum properties. Consequently, the larger batches of pulp for the paper machine trials were refined to about this freeness. Because the brightness of all the thermomechanical pulps was too low for newsprint, they were bleached with hydrogen peroxide before being used in the paper machine trials.

Papermaking

Pulps from the Philippine hardwood mixtures were used in a variety of products including newsprint, tissue and toweling, and tablet papers. The conditions used to process the pulps and the quantities of size and filler added were based on previous experience. Thus only a minor study was made of these important variables with these pulps. Newsprint experiments were repeated with pulps made from Ghanaian wood mixtures.

Table 3.--Handsheet properties of unbleached and bleached kraft pulps made from Philippine, Ghanaian, and Colombian hardwood mixtures and commercial market pulps from North American hardwoods

Kraft pulp type	Handsheet properties						Pulp properties	
	Freeness (Canadian Standard)	Beating time	Burst factor	Tear factor	Breaking length	Apparent density	Brightness	Viscosity
	Ml	Min			Km	G/cm^3	Pct	cP
PHILIPPINE MIXTURE--47 SPECIES								
Unbleached	615	0	32.4	116.0	6.8	0.56	--	--
(Kappa No. 22.8)	550	11	47.5	120.5	8.6	.59	--	--
	350	32	72.5	116.0	11.5	.67	--	--
Bleached--CEH	570	0	26.0	117.0	5.1	.60	76.4	8.7
	550	3	34.0	118.0	6.3	.62	--	--
	350	26	64.5	108.0	9.8	.69	--	--
Bleached--CEDED	580	0	27.7	130.4	4.9	.62	88.8	11.6
	550	6	34.0	132.0	5.9	.63	--	--
	350	28	61.5	131.0	9.0	.70	--	--
Bleached--CEDED	575	0	23.7	98.5	4.6	.62	86.2	--
(paper machine	550	6	42.0	113.0	5.7	.63	--	--
dried)	350	33	60.0	120.0	9.1	.70	--	--
PHILIPPINE MIXTURE--24 SPECIES								
Unbleached	605	0	34.5	114.0	7.0	.60	--	--
(Kappa No. 23.7)	550	8	53.5	108.5	9.2	.66	--	--
	350	34	79.0	96.5	11.7	.73	--	--
Bleached--CEH	515	0	41.4	87.5	5.9	.67	85.0	--
	350	23	64.5	70.5	9.0	.64	--	--
COLOMBIAN MIXTURE								
Unbleached	625	0	27.0	122.2	6.3	.57	--	--
(Kappa No. 27.6)	550	10	45.0	117.0	8.5	.61	--	--
	350	25	63.0	108.0	10.4	.67	--	--
Bleached--CEDED	575	0	19.0	109.0	4.2	.58	86.0	10.2
	550	5	28.0	114.0	5.4	.61	--	--
	350	24	53.0	118.0	8.1	.68	--	--
Bleached--CEDED	615	0	13.6	94.2	3.4	.56	--	--
(paper machine	550	12	23.5	123.0	4.9	.60	--	--
dried)	350	32	45.5	113.0	7.5	.67	--	--
GHANAIAN MIXTURE								
Unbleached	640	0	25.3	125.1	5.8	.54	--	--
(Kappa No. 22.8)	550	9	50.0	129.5	8.8	.60	--	--
	350	27	82.0	118.5	12.2	.69	--	--
Bleached--CEH	505	0	40.5	101.7	6.5	.64	76.0	7.3
	350	18	66.5	86.5	9.3	.71	--	--
Bleached--CEDED	565	0	25.0	118.2	4.4	.62	85.0	10.2
	550	3	30.0	122.0	4.8	.63	--	--
	350	19	58.0	121.0	8.5	.71	--	--
Bleached--CEDED	585	0	15.4	100.3	3.4	.58	--	--
(paper machine	550	6	22.0	111.5	4.3	.60	--	--
dried)	350	27	48.0	117.0	7.4	.68	--	--
COMMERCIAL PULPS								
Bleached market pulp	680	0	10.6	99.6	3.0	.55	89.4	11.2
(southern U.S.	550	18	35.5	117.0	6.4	.64	--	--
hardwoods--dried)	350	35	55.0	110.0	8.1	.69	--	--
Bleached market pulp	565	0	12.1	72.1	2.7	.60	88.9	11.2
(eastern Canadian	550	3	14.0	73.0	3.1	.61	--	--
hardwoods--dried)	350	36	37.0	81.0	6.1	.71	--	--

RESULTS

Kraft Pulp Properties

The handsheet properties of the unbleached and bleached kraft pulps are given in table 3. All the unbleached kraft pulps were remarkably similar in properties and were as good or better than kraft pulps made from temperate zone hardwoods. As expected, the semibleached pulps made with a hypochlorite stage and used in the newsprint paper machine trials lost some strength. The fully bleached pulps, on the other hand, retained most of their strength and in some instances actually gained strength, especially in tearing resistance.

The paper machine-dried fully bleached pulps that were made to demonstrate the feasibility of producing market-type pulps all lost some strength during drying. Nevertheless, all of these experimental, market-type pulps, regardless of the wood mixture origin, were as good or better in strength properties than the two commercial market pulps made from either southern U.S. hardwoods or eastern Canadian hardwoods.

Thermomechanical Pulp Properties

The handsheet properties of the bleached thermomechanical pulps made from the Philippine and Ghanaian hardwood mixtures are given in table 4. All these pulps had adequate strength properties for production of the subject papers.

The bursting and tensile strengths of the pulp made from the Philippine 3-species mixture were somewhat lower than those of the 5-species mixture, primarily because of the higher freeness (which however, was lowered for the paper machine runs by additional refining). The only deficiency of the thermomechanical pulp made from the Philippine 24-species mixtures was the brightness, which was only 51 percent compared to 66 and 67 percent for the 3- and 5-species mixtures. However, this pulp had a better scattering coefficient and opacity than the others. This, of course, is partly due to its lower brightness.

The thermomechanical pulp made from the Ghanaian mixture was better in strength properties than any of those made from the Philippine mixtures.

These results demonstrate that thermomechanical pulps with good strength properties can be made from a wide variety of mixtures, and that the number of species and their density range depend mainly on the pulp brightness required for the papers being made.

Newsprint

Results for the various experimental newsprints are presented in table 5. For comparison, properties of commercial newsprint from the Philippines and Canada have been included.

Table 4.--Handsheet properties of bleached thermomechanical pulps made from Philippine and Ghanaian hardwood mixtures

Mixture	Freeness (Canadian Standard)	Burst factor	Tear factor	Breaking length	Apparent density	Brightness	Scattering coefficient	Opacity
	Ml			Km	G/cm^3	Pct		Pct
Philippine 3 species	170	7.0	39.6	2.2	0.42	66.1	655	90.0
Philippine 5 species	105	11.4	32.6	3.0	.45	67.2	673	91.4
Philippine 24 species	115	9.2	27.6	2.3	.42	51.0	690	96.9
Ghanaian 4 species	120	13.7	40.6	3.5	.54	66.8	662	90.8

Table 5.--Properties[1] of nominal 32-pound (52 g/m^2) newsprint from Philippine and Ghanaian hardwoods

Amount of hardwood	Thickness	Bursting strength	Tearing resistance (av.)	Tensile strength (av.)	Opacity	Scattering coefficient	Brightness (Elrepho)	Air resistance (Gurley)	Smoothness (Bekk) (av.)
Pct	Mil	Pts	G	Piw	Pct	Cm^2/g	Pct	$S/100\ cm^3$	Sec
				PHILIPPINES					
[2]80	3.2	9.4	21.6	8.7	87.4	494	58.1	11	19.5
[3]90	3.9	9.2	24.5	8.4	85.0	489	61.9	6	16.3
[4]100	3.6	10.4	19.5	9.7	89.8	487	61.4	11	20.8
[5]90	3.5	11.5	26.8	10.6	91.3	503	46.5	19	25.9
				GHANA					
[3]90	3.1	11.6	26.1	11.3	83.6	507	66.0	35	31.9
				COMMERCIAL PAPER, PHILIPPINE					
--	3.6	7.5	19.9	5.8	96.2	660	45.3	--	--
				COMMERCIAL PAPER, CANADIAN					
--	3.5	6.0	17.7	7.7	91.2	456	54.6	17	28.3

---

[1] Tested according to TAPPI Standard Methods.

[2] Bleached thermomechanical pulp (3 lighter colored woods); remainder long-fiber sulfite pulp.

[3] 70 pct bleached thermomechanical pulp (3 lighter colored woods with the Philippine and 4 with Ghanaian mixture), 20 pct semibleached hardwood kraft, and 10 pct long-fiber sulfite pulp.

[4] 70 pct bleached thermomechanical pulp (3 lighter colored woods) and 30 pct semibleached hardwood kraft.

[5] Same furnish as footnote 3, except 24 of the lower density woods were used for the thermomechanical pulp.

The newsprint papers from the Philippine hardwoods had good strengths, generally in the range of the commercial papers. Acceptable newsprint was made from 100 percent of these hardwoods (70 pct thermomechanical pulp and 30 pct hardwood kraft). While its opacity was not as high as the commercial papers, it was somewhat higher in brightness. In terms of scattering power (scattering coefficient), however, it was as good as the newsprint from Canada. The printing characteristics and smoothness were also in the range of these commercial sheets.

Replacing part of the hardwood kraft with commercial softwood sulfite pulp, which may be needed for high-speed runnability, had little or no effect on sheet properties. This sheet was comparable in strength to the paper made with 80 percent thermomechanical pulp and 20 percent sulfite pulp. The printability and optical properties were better with the higher thermomechanical pulp level. The thermomechanical pulp used in all these runs was made using the three lower density species that were light in color.

Increasing the number of Philippine species to 24 for the thermomechanical pulp still yielded newsprint paper with adequate strength properties. However, the brightness, as expected, was lower than for North American newsprint. This paper was made from a furnish containing 70 percent bleached thermomechanical and 20 percent bleached kraft pulps, both made from the same hardwood mixture, and 10 percent long-fibered kraft pulp. While the brightness might limit its acceptance in a world market, its quality may still be adequate for some local markets. The brightness was as good, for example, as newsprint now produced in the Philippines.

The newsprint results obtained with the Philippine woods were verified with pulps made from Ghanaian wood mixtures. The furnish contained 70 percent bleached thermomechanical pulp, 20 percent bleached hardwood kraft pulp, and 10 percent long-fibered sulfite pulp. This would indicate the general feasibility of tropical hardwoods in other forest regions for newsprint manufacture.

Tissue and Toweling Papers

Results for these experimental papers are presented in table 6. For comparison, tissue and toweling papers were also made on the FPL experimental paper machine using a furnish of 80 percent hardwood bleached kraft pulp and 20 percent of long-fiber kraft pulp, both obtained from North American manufacturers. These pulps had been received in air-dried lap form. The Philippine hardwood kraft pulp used in these experiments consisted of equal parts of never-dried pulp and pulp dried to about 80 percent solids content. In addition to these experimental reference papers, properties of "weigh sheets" taken directly from a commercial paper machine prior to converting are also included in the table.

Table 6.--Properties[1] of sanitary tissues and toweling from Philippine hardwoods

Bleached hardwood kraft[2]	Tensile strength, MD	Stretch, MD	Water absorbency (0.1 cm^3)	Softness--overall
Pct	Piw	Pct	Sec	
		FACIAL TISSUE, 12-POUND (20 g/m^2)		
80	0.42	21.4	46.4	1,184
40	1.03	27.6	65.2	418
		TOILET TISSUE, 14-POUND (23 g/m^2)		
80	1.15	6.0	31.1	420
40	1.66	10.2	49.8	266
		CREPED TOWELING, 30-POUND (49 g/m^2)		
80	8.60	7.9	33.8	26
40	6.40	7.4	18.4	33

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[1] Tested according to TAPPI Standard Methods.

[2] All furnishes contain 20 pct commercial long fiber bleached kraft pulp. The furnishes with 40 pct bleached kraft had 40 pct hardwood (3 of the lighter colored species) bleached thermomechanical pulp.

Table 7.--Properties[1] of 16-pound (60 g/m^2) tablet papers from Philippine hardwoods

Amount of hardwood	Thickness	Bursting strength	Tearing resistance (av.)	Tensile strength (av.)	Air resistance (Gurley)	Opacity	Brightness (Elrepho)	Smoothness (Bekk) (av.)
Pct	Mil	Pts	G	Piw	$S/100\ cm^3$	Pct	Pct	Sec
[2] 80	3.4	22.4	45.0	17.9	11.3	82.8	78.4	22.9
[3] 80	3.4	18.3	39.2	15.2	15.4	82.5	76.7	21.0
[4] 90	3.8	17.9	35.1	15.1	23.8	85.8	75.8	18.0
Commercial U.S.	3.2	23.9	50.9	16.7	13.4	83.6	81.8	42.4

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[1] Tested according to TAPPI Standard Methods.

[2] 60 pct bleached kraft pulp, 20 pct bleached thermomechanical pulp, remainder long-fiber kraft pulp.

[3] 45 pct bleached kraft pulp, 35 pct bleached thermomechanical pulp, remainder long-fiber kraft pulp.

[4] 40 pct bleached kraft pulp, 50 pct bleached thermomechanical pulp, remainder long-fiber kraft pulp.

Facial Tissue

A soft, absorbent facial tissue was made with 80 percent Philippine hardwood kraft pulp. This tissue was somewhat better in these characteristics than the reference tissue made with commercial hardwood kraft pulp, which in turn was better than the "weigh sheets." Its cross machine tensile strength was slightly lower than the experimental reference,but better than that of the "weigh sheets."

Replacing half of the Philippine hardwood kraft pulp with the Philippine hardwood thermomechanical pulp resulted in a less soft and absorbent facial tissue but still softer than the "weigh sheets." It had good strength properties.

These facial tissues were dry-creped at 95 percent solids or above with 0.05 percent of a polyamide resin added to the furnish for better adhesion at the creping dryer.

Toilet Tissue

Good-quality toilet tissues were also made with the Philippine hardwoods. The 80-20 Philippine hardwood kraft and long-fiber sheet had the best softness, and its absorbency was comparable to the experimental reference. While its strength was slightly lower than the experimental reference, it was somewhat stronger than the "weigh sheet." Adding thermomechanical pulp lowered the softness and absorbency, but did not adversely affect the strength. These tissues were wet-creped at about 53 percent solids.

Toweling

The toweling paper made with 80 percent Philippine hardwood kraft pulp had more than adequate strength, but it was not as soft or as absorbent as the experimental control. With less processing, better softness and absorbency undoubtedly could be obtained at a sacrifice of some excess strength. Both these characteristics improved when half of the kraft pulp was replaced with thermomechanical pulp. Increasing the amount of thermomechanical pulp in the furnish from 40 to 60 percent had a slight adverse effect on both softness and absorbency, but not on strength. All of the experimental toweling papers easily met the requirements specified by the Government in Federal Specification UU-T-591d for paper towels.

All furnishes had 0.25 percent wet-strength resin added continuously. The webs were wet-creped at 50 to 60 percent solids.

Tablet Papers

Results for the various tablet papers are presented in table 7. For comparison, properties of a commercial U.S. tablet have been included.

Acceptable tablet paper was made from a furnish consisting of 60 percent Philippine hardwood kraft pulp and 20 percent each of Philippine hardwood thermomechanical pulp and a commercial long-fiber pulp. Except for tear and smoothness, the paper was comparable to a commercial tablet paper used for reference. The tear could perhaps be improved with less refining of the long-fiber pulp or with a slightly higher percentage in the furnish. The experimental tablet papers were not as smooth as the reference, presumably due to the greater degree of recovery from compression generally noted with thermomechanical pulps. The addition of the cationic starch to the furnish had little or no effect on the sheet properties.

Increasing the thermomechanical pulp in the furnish to 35 percent resulted in a reduction in strength properties. When 50 percent thermomechanical pulp was used, a noticeable improvement in opacity resulted. This paper had strengths nearly comparable to the paper with 35 percent thermomechanical pulp.

CONCLUSIONS

(1) Bleached market grades of kraft pulps can be made from mixed tropical hardwoods which are as good or better in strength than commercial North American hardwood market pulps.

(2) The fact that kraft pulps from mixtures of species from the Philippines, Ghana, or Colombia were all nearly the same in quality suggests that mixed tropical hardwoods, regardless of source, are a good raw material for such pulp.

(3) Good-quality thermomechanical pulps can be made from mixtures of the lowest density and lightest colored tropical hardwoods. The range of species can be extended to include higher density, darker colored woods provided high brightness is not required.

(4) Acceptable quality newsprint can be made from 100 percent tropical hardwood pulps for local markets but may require the addition of a small quantity of long-fibered pulp for the world market.

(5) Acceptable-quality sanitary tissue and toweling can be made using 80 to 90 percent tropical hardwood pulps. Thermomechanical pulps can be used in place of part of the kraft pulp with no significant changes in quality.

(6) Acceptable-quality tablet papers can be made with as much as 80 percent tropical hardwood pulp. Part of the tropical hardwood pulp can be made by the thermomechanical pulping process, but this pulp will require bleaching even when using the lightest colored species.

LINERBOARD, CORRUGATING MEDIUM, AND CORRUGATED CONTAINERS FROM MIXTURES OF TROPICAL HARDWOODS

By

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SUMMARY

Corrugated fiberboard containers were successfully made from nominal 42-pound, starch surface-sized linerboard consisting of 50 percent Philippine or Colombian hardwood high-yield kraft pulp and 50 percent western kraft softwood pulp, together with 26-pound corrugating medium made from 100 percent Philippine or Colombian hardwood high-yield kraft screenings.

The screened pulp from high-yield digestions of Philippine hardwoods (Kappa 72.3) had about the same bursting and tensile strengths as the fully cooked pulp (Kappa 26.1), but about 13 percent less tearing resistance. The screened pulp from high-yield digestions of Colombian hardwoods (Kappa 85.0) had about 30 percent less bursting strength and tearing resistance than the fully cooked pulp (Kappa 24.7) and about 20 percent less tensile strength.

Pilot-scale semichemical pulps were made from mixtures of tropical hardwoods by the neutral sulfite, kraft, green liquor, and soda-carbonate processes. These pulps were converted into nominal 26-pound-per-1,000-square-foot corrugating medium and evaluated for resistance to fracturing during corrugating.

Most mediums fractured when fluted at 20 feet per minute with a minimum of sheet tension. Decreasing the neutral sulfite pulp yield from 74 to 65 percent, refining the pulp more to give better bonding, and lowering the paper machine headbox consistency to give a better formed sheet did not improve runnability on the corrugator. Increasing the sulfidity of the kraft pulping liquor from 25 to 50 percent was also found to be ineffective. Surface frictional tests, microscopic examinations, and chemical analysis failed to reveal causes for the poor performance on the corrugator. However, adding oleic acid to the paper machine furnish or passing the medium over polyethylene bars as it was being fed to the corrugator effectively overcame the runnability deficiency of the corrugating mediums.

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INTRODUCTION

A program sponsored by the Agency for International Development involved this study to determine the suitability of using tropical hardwoods for corrugated fiberboard containers. Woods from Colombia, the Philippines, and Ghana were evaluated.

EXPERIMENTAL

Wood Mixtures

Chips from the various tropical hardwoods were made from bark-free wood in a commercial-size, four-knife chipper. The nominal length of the chips was 5/8 inch, with the fines and oversize being removed prior to blending of the individual species. The mixtures are described by Laundrie in another paper in this section.[1]

Philippine

The mixture contained equal amounts (dry-weight basis) of 47 Philippine species.

Colombian

The mixture contained varying amounts of 17 Colombian species.

Ghanaian

Fifteen Ghanaian species were used in the mixture.

Kraft Pulping

Based on the results of preliminary kraft pulping studies, pilot-scale digestions were made with the Philippine and Colombian mixtures producing

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[1] Laundrie, James F. 1978. Kraft and NSSC Pulping of Mixed Tropical Hardwoods.

a fully cooked kraft pulp and a kraft pulp with a high amount of screenings. The fully cooked pulp for linerboard production was made according to the following conditions:

(1) 16.0 percent active alkali.

(2) 25 percent sulfidity.

(3) 4-to-1 water-to-wood ratio.

(4) 90 minutes to raise the temperature to 170° C.

(5) 75 minutes at 170° C.

At the end of the cooking period, the digester was blown, and the resulting pulps were washed, screened through a 0.012-inch slotted flat screen, and wet-lapped.

Pilot-scale digestions were also made to provide both a screened pulp for use in linerboard and screenings for use in corrugating medium. The conditions used were the same as those of the first series except for time at 170° C, which was reduced to only 5 minutes. As with the fully cooked digestions, these digestions were similarly blown, washed, screened, and wet-lapped. The screenings were subsequently fiberized at 18 percent consistency to a Canadian Standard (CS) freeness of about 700 milliliters, and then refined at 12 percent consistency to a freeness of about 350 milliliters, both in a 36-inch-diameter, double-rotating disk mill. The screened pulp made from the Philippine hardwood had a Kappa number of 72.3, while the pulp from the fiberized screenings had a Kappa number of 122. The screened pulp made from the Colombian hardwoods had a Kappa number of 85.0, while the pulp from the fiberized screenings had a Kappa number of 130.

Semichemical Pulping

Again, based on the results of preliminary pulping studies, pilot-scale neutral sulfite semichemical (NSSC) digestions were made to obtain pulp yields of about 75 percent. The following conditions were used:

(1) 16.0 percent sodium sulfite.

(2) 4.0 percent sodium carbonate.

(3) 3.5-to-1 water-to-wood ratio.

(4) 15 minutes' presteaming of the chips at 15 pounds per square inch.

(5) 120 minutes to raise the temperature to 175° C.

(6) 90 minutes at 175° C.

In addition to the NSSC pulps, two mixtures were pulped to produce pilot-scale semichemical pulps for conversion into corrugating medium on the paper machine. These were a mixture of Philippine, Colombian, and Ghanaian hardwoods, pulped using the kraft and green liquor processes, and a Colombian mixture pulped with the soda-carbonate process. The various pulping conditions used are given in table 1.

With few exceptions, the following procedures were used. At the end of cooking, the liquor was blown from the digester and, without washing, the cooked chips were fiberized at about 18 percent consistency in a 36-inch-diameter, double-rotating disk mill to a CS freeness of about 700 milliliters. The fiberized pulps were diluted with hot water to about 2 percent consistency, screened through a 0.012-inch slotted flat screen, wet-lapped, and crumbed before refining at about 12 percent consistency in the same disk mill to a CS freeness of about 350 milliliters.

Papermaking

The screen accepts from the high-yield kraft pulps were converted into nominal 42-pound-per-1,000-square-foot linerboard on an experimental Fourdrinier paper machine. Approximately 2 percent cornstarch was applied using a horizontal size press on the paper machine.

Nominal 26-pound-per-1,000-square-foot corrugating mediums were made on the paper machine from the pulps described (table 1). In most runs the refining and machine conditions were maintained as near constant as possible to determine the effect of pulp yield and pulping process on runnability. In one run (7175) 0.25 percent oleic acid (based on the dry weight of pulp) was added to the pulp furnish in an attempt to change the surface frictional resistance of the medium. This run plus its control (7174) were made using dry broke from previous runs. A series of runs (7169-7173) were made varying headbox consistency and degree of pulp refining.

Converting

Runnability

The corrugating mediums were evaluated for resistance to fracturing on the FPL singlefacer by increasing the speed from 0 to 600 feet per minute with a minimum web tension (approximately 0.5 piw) and then increasing the web tension at a constant web speed of 600 feet per minute.

Bonding

Conventional Stein-Hall starch corrugating adhesive was used to combine the linerboards to the corrugated medium. Pin adhesion tests were conducted to evaluate the bond strength.

Scoring

Each of the combined boards was subjected to three-point roller scoring (wheel clearance, 0.031 in.) after the combined boards were conditioned at 80° F, 30 pct RH; 73° F, 50 pct RH; or 80° F, 90 pct RH. After scoring, each scoreline made perpendicular to the flutes was evaluated

Table 1.--Pilot-scale semichemical pulping of tropical hardwood mixtures for paper machine and corrugating runnability trials

Wood mixture	Digestion Nos.	Chemicals charged[1/] Na_2SO_3	Chemicals charged Na_2CO_3	Chemicals charged NaOH (Na_2O)	Chemicals charged Na_2S (Na_2O)	Liquor-to-wood ratio	Cooking temperature	Time to temperature	Time at temperature	Spent liquor Na_2SO_3	Spent liquor NaOH (Na_2O)	Spent liquor Na_2S (Na_2O)	Spent liquor pH	Kappa Nos.	Estimated yield[2/]	Paper machine run Nos.
		Pct	Pct	Pct	Pct		°C	Min	Min	G/L	G/L	G/L			Pct	
							NEUTRAL SULFITE[3/]									
Colombian	2549 2550	16.0	4.0	—	--	3.5	175	120	90	15.0	--	—	8.5	--	74	7157
Do....	2551 2552	16.0	4.0	3.0	--	3.5	175	120	70	13.1	--	--	9.8	--	74	7158
Do....	2553 2554	18.0	4.5	--	--	3.5	175	120	230	--	--	--	8.7	--	65	7159
Do....	2555	18.0	4.5	—	—	3.5	175	120	230	10.3	--	--	8.7	127	65	7166
Do....	2573 2574	18.0	--	—	5.0	3.5	170	120	30	17.9	--	5.7	10.3	128	65	7183
PGC[4/]	2556- 2567	18.0	4.5	—	--	3.5	175	120	230	10.3	--	--	8.7	132	66	7169- 7175
PGC[4/]	2568	16.0	4.0	—	--	3.5	175	120	90	--	--	--	--	--	74	7179
							KRAFT									
Colombian	4590- 4595	--	--	12.0	4.0	4	168	80	5	—	6.8	7.7	--	[5/]85	57	7168
														[6/]130	65	7160
Do....	4596	--	--	9.0	3.0	4	165	60	5	--	6.0	6.0	--	142	67	7163
Do....	4618 4619	--	--	5.0	5.0	4	170	90	10	--	0	10.7	11.3	132	66	7182
PGC[4/]	4605 4606	--	--	9.0	3.0	4	165	60	5	--	--	—	--	142	67	7176
PGC[4/]	4607 4608	—	—	10.5	3.5	4	170	60	10	--	4.3	7.6	9.9	90	59	7177
							GREEN LIQUOR									
Colombian	4597	--	106	—	21.0	4	165	60	5	—	--	45.0	13.0	99	60	7164
Do ...	4598	--	106	—	21.0	4	165	60	5	—	—	53.0	12.9	98	60	7165
Do....	[3/]4616 4617	--	20.0	2.5	7.5	3.5	170	60	180	--	0	15.7	10.2	113	62	7181
Do....	[3/]4621	--	24.0	3.0	9.0	3.5	170	60	180	--	--	—	--	80	56	7185
PGC[4/]	[3/]4609 4610	--	20.0	2.5	7.5	3.5	170	60	180	--	--	15.0	10.0	96	60	7178
							SODA-CARBONATE									
Colombian	[3/]2576	--	16.0	10.0	--	3.5	170	90	60	—	13.3	--	12.6	152	69	7184

[1/] Moisture free wood basis.
[2/] Based on similar small scale digestions and Kappa number.
[3/] Chips were presteamed for 15 min at 15 lb/in.^{2}g.
[4/] Mixture of Philippine, Ghanaian, and Colombian hardwoods.
[5/] Screened pulp.
[6/] Fiberized screenings.

by bending the material on one side of the scoreline back 90° and then forward 180° and measuring the amount of visual cracking. The scorelines made parallel to the flutes were evaluated by bending forward 180° and backward 90° and then measuring the amount of visual cracking.

Containers

The combined board was roller scored (wheel clearance, 0.052 in.), slotted, and formed into containers using a stapled manufacturer's joint. The containers were 10-3/4 inches long, 8-1/16 inches wide, and either 3-1/4 or 8 inches high. The 8-inch containers had short flaps due to the 12-inch width limitation of the paper machine. The containers were tested in top-to-bottom, side-to-side, and end-to-end compression. The impact resistance of the containers was determined using a container 10-3/4 by 8-1/16 by 3-1/4 inches filled with a 12-pound metal can load. These containers were dropped from various heights on the container edge diagonally opposite the manufacturer's joint. The impact resistance was determined as the height at which half the containers would be expected to fail and half would not. A container was considered failed if any of the load was spilled or if a horizontal scoreline was split its entire length.

RESULTS

Pulp Properties

The handsheet properties of the screened kraft pulps are given in table 2.

The screened pulp from the high-yield Philippine hardwood digestions with a Kappa number of 72.3 had about the same bursting and tensile strengths as the fully cooked pulp (Kappa 26.1) but about 13 percent less tearing resistance.

The screened pulp from the high-yield Colombian hardwood digestions with a Kappa number of 85.0 had about 30 percent less bursting strength and tearing resistance than the fully cooked pulp (Kappa 24.7) and about 20 percent less tensile strength.

Paperboard Properties

Linerboard

The properties of the linerboards are given in table 3. The burst, ring crush, and tensile strength of the nonstarch-sized linerboards were all lower than the softwood control that was made from a commercial southern pine kraft pulp. The tear, fold, and modulus of elasticity were higher than the control. Surface sizing with cornstarch enhanced most of the properties. With linerboard 7144, cornstarch sizing resulted in a burst value of 102, but the weight of this linerboard was 45.0 pounds per 1,000 square feet.

Table 2.--Handsheet properties of screened kraft pulps

Wood mixture	Kappa number	Freeness (Canadian Standard)	Beating time	Burst factor	Tear factor	Breaking length	Apparent density
		Ml	Min			Km	G/cm^3
		FROM FULLY COOKED DIGESTIONS					
Philippine	26.1	600	3	28	120	7.0	0.58
		500	17	46	125	9.2	.65
		400	28	62	118	10.3	.67
		300	37	73	113	10.9	.69
		FROM HIGH-YIELD DIGESTIONS					
Philippine	72.3	600	21	38	108	7.1	.57
		500	33	52	107	8.6	.61
		400	44	63	103	9.6	.64
		300	55	68	98	10.3	.66
		FROM FULLY COOKED DIGESTIONS					
Colombian	24.7	600	3	29	130	6.4	.52
		500	15	47	147	8.4	.56
		400	22	55	159	9.3	.59
		300	28	60	158	9.9	.61
		FROM HIGH-YIELD DIGESTIONS					
Colombian	85.0	600	11	23	106	5.4	.50
		500	26	31	109	6.6	.53
		400	34	38	112	7.5	.54
		300	42	44	112	8.3	.55

Table 3.--Properties of linerboard made from various mixtures of tropical hardwood unbleached kraft and softwood unbleached kraft

Machine run No.	Furnish[1]					Properties																	
	Tropical hardwood unbleached kraft	Softwood unbleached kraft[2]	Disk (D) or conical (C) refiner	Freeness (Canadian Standard)	Surface sized with starch	Weight		Thickness	Density	Bursting strength	Tearing resistance[3]		Folding endurance[3]		Ring crush[3]		Tension[3]						Thickness[4]
						Square meters	1,000 square feet				MD	CD	MD	CD	MD	CD	Maximum stress		Modulus of elasticity		Strain to failure		
																	MD	CD	MD	CD	MD	CD	
	Pct	Pct		Ml	Pct	G	Lb	Mils	G/cm^3	Pct	G	G	Double folds	Double folds	Lb	Lb	Lb/in.^{2}	Lb/in.^{2}	1,000 lb/in.^{2}	1,000 lb/in.^{2}	Pct	Pct	Mils
										CONTROL[5]													
	--	--	D	500	--	205	42.0	12.2	0.66	114	313	328	408	432	152	112	8,420	3,680	864	378	2.2	6.3	11.3
										PHILIPPINE HARDWOODS[6]													
7143	50	50	C	540	--	212	43.6	12.0	.70	78	351	366	2,030	951	115.0	86.0	7,380	3,240	1,018	369	1.3	4.1	10.7
7144	50	50	C	540	2.2	219	45.0	11.7	.74	102	351	355	2,068	997	134.6	108.1	8,830	3,930	1,030	430	1.7	5.4	10.8
										COLOMBIAN HARDWOODS[6]													
7161	50	50	C	520	--	209	43.0	12.4	.67	66	322	370	942	533	113.0	87.5	5,870	3,180	994	407	1.5	3.3	11.2
7162	50	50	C	520	2.1	212	43.6	11.9	.70	88	346	352	1,035	913	134.1	107.9	7,080	3,790	1,288	444	1.7	4.2	11.1

1/ All linerboard furnishes were treated with H_2SO_4 to a pH of 7.0, 1 pct rosin size added, and the pH adjusted to 5 with alum.

2/ Western softwoods refined to approximately 670 ml (Canadian Standard freeness).

3/ MD = machine direction, CD = cross direction.

4/ Thickness measurements made using the procedure described by Setterholm (Tappi, Vol. 57, No. 3, March 1974).

5/ 100 pct southern pine kraft.

6/ Linerboard furnish made from the screen accepts of high-yield cooks from Philippine (Kappa 72.3) or Colombian (Kappa 85.0) hardwoods.

Table 4.--Properties of corrugating medium made from various 100 percent mixtures of tropical hardwoods compared to a U.S. hardwood mixture

Machine run No.	Freeness (Canadian Standard)	Properties[1]																				Concora (CMT)
		Weight		Thickness	Density	Bursting strength	Tearing resistance		Folding endurance		Water absorbency (0.1 cm^3)		Ring crush		Tension							
															Maximum stress		Modulus of elasticity		Strain to failure		Thickness[2]	
		Square meters	1,000 square feet				MD	CD	MD	CD	Wire	Felt	MD	CD	MD	CD	MD	CD	MD	CD		
	Ml	G	Lb	Mils	G/cm^3	Pts	G	G	Double folds	Double folds	Sec	Sec	Lb	Lb	$Lb/in.^2$	$Lb/in.^2$	1,000 $lb/in.^2$	1,000 $lb/in.^2$	Pct	Pct	Mils	Lb
									U.S. HARDWOODS													
[3]6929	410	127	26.0	10.1	0.49	40	70	78	7	8	13	13	62.1	51.0	5,920	3,240	768	374	1.6	2.8	7.0	64.5
									PHILIPPINE HARDWOODS													
[4]7136	240	127	26.0	8.5	.59	41	120	123	191	98	98	94	59.7	46.8	4,920	2,980	566	343	2.2	4.8	7.2	62.8
[3]7137	355	128	26.3	10.0	.50	46	78	93	43	29	16	18	78.6	57.7	5,300	2,710	583	269	1.9	3.5	8.6	81.0
									COLOMBIAN HARDWOODS													
[4]7160	290	122.9	25.2	9.2	.52	33	108	110	57	36	--	--	62.9	47.8	4,380	2,550	620	310	1.6	3.7	8.1	53.0
[3]7157	350	126.9	26.0	9.5	.52	42	92	106	34	35	--	--	72.4	56.4	5,170	2,890	650	315	2.1	3.3	8.2	67.1

[1] All tests according to TAPPI standard methods except as indicated. MD = machine direction; CD = cross direction.
[2] Thickness measurements made using the procedure described by Setterholm (Tappi, Vol. 57, No. 3, March 1974).
[3] Neutral sulfite semichemical.
[4] Kraft screenings.

Corrugating Medium

The properties of the nominal 26-pound-per-1,000-square-foot corrugating mediums are given in table 4. The results indicate that mediums made from 100 percent NSSC tropical hardwood pulps can be satisfactory in terms of strength properties, but these same mediums could not be run on the singlefacer without severe cracking at 20 feet per minute and minimum tension. Thus, they could not be converted into corrugated fiberboard containers.

The medium made from the screening rejects from the high-yield kraft cook of Philippine hardwoods had lower cross machine ring crush than the control (U.S. mixed hardwoods), 46.8 versus 51.0, and comparable Concora (CMT) values, 62.8 versus 64.5. This medium was successfully run on the corrugator at 600 feet per minute and minimum tension and only had slight cracking at 1.8 pounds per lineal inch of web tension. Thus this medium (7136) was combined with each linerboard: One made from the screen accepts from the same high-yield pulp (7143) and the other also made from this same pulp with 2.2 percent cornstarch applied to its surface (7144).

The medium (7160) made from the screening rejects from the high-yield kraft cook of Colombian hardwoods had lower CMT and ring crush than the U.S. NSSC medium (6929) and ran without fracturing on the corrugator at 400 feet per minute at 1.0 pound per lineal inch of web tension. This medium was similarly combined with each linerboard: One made from the screen accepts from the high-yield pulp (7161) and the other also made from this same high-yield pulp surface sized with 2.1 percent cornstarch (7162).

Because of the problems with runnability of the mediums made from typical NSSC pulp, a series of different cooking conditions and pulp processes were evaluated as previously mentioned and detailed in table 1.

Most of these experimental corrugating mediums had reasonable properties, but only a few could be corrugated at a reasonable speed without fracturing. Again those made with NSSC fractured at less than 20 feet per minute. This was noted with both the Colombian mixture and the mixture from the three countries (Philippines, Ghana, and Colombia). Decreasing pulp yield from 74 to 65 percent, refining the pulp more for better bonding, lowering the headbox consistency to give a better formed medium, or adding 25 percent hardwood kraft pulp did not improve the runnability. However, the NSSC mediums did run successfully either when oleic acid was added to the pulp furnish or when polyethylene was applied to the medium during corrugating.

For the polyethylene application, two polyethylene bars were mounted on the corrugator, such that each side of the medium was in continuous contact with one of them. A minute quantity of the bar material was transferred to the medium, altering the frictional resistance between the medium and the corrugating rolls.

Table 5.--Physical properties of the combined board made from high-yield tropical hardwood kraft[1]

Machine run No.[2]	Starch	Basis weight	Burst[3]		Pin adhesion[3]				Flat crush[3]		Short column compression[3]						Flexural stiffness[3][4]				Scoreline cracking[5] (scores parallel to flutes)		
			Value	CV	Single face side		Double back side		Value	CV	80° F, 30 pct RH		73° F, 50 pct RH		80° F, 90 pct RH		Parallel to length		Perpendicular to length		80° F, 30 pct RH	73° F, 50 pct RH	75° F, 90 pct RH
					Value	CV	Value	CV			Value	CV	Value	CV	Value	CV	Value	CV	Value	CV			
	Pct	Lb/1,000 ft^2	Pts	Pct	Lb/in.	Pct	Lb/in.	Pct	Lb/in.^{2}	Pct	Lb/in.	Pct	Lb/in.	Pct	Lb/in.	Pct	Lb/in.	Pct	Lb/in.	Pct	Pct	Pct	Pct
CONTROL[6]																							
	0	130.0	257	7.7	3.76	8.8	6.90	7.4	27.4	5.7	--	--	63.7	2.2	30.9	4.2	109.0	3.0	230	8.6	19.7	3.1	0
PHILIPPINE																							
7143-7136-7143	0	129.4	196	9.0	5.03	8.6	6.70	4.5	28.0	3.9	60.3	3.0	54.8	3.0	25.4	4.4	105.5	4.0	272	16.5	63.1	27.6	1.9
7144-7136-7144	2.2	131.6	246	8.7	3.46	6.5	5.50	9.8	28.5	4.2	71.8	4.3	64.0	3.0	27.6	3.4	116.9	2.2	285.6	15.7	47.2	18.7	0
COLOMBIAN																							
7161-7160-7161	0	126.6	135	5.7	4.99	20.6	6.09	18.5	20.7	2.3	53.5	7.05	48.5	4.45	22.2	5.6	117.2	4.3	202	6.83	22.7	0	0
7162-7160-7162	2.1	129.9	171	8.6	5.35	17.4	5.75	13.4	21.3	2.6	61.2	5.4	54.0	3.6	29.5	3.7	134.3	5.7	233	8.4	44.7	4.6	0

[1] All conditioning and testing done at 73° F, 50 pct RH unless otherwise noted.
[2] Full description of machine run numbers given in tables 3 and 4.
[3] CV = coefficient of variation.
[4] 4-point bending; flutes parallel and perpendicular to specimen length.
[5] Score wheel clearance was 0.031 in. for scoring tests. For scoring the boxes, the clearance was 0.052 in. (There was no scoreline cracking of the boxes.)
[6] Southern pine facings and U.S. hardwood medium.

The medium made with the screening rejects from the mixed Colombian hardwood high-yield kraft pulp was successfully corrugated as was the medium made with the screen accepts from this same pulp. However, when a kraft semichemical pulp from mixed Colombian hardwoods was cooked to the same Kappa number as the screening rejects, the resultant medium could not be corrugated at 20 feet per minute without fracturing. Employing the same pulping conditions with the mixture from the three countries, the medium ran at less than 400 feet per minute. Increasing the sulfidity from 25 to 50 percent had no effect on the medium's ability to run on the corrugator. The polyethylene bars also improved the runnability of one of the kraft mediums which previously did not run (7163).

The mediums made with the green liquor pulps containing the Colombian mixture did not corrugate when the amount of alkali in pulping was comparable to that used commercially with this type semichemical pulp. When the effective alkali in the green liquor cook was increased to the level of that used in the kraft semichemical cooks, the medium had improved runnability characteristics. With the wood mixture from the three countries and the lower alkali level in the green liquor cook, the medium had good runnability characteristics (7178).

The only soda carbonate medium made could not be corrugated at 20 feet per minute without fracturing.

The physical properties of the mediums gave no indication for the differences in runnability noted with the various experimental mediums. Thus, selected mediums with both good and poor running characteristics were analyzed microscopically, chemically, and for surface frictional resistance. Again no relationship was indicated. Microscopic examinations included surface appearance as well as formation differences as shown with transparent microscopy. Ash, silica, extractives, and elemental determinations were made. Except for ash, only small quantities of a given chemical component were present. Two surface friction tests were tried, with neither indicating causes for the large differences noted in runnability.

Combined Board

Results of the evaluation of the combined boards are given in table 5.

None of the material conditioned at 30, 50, or 90 percent relative humidity exhibited scoreline cracking when scored and folded perpendicular to the flutes. For the scores made parallel to the flutes, the experimental materials were more susceptible to cracking than the softwood control; however, increasing the moisture content or the score wheel clearance significantly reduced the cracking.

The starch-treated material made from the Philippine hardwoods cracked less than the untreated material. This was the reverse of what might be expected based on the stiffness of the two materials, but it was in line with the machine direction strain-to-failure values. The starch-treated

Table 6.--Properties of containers[1] made from high-yield tropical hardwood kraft[2]

Machine run No.[3]	Starch	Top-to-bottom compression[4]								Side-to-side compression[4] (3-1/4 in. high)				End-to-end compression[4] (3-1/4 in. high)				Impact resistance[5]
		8 in. high				3-1/4 in. high												
		Load	CV	Deformation	CV	Load	CV	Deformation	CV	Load	CV	Deformation	CV	Load	CV	Deformation	CV	
	Pct	Lb	Pct	In.	Pct	Lb	Pct	In.	Pct	Lb	Pct	In.	Pct	Lb	Pct	In.	Pct	In.
									CONTROL[6]									
	0	917 483	8.5 29.1	0.82 .50	7.0 0.0	676	6.1	0.45	16.3	412	8.7	0.34	36.7	283	5.8	0.26	15.4	81
									PHILIPPINE									
7143-7136-7143	0	687 512	2.7 23.1	.28 .50	34.4 0.0	635	4.6	.53	20.0	336	5.2	.32	9.0	259	3.2	.33	11.4	98
7144-7136-7144	2.2	835 620	7.0 19.7	.81 .50	19.2 0.0	720	6.4	.54	7.4	[7]423	7.5	.38	9.3	[7]311	4.1	.36	19.3	94
									COLOMBIAN									
7161-7160-7161	0	570 502	7.4 11.1	.57 .50	4.1 0.0	478	4.6	.43	4.1	332	11.8	.40	29.3	218	6.4	.32	25.8	77
7162-7160-7162	2.1	703 540	8.4 17.1	.68 .50	16.7 0.0	560	6.0	.45	6.4	373	11.8	.36	21.9	252	10.7	.31	21.7	94

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[1] Containers were 10-3/4 in. long by 8-1/16 in. wide by height indicated. Results are the average of 10 tests except as noted.

[2] All conditioning and testing done at 73° F, 50 pct relative humidity.

[3] Full description of machine run numbers given in tables 3 and 4.

[4] CV = coefficient of variation.

[5] Tested with single drop of container with 12-lb can load.

[6] Southern pine facings and U.S. hardwood medium.

[7] Average of 5 tests.

material made from the Colombian hardwoods cracked more than the untreated material. This was in line with what might be expected based on the stiffness of the two materials but not the machine direction strain-to-failure values. No cracking was encountered in the scoring of the combined board when the score wheel clearance was 0.052 inch and the atmospheric conditions were 73° F, 50 pct RH.

As expected, from the properties of the linerboard made from the Philippine hardwoods, the burst of the combined board was below 200 for the material made with high-yield pulp and not surface sized. However, the combined board with the starch surface-sized facings exceeded the minimum burst requirement. The flat-crush values were comparable to the U.S. hardwood NSSC control material. The increased edgewise compressive strength, as measured by the short column tests of the starch-treated material, was expected, and the effect of moisture content on edgewise compressive strength was also in line with previous work.

As expected from the properties of the linerboard made from the Colombian hardwoods, the burst of the combined board was well below 200 for the material made with high-yield pulp and not surface sized. Nor did the combined board with the starch surface-sized facings meet the minimum burst requirement. The flat-crush values and the edgewise compressive strength were low. The effect of moisture content on edgewise compressive strength was in line with previous work.

Containers

The compressive and impact properties of the containers are given in table 6.

The compressive strength of the containers made from the starch-treated Philippine hardwood material was comparable to the softwood control; however, the corrugated fiberboard made with untreated linerboards was lower in compressive strength. Both the treated and untreated containers were better in impact resistance than the control.

The compressive strength of the containers made from both the starch-treated and untreated Colombian hardwood material was equal or lower than the control. Only the starch-treated containers were better in impact resistance than the control.

CONCLUSIONS

1. Corrugating mediums with good quality, as measured by the usual paperboard tests made on this product, can be made from mixed tropical hardwood semichemical pulps using the neutral sulfite, kraft, green liquor, or soda-carbonate pulping processes; but a severe problem exists in running these mediums through the corrugator--one that can apparently be overcome by the addition of a lubricant.

2. Corrugating medium made from high-yield kraft screenings can be successfully fluted and combined with linerboard made from a mixture of 50 percent screened tropical hardwood high-yield kraft pulp and 50 percent western softwood unbleached kraft pulp.

3. Corrugated fiberboard containers can be made from nominal 42-pound, starch surface-sized linerboard consisting of 50 percent screened tropical hardwood high-yield kraft pulp and 50 percent western kraft softwood pulp, and 26-pound corrugating medium made from 100 percent tropical hardwood high-yield kraft screenings.

HARDBOARDS FROM MIXED TROPICAL HARDWOODS

By

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SUMMARY

Hardwood mixtures from Colombia, Ghana, and the Philippines were found suitable for the manufacture of hardboard. Low energy was required to fiberize the chips into hardboard fiber. High-density hardboards made from these tropical wood mixtures by both the dry- and wet-formed processes met the Voluntary Product Standard for standard hardboard, except for some dry-formed hardboards with 2 percent resin.

Dry-formed, medium-density hardboard made with urea resin had strength properties adequate for furniture core stock. Medium-density hardboard made with phenol-resorcinol resin had strength and accelerated aging properties suitable for exterior siding. All hardboards had excellent surface characteristics, which are desirable for finishing.

The feasibility of storing mixed tropical hardwood chips for long periods, with minimal impact on quality of hardboards made from the chips, was also established.

INTRODUCTION

In an effort to expand the resource base for fiber used in hardboard and to establish new local industries in developing countries, a study was made to determine the suitability of using mixed tropical hardwoods. Fiber for hardboard was obtained from Colombia, Ghana, and the Philippine Islands. This study was part of a large program on the utilization of tropical hardwoods that was sponsored by the Agency for International Development.

EXPERIMENTAL

Wood Mixtures

Seventeen species of Colombian hardwoods, 22 species of Ghanaian hardwoods, and 50 species of Philippine hardwoods (described by Laundrie (2) in his tables 1-3) were used to make the pulps for hardboard. The chips were made from bark-free wood in a commercial size, four-knife chipper. The nominal length of the chips was 5/8 inch, and the fines and oversize material were removed prior to blending of individual species to obtain the mixtures (described by Laundrie (2), table 4). The weighted average specific gravity of the Colombian mixture was 0.667, and that of the Ghanaian mixture was 0.470. Weighted average specific gravities of the three Philippine mixtures were 0.505 for mixture A, 0.643 for B, and 0.538 for C.

Chip Storage

Chips from Philippine mixture C were stored for 9 months in an insulated box constructed of 8-1/2-inch-thick walls of polystyrene foam, with an interior volume of 3.9 cubic feet (inside dimensions 22-1/2 by 13-1/2 by 22 in.). The box was fitted with air inlet and outlet manifolds and was fed with water-saturated air at ambient temperature at a measured rate.

Pulp Preparation

Chips were converted into hardboard quality pulp using (1) a small batch-type Asplund Defibrator at FPL,[1/] (2) a Bauer 418 pressurized refiner in the pilot plant of C. E. Bauer, Springfield, Ohio,[1/] and (3) a small batch-type pressurized refiner at FPL.

Asplund pulps with yields of 88 to 90 percent were made from each of the three Philippine chip mixtures. The chips were given an initial 3-minute steaming at 175 pounds per square inch, followed by a 3.5- to 4-minute fiberizing in the mill at 125 pounds per square inch. In addition, 80 to 82 percent yield pulp was also made from (1) Philippine mixture B, (2) oversize and undersize screenings from Philippine mixture B, and (3) 50-50 blend of screenings and chips from Philippine mixture B. These pulps were prepared at 13.5 to 14 minutes of steaming at 175 pounds per square inch followed by 2 minutes of fiberizing at 125 pounds per square inch.

Bauer-refined pulp was made from the Colombian mixture, Ghanaian mixture, and Philippine mixtures A and B. All chip mixtures were subjected to 3.5 minutes of steaming at 85 pounds per square inch. The amount of energy used in producing the pulps was 6.1 horsepower-days per air-dry ton for the Colombian mixture, 5.7 horsepower-days per air-dry ton for the Ghanaian mixture, and 2.1 to 2.9 horsepower-days per air-dry ton for the Philippine mixtures.

The small batch-type pressurized refiner at FPL was used to convert Philippine mixture C chips, before and after 9 months' storage, into hardboard-quality pulp. The chips were given an initial 20-minute steaming at 85 pounds per square inch in the digester tube before entering the refiner. The laboratory pressurized refiner was not equipped for power determinations.

Boardmaking

Dry-formed, 1/8-inch, high-density hardboards were made at FPL. The pulps were first air dried and then sprayed with either 2 or 4 percent resin by weight, based on the pulp, while tumbling in a rotating drum. The resin was a phenol-formaldehyde type commonly used for dry-formed hardboard. Mats 14 by 14 inches were formed on a "banjo-type" former, cold pressed, and then hot pressed between platens at a temperature of 375° F for 6 minutes.

[1/] Mention of trade names is solely to identify material and equipment used and does not imply endorsement by the U.S. Department of Agriculture.

Wet-formed, 1/8-inch, high-density hardboards were also made at FPL. The pulp in a water slurry was treated with 1 percent phenol-formaldehyde resin of a type commonly used for wet-formed hardboards and 0.75 percent wax size. Eight-inch-diameter mats were formed in the Asplund Drainage Tester, cold pressed, and then hot pressed at a platen temperature of 375° F for 6 minutes.

Dry-formed, medium-density hardboards, approximately 32 by 34 inches, were made in the pilot plant of Miller-Hofft, Richmond, Va. The fiber, after flash drying, was treated with 1 percent wax size and 8 percent urea-melamine resin or phenol-resorcinol resin. The mats were pressed in a high-frequency press and the boards shipped to FPL for evaluation.

All of the high-density hardboards and the medium-density hardboards made with phenol-resorcinol resin were given a further heat treatment by exposing them for 1 hour in a circulating-air oven at 320° F.

Test Methods

Evaluations were made on test specimens preconditioned 30 days at 50 percent relative humidity and 73° F using test procedures generally specified in ASTM Standard D 1037-72a (1). The only exception was that dimensional movement was determined on 1/2- by 6-inch specimens preconditioned for 30 days at 50 percent relative humidity, followed by exposure to the following conditions: (1) 90 percent relative humidity and 80° F for 30 days, (2) immersion in water for 30 days, and (3) drying in an oven at 220° F for 72 hours. Length, thickness, and weight changes were determined before and after exposure to each condition.

Chip weight loss after aging was calculated from the ovendry weight of the chips before and after aging.

RESULTS

High-Density Hardboards

Dry-Formed

With one exception, dry-formed hardboards made from the Colombian, Ghanaian, and Philippine mixtures met the requirements of Voluntary Product Standard PS 58-73 (4) for those properties evaluated (table 1). The exception was for hardboards made from the Colombian mixture using 2 percent phenolic resin, where all strength properties were below the standard. However, these boards did have excellent linear stability.

With the Ghanaian mixture and 2 percent phenolic resin, the dry-formed hardboards just met the minimum requirements for modulus of rupture and tensile strength, with the internal bond strength well above the minimum. Linear stability likewise was good. Philippine mixtures A and B, with 2 percent phenolic resin, had strength properties much higher than required.

Table 1.--Properties[1] of 1/8-inch-thick, high-density hardboards

Source	Chip mixture	Resin content	Static bending[2]		Internal bond strength	Tensile strength	Dimensional movement from 50 pct RH to--			
							90 pct RH		Water soak	
			Modulus of rupture	Modulus of elasticity			Length	Thickness	Length	Thickness
		Pct	$Lb/in.^2$	$1,000 lb/in.^2$	$Lb/in.^2$	$Lb/in.^2$	Pct	Pct	Pct	Pct
					DRY FORMED					
Colombia		2	3,080	340	100	1,810	0.13	12.2	0.08	32.6
Do....		4	7,020	610	200	3,850	.07	6.9	.07	18.4
Ghana		2	5,100	590	190	2,660	.11	10.9	.12	31.6
Do.....		4	8,080	720	300	4,320	.08	6.9	.09	17.6
Philippine	A	2	7,560	700	210	4,270	.08	9.1	.08	24.1
Do....	A	4	8,990	760	300	5,810	.09	7.8	.06	19.3
Do....	B	2	7,200	660	200	4,350	.08	9.1	.10	26.0
Do....	B	4	7,890	670	220	4,620	.07	9.3	.06	22.6
					WET FORMED					
Colombia		1	8,110	590	430	--	.08	8.8	.28	34.7
Ghana		1	8,380	600	350	--	.13	9.3	.36	36.7
Philippine	A	1	6,620	540	120	--	.17	12.6	.44	41.9
Do....	B	1	5,720	470	100	--	.18	13.9	.48	46.9
Voluntary Product Standard PS 58-73		--	5,000	--	100	2,500	--	--	--	--

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[1] Strength properties determined according to ASTM Standard D 1037-72a.

[2] Values adjusted to density of 60 lb/ft^3.

With all the tropical wood mixtures, increasing the phenolic resin content to 4 percent yielded strength properties much higher than required. Linear movement between 50 and 90 percent relative humidity was minimal, and thickness movement was slight.

Based on these results, to make dry-formed hardboards which meet the requirements of U.S. Voluntary Product Standard PS 58-73 for basic hardboard, 2 percent or less resin would be needed when using the Ghanaian or Philippine mixtures, and about 3 percent resin when using the Colombian mixture.

Wet-Formed

Good-quality wet-formed boards were made with 1 percent resin addition (table 1). Boards made from all the tropical wood mixtures exceeded the requirements of the Product Standard for those properties evaluated. Linear and thickness movements were very good for all sets of boards. Obviously, something less than 1 percent resin would be required with these mixtures to produce satisfactory wet-formed hardboards.

Medium-Density Hardboards

Medium-density hardboards of good quality were made from Colombian, Ghanaian, and Philippine mixtures (table 2). The 3/4-inch-thick boards bonded with urea-melamine resin had good surface and edge characteristics and good linear stability--desirable properties for furniture. While they did not possess as high strength and stiffness as commercial boards (3) now used by the furniture industry in the United States, these properties are of secondary importance for many furniture applications. If more strength is needed, this can undoubtedly be achieved by increasing in board density or by adding more resin binder.

These experimental boards had much better linear stability than the commercial boards. A portion of the linear movement differences could be attributed to the differences in humidity exposures. Thickness swelling was also very good for all chip mixtures. Both linear and thickness stabilities are very important properties for furniture use.

In an attempt to provide better durability, melamine resin was added to the urea adhesive system at levels of 6, 15, and 35 percent. The results of strength tests before and after water soaking showed that these melamine levels had only a negligible effect on dry or wet board properties and properties after aging.

The 7/16-inch boards with a density of 48 pounds per cubic foot and bonded with a phenol-resorcinol adhesive were investigated as a potential product for exterior siding. With one exception, the boards retained 50 percent or more of their initial strength after water soaking and accelerated aging. The exception was internal bond strength, with only a 25 percent strength retention after accelerated aging. Boards made from all chip mixtures were nearly equal in strength properties, with very little dimensional movement. Boards made from all chip mixtures

Table 2.--Properties[1] of dry-formed, medium-density hardboards

Source	Chip mixture	Condition at test	Static bending[2] Modulus of rupture	Static bending[2] Modulus of elasticity	Internal bond strength	Tensile strength	Dimensional movement from 50 pct RH to-- 90 pct RH Length	Dimensional movement from 50 pct RH to-- 90 pct RH Thickness	Dimensional movement from 50 pct RH to-- Water soak Length	Dimensional movement from 50 pct RH to-- Water soak Thickness
			Lb/in.^{2}	1,000 lb/in.^{2}	Lb/in.^{2}	Lb/in.^{2}	Pct	Pct	Pct	Pct
			3/4 IN. THICK, 42-LB/FT^3 DENSITY[3]							
Colombia		Dry	3,340	380	140	2,560	0.15	6.7	0.21	30.8
Do....		Wet	2,140	200	--	--	--	--	--	--
Ghana		Dry	3,870	420	130	2,770	.15	6.7	.21	27.9
Do....		Wet	2,230	200	--	--	--	--	--	--
Philippine	A	Dry	3,910	408	120	2,650	.20	7.3	.30	25.0
Do....	B	...do....	3,580	420	100	2,300	.16	7.5	.31	26.0
			7/16 IN. THICK, 48-LB/FT^3 DENSITY[4]							
Colombia		...do....	3,570	420	160	2,640	.11	7.4	.14	14.9
Do....		Wet	2,550	250	--	2,270	--	--	--	--
Do....		Aged	2,080	210	40	1,610	--	--	--	--
Ghana		Dry	4,530	490	240	3,250	.11	6.1	.16	12.9
Do....		Wet	3,100	280	--	2,650	--	--	--	--
Do....		Aged	2,860	270	60	2,180	--	--	--	--
Philippine	A	Dry	4,730	480	150	2,710	.14	5.7	.17	11.6
Do....		Wet	3,430	290	--	2,160	--	--	--	--
Do....		Aged	2,540	180	40	--	.21	4.5	.29	9.6
Do....	B	Dry	4,170	440	220	2,830	.13	5.9	.20	11.2
Do....		Wet	3,070	270	--	2,210	--	--	--	--
Do....		Aged	2,540	190	80	--	.22	4.7	.28	8.9

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[1] Strength properties determined according to ASTM Standard D 1037-72a.

[2] Values adjusted to either 42- or 48-lb/ft^3 density (except for aged specimens).

[3] Boards contain 8 pct urea resin, which was fortified with 6 pct melamine.

[4] Boards contain 8 pct phenol-resorcinol resin.

should be suitable for siding, because of their good strength retention after water soaking and accelerated aging and minimal dimensional movement.

Pulp Preparation

The amount of power used to prepare pulps from the Colombian and Ghanaian mixtures was comparable to that required to pulp domestic hardwoods, but greater than the power required for the Philippine hardwood mixtures. These differences may be due to differences in plate gap settings. A closer setting was used for the Colombian and Ghanaian mixtures than for the Philippine mixtures.

Pulp Yield

There was some apprehension that the higher specific gravity species in the Philippine mixtures would reduce hardboard strengths. One means of obtaining higher strengths might be to lower the pulp yield. But reducing the pulp yield from about 90 to 80 percent gave no clear advantage. The boards made with the lower yield pulp exhibited not only more linear movement, but they were not as strong. On the positive side, thickness swelling might have been improved.

Utilization of Chip Screenings

Hardboard was also considered a possible outlet for the screenings from the chipping operation. Hardboard made from 100 percent screenings (mixture of both oversize and undersize material) was somewhat lower in bending and tensile strengths than hardboard produced from the screened chip mixture (Philippine B). Blending screening rejects with an equal amount of chips, by weight, from the same species mixture improved strength, but not enough to meet the requirements for standard hardboard specified in the Product Standard. With a greater percentage of regular chips or a 90-percent-yield pulp instead of 80 percent, it may be possible to produce acceptable boards with screenings.

Long-Term Chip Storage and Hardboards Made from Stored Chips

Wood chips deteriorate to different degrees under long-term storage conditions. A sample of Philippine mixture C, along with a temperate hardwood (aspen) control, were pulped and made into 1/8-inch high-density hardboard after 9 months' storage.

Biological activity was apparently less in the tropical hardwood mixture than in the aspen. During storage the tropical hardwood mixture reached a maximum temperature of 92° F and had a 9.4 percent weight loss. In contrast, the aspen chips reached a maximum temperature of 113° F and had a 22.4 percent weight loss. The tropical hardwood chip mixture was not as fresh and green initially as the aspen chips, which might have influenced biological activity.

Table 3.--Properties of 1/8-inch-thick, high-density, dry-formed hardboards

Chip mixture	Static bending			Internal bond maximum stress	Tensile strength maximum stress	Dimensional movement from 50 pct RH to--			
						90 pct RH		30-day water soak	
	Density	Modulus of rupture	Modulus of elasticity			Length	Thickness	Length	Thickness
	Lb/ft^3	Lb/in.^{2}	1,000 lb/in.^{2}	Lb/in.^{2}	Lb/in.^{2}	Pct	Pct	Pct	Pct
Fresh Philippine "C"	61.1	7,390	730	510	5,470	0.10	7.86	0.09	22.60
Aged Philippine "C"	65.5	8,650	860	530	4,910	.15	7.30	.19	18.60
Fresh aspen	64.4	7,620	715	380	5,380	.26	5.52	.35	16.38
Aged aspen	64.3	6,170	675	210	3,330	.38	3.64	.58	9.61

Hardboards from the aged tropical hardwood chip mixture were stronger in static bending and internal bond, but lower in tensile strength, than boards made from fresh tropical hardwood chips (table 3). Hardboards made from the aged chips had greater linear movement, but less thickness swelling with changes in moisture. In comparison, high-density hardboards made from aged aspen chips were generally weaker and moved more in the linear direction than hardboards made from fresh aspen chips (table 3).

CONCLUSIONS

(1) The Colombian, Ghanaian, and Philippine hardwood mixtures can be easily converted into good-quality, pressurized refined pulp, consuming less energy than required for most U.S. species.

(2) The tropical hardwood mixtures evaluated can be used with minimal effect on hardboard quality.

(3) Good-quality, high-density hardboards can be made by either the dry- or wet-forming process.

(4) Medium-density hardboards from the mixed tropical woods, when bonded with conventional urea resin binders, are suitable for furniture; when bonded with phenol-resorcinol, they are sufficiently durable for exterior application.

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PROPERTIES OF PARTICLEBOARDS FROM MIXTURES OF PHILIPPINE HARDWOODS

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PROPERTIES OF PARTICLEBOARDS FROM MIXTURES OF PHILIPPINE HARDWOODS

By

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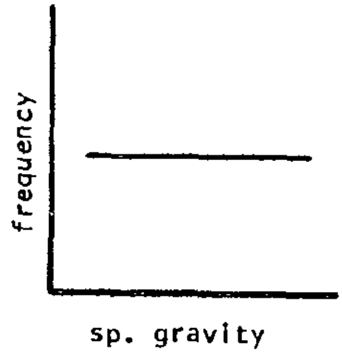
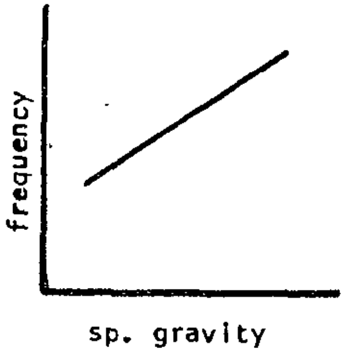
INTRODUCTION

Three bark free chip mixtures--A, B, and C--each comprised of different proportions of 50 Philippine hardwood species and representing three potential naturally occurring density distributions were hammermilled to produce furnishes for the manufacture of laboratory particleboards. The chips were nominal 5/8 inch (16 mm) in length and were produced in an industrial-size chipper. Particleboards also were manufactured from a furnish of planer shavings with a species composition of chip mixture C and from furnishes of steamed and unsteamed ring-flaked chips of mixture A. The average specific gravities (ovendry weight and green volume basis) were 0.50, 0.70, and 0.52 for chip mixtures A, B, and C respectively. Their frequency distributions are shown below.



A



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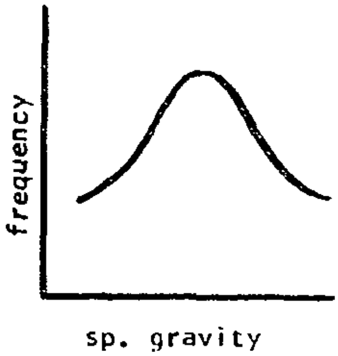

C

Hammermilling was chosen as the primary method of chip breakdown because of its relative simplicity and economic attractiveness. Ring flakes and planer shavings were included to determine to what extent, if any, they improved board properties over hammermilling. Mixture A was chosen for ring flaking because of its low average specific gravity (0.50), but Mixture C (0.52) also could have been used. Mixture C was chosen for the planer shavings because it contained the highest proportion of species in the density range of commercial sawlog species, the commercial source of planer shavings.

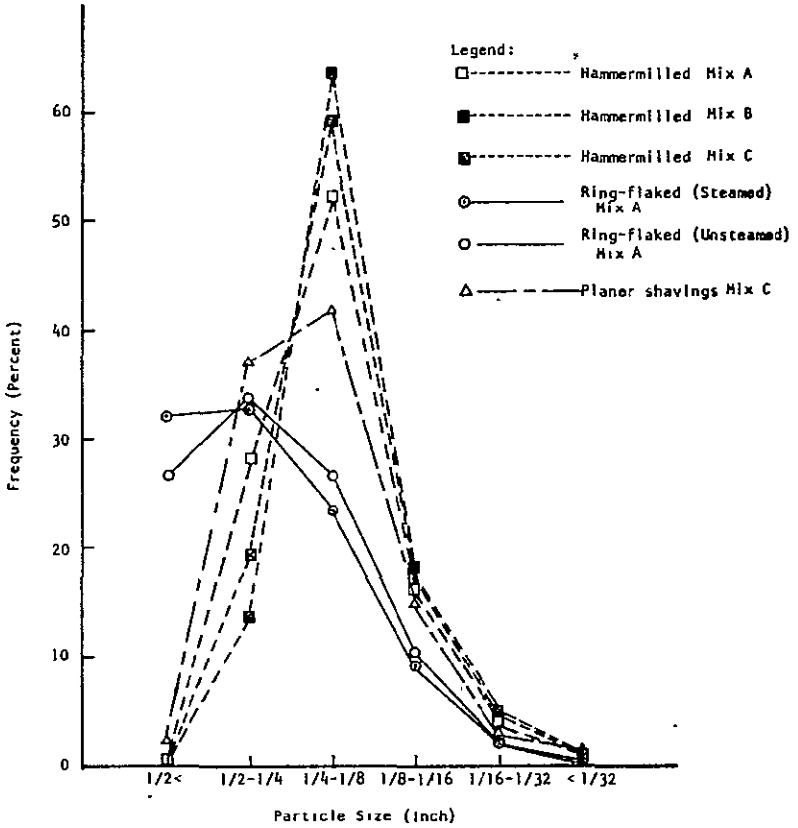

Figure 1.--Distribution of particle size for the various furnishes as determined by sieve analysis. The values on the χ axis are the diameters, in inches, of the circular holes in a William's chip screen.

PREPARATION OF PARTICLE FURNISHES

The furnishes from hammermilled chips were prepared by milling green chips in a 10-in. (25.4 cm) hammermill. The green particles were air dried and screened and all material passing a 1/32-in. (0.79 mm) screen[1/] was rejected as fines[2/] and that retained on the 1/4-in. (6.35 mm) screen was rejected as being too coarse. There was very little difference in the amount of usable material obtained from the three chip mixtures.

Planer shavings were produced on an 8-in. (20.3 cm) jointer-planer from green blocks of the 50 Philippine species. After air drying, the shavings were mixed together in proper proportions to obtain a species mixture identical to chip mixture C. The mixture was then hammermilled (no screen) to break up the large curled shavings and screened to remove fines. The average thickness of the planer shavings was 0.020 in. (0.51 mm) and ranged from 0.005 in. (0.13 mm) to 0.047 in. (1.19 mm).

Green flakes from both steamed and unsteamed chips of chip mixture A were produced in a Pallmann PZ6 ring flaker. The chips were steamed in a fiber drum, and after the internal drum temperature had stabilized at 101° C, steaming was continued for another 50 minutes. The hot chips were fed immediately into the PZ6 flaker. After flaking, both furnishes were air dried and then screened to remove fines. The average thickness of flakes from steamed chips was 0.018 in. (0.46 mm) and ranged from 0.004 in. (0.10 mm) to 0.037 in. (0.94 mm). Flakes from unsteamed chips averaged 0.015 in. (0.38 mm) in thickness and ranged from 0.004 in. (0.10 mm) to 0.034 in. (0.86 mm).

Sieve analyses of the six furnishes after they had been screened to remove fines are shown in figure 1. Of the three hammermilled furnishes, chip mixture B, which had the highest average specific gravity, produced the least amount of large material and the greatest amount in the middle range. All three had approximately the same amount of small material. Steaming the chips prior to ring flaking resulted in a somewhat higher percentage of large material (that retained on the 1/2-in. (12.7 mm) screen) but less in the middle and lower ranges. The furnish of planer shavings did not contain the large particles characteristic of the ring flaked furnishes, but its average size was greater than that of the hammermilled chips.

[1/] The diameter of the circular holes in the William's chip screen.

[2/] In this report, fines are defined as all material passing a screen with 1/32-in. (0.79 mm) diameter circular holes.

EXPERIMENTAL DESIGN AND PROCEDURE

The following experimental design and manufacturing conditions were employed.

I. Seven particle furnishes:

1. Chip mixture A - hammermilled chips - urea resin
2. Chip mixture B - hammermilled chips - urea resin
3. Chip mixture C - hammermilled chips - urea resin
4. Chip mixture A - hammermilled chips - phenolic resin
5. Chip mixture A - ring flaked chips - urea resin
6. Chip mixture A - presteamed ring flaked chips - urea resin
7. Planer shavings with composition of chip mixture C - urea resin

II. Two board densities (nominal): 42 pcf (673 kg/m^3) and 48 pcf (769 kg/m^3) based on ovendry weight and volume at 50% RH.

III. Two resin contents: 5% and 8% solids based on the ovendry weight of wood in the panels.

IV. Replications: Two (56 boards manufactured)

V. Board size: 18 in. (45.7 cm) square x 1/2 in. (12.7 mm) thick

VI. Board construction: Homogeneous

VII. Resin types: Borden Chemical's WW-17 GN liquid area formaldehyde and PB-65 liquid phenol formaldehyde.

VIII. Wax size: 0.5% solids (Hercules' Paracol 404N wax emulsion)

IX. Press temperature: 320° F (160° C) and 375° F (191° C) for urea and phenolic bonded boards respectively.

X. Press time: 7.5 and 9.0 minutes for urea and phenolic bonded boards respectively.

XI. Time to 1/2-in. (12.7 mm) stops: 1.2 to 2.2 minutes depending on board density and type of furnish.

The resins and wax size were applied to the particles in a rotating drum-type laboratory blender, post blended for 5 minutes, and then hand felted into 18-in. (45.7 cm) square mats. The mats were then pre-pressed and hot pressed. After pressing the urea bonded boards were cooled immediately whereas the phenolic boards were hot stacked for 24 hours to insure complete cure of the resin. Four 2.5-in. (6.4 cm) x 14-in. (35.6 cm) static bending samples and two 1.75-in. (4.4 cm) x 14-in. (35.6 cm) linear expansion (LE) samples were cut from each panel. All samples were equilibrated at a 72° F (22° C) and 50% relative humidity (RH) control condition prior to testing. Board densities were determined by ovendrying the LE samples after testing.

For the urea-bonded boards, all four static bending samples were used to determine modulus of elasticity (MOE) and modulus of rupture (MOR) at the 50% RH control condition. Internal bond strengths (IB) were determined from two 2-in. (5.1 cm) square specimens cut from one-half of the static bending samples after they had been tested. The remaining half of each static bending sample was cut into one 2-1/2-in. x 5-in. (6.4 cm x 12.7 cm) water soak sample from which percent water absorption and thickness swelling were determined after water soaking for 24 hours at 72° F (22° C).

For the phenolic-bonded boards, two of the four static bending samples from each board were tested at the control condition, and the remaining two were subjected to the ASTM accelerated aging test.[3/] After aging, the samples were re-equilibrated at the control condition and tested in static bending. MOR and MOE were calculated based on the original thickness. Internal bond strengths of both the control and aged samples were obtained in the same manner as for the urea boards.

Percent linear and thickness swelling at 72° F (22° C) from equilibrium at 50% RH to equilibrium at 90% RH and back to equilibrium at 50% (50% to 90% to 50% RH) were obtained from the LE samples.

RESULTS

The experimental results for the 12 urea bonded board types (treatments) are shown in figures 2 through 7 and table 1. Significant differences between board types at the 95% confidence level were determined by both Scheffé's[4/] test and the less conservative Q[5/] method. Throughout this paper, statements concerning significant differences are based on Scheffé's S-method unless otherwise indicated.

The static bending properties adjusted to 45 pcf (721 kg/m^3) density are shown in figures 2 and 3. It is evident from the data that the ring-flaked furnishes produced boards with superior MOR's and MOE's, and that steaming the chips prior to flaking had no significant effect on these properties. For the boards from hammermilled chips, there were no significant differences in either MOR or MOE between boards from chip mixtures A, B, or C at either resin level. Although the MOR of the chip mixture B boards was lower than those from mixtures A and C, it was significantly different only by the Q method. The high average specific gravity of chip mixture B (0.70) and corresponding lower densification during board manufacture would account for the reduced MOR of boards from mixture B. The boards from planer shavings of chip mixture C had static bending properties intermediate to the boards from the ring flaked and

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[3/] ASTM D 1037-72a. Standard methods of evaluating the properties of wood-base fiber and particle panel materials.

[4/] H. Scheffé. 1967. The Analysis of Variance, John Wiley and Sons, Inc., New York, 68-72.

[5/] G. W. Snedecor and W. G. Cochran. 1967. Statistical Methods, The Iowa State University Press, Ames, Iowa, 272-274.

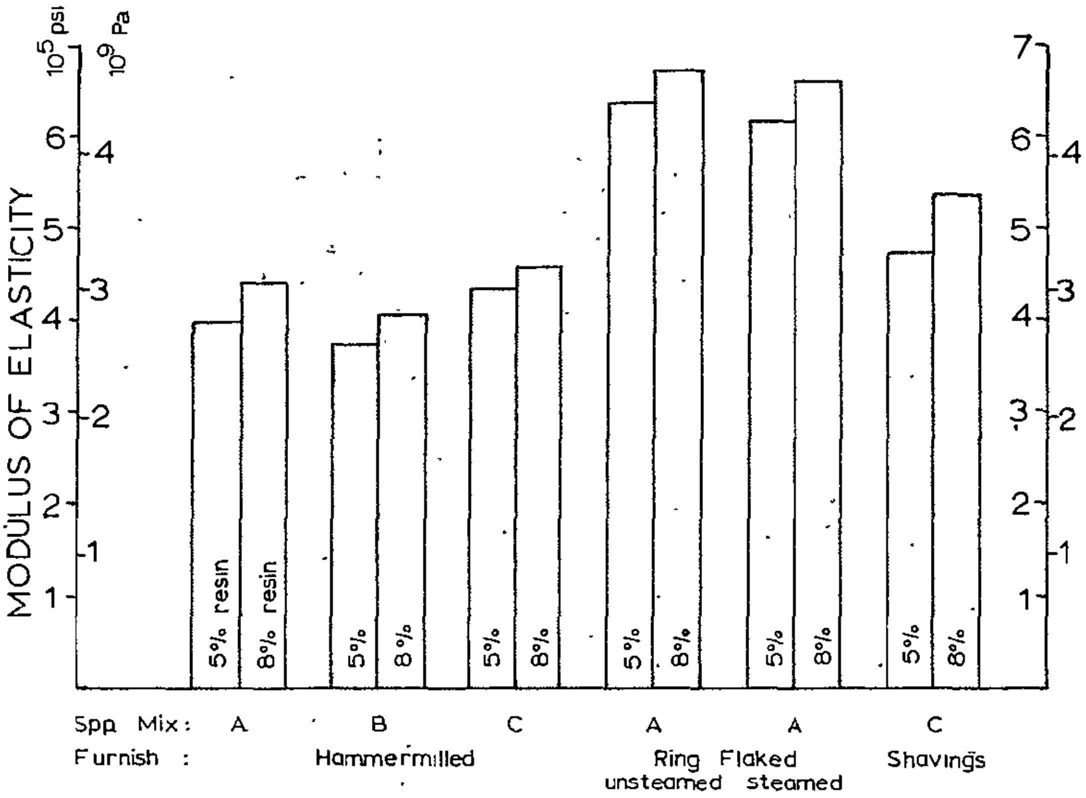

Figure 2.--Predicted mean values for modulus of elasticity of 45 pcf (721 kg/m^3) urea-bonded particleboards from Philippine species.

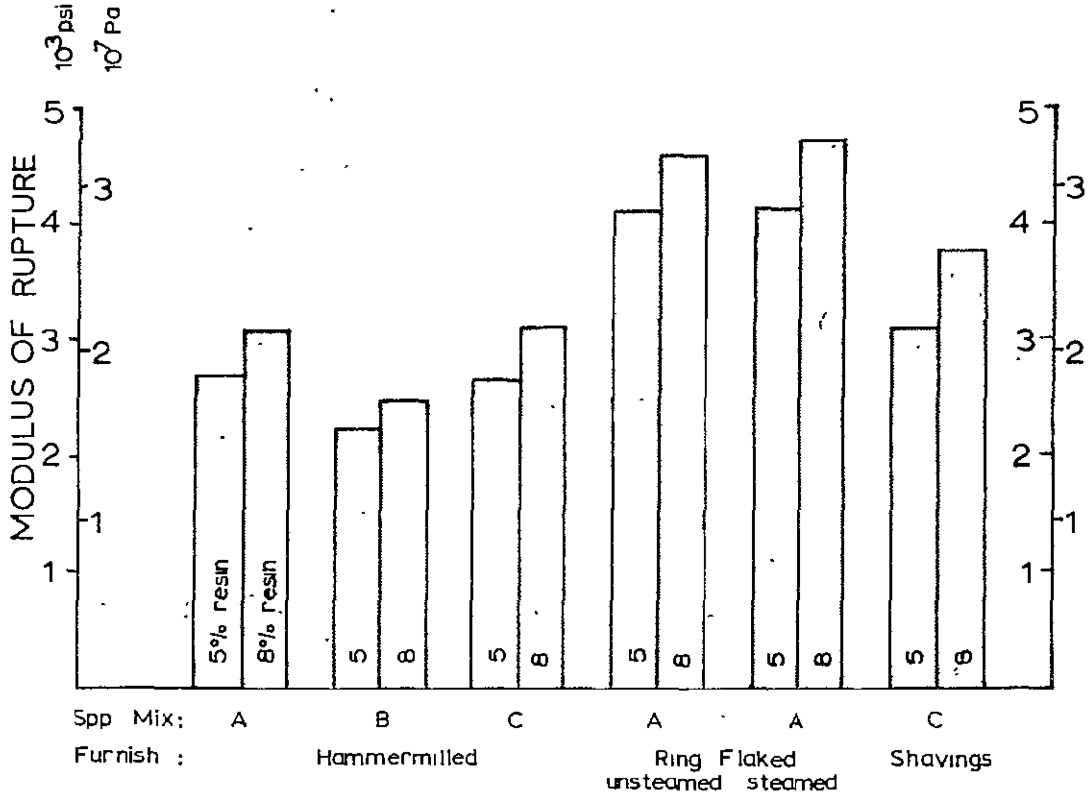

Figure 3.--Predicted mean values for modulus of rupture of 45 pcf (721 kg/m^3) urea-bonded particleboards from Philippine species.

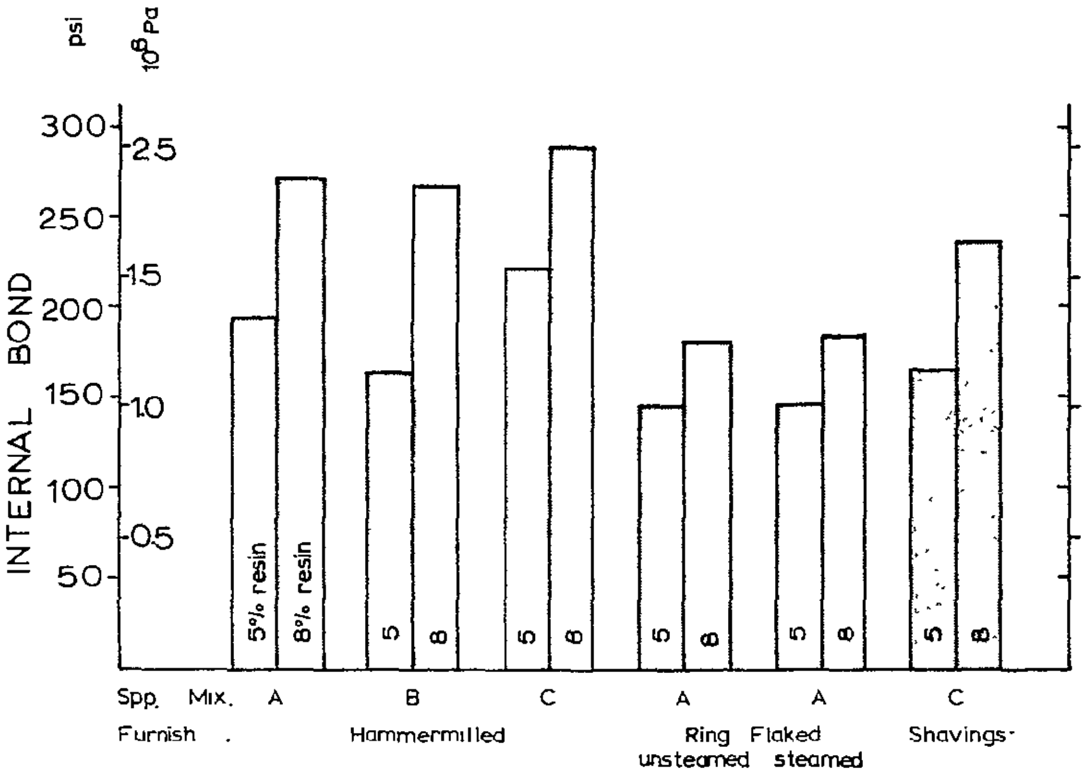

Figure 4.--Predicted mean values for internal bond strengths of 45 pcf (721 kg/m^3) urea-bonded particleboards from Philippine species.

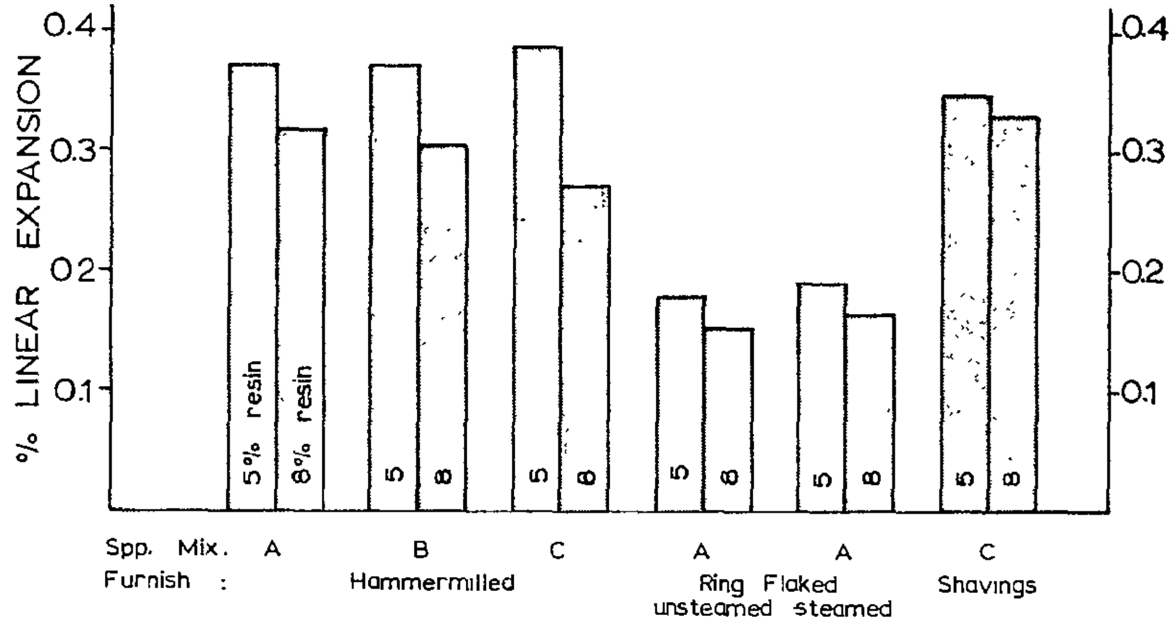

Figure 5.--Predicted mean values for linear expansion (50% to 90% to 50% RH) of 45 pcf (721 kg/m^3) urea-bonded particleboards from Philippine species.

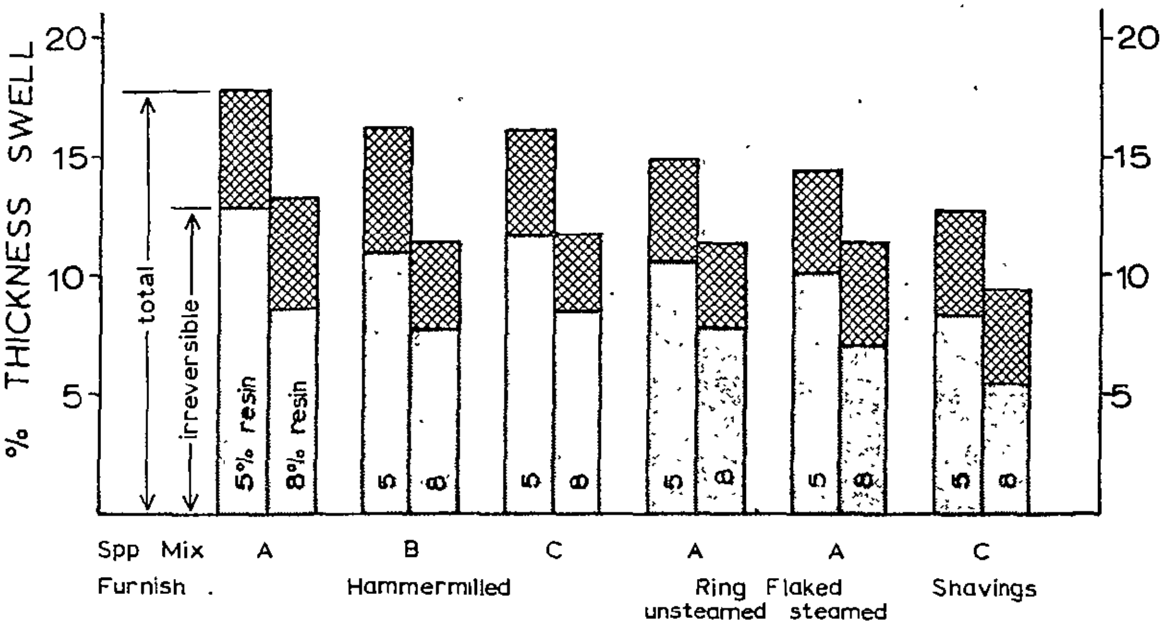

Figure 6.--Predicted mean values for total and irreversible thickness swellings (50% to 90% to 50% RH) of 45 pcf (721 kg/m^3 urea-bonded particleboards from Philippine species.

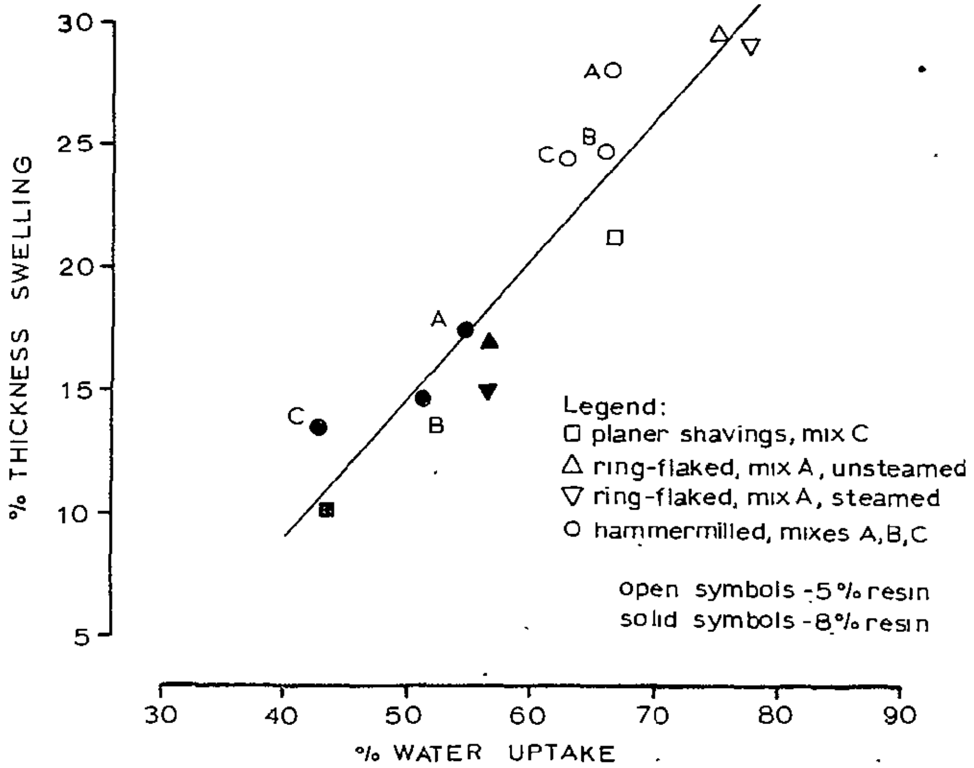

Figure 7.--Percent water uptake and thickness swelling from a 24-hour water soak at 22° C.

hammermilled furnishes. For all six furnish types, both MOR and MOE were improved by increasing both urea resin content and board density.[6]

Internal bond strengths (IB) of the urea bonded boards adjusted to 45 pcf are illustrated in figure 4. Generally speaking, the IB's were all quite high but not unusual for homogeneous laboratory particleboards. The boards from hammermilled chips showed a greater overall strength than those from ring-flaked chips and planer shavings. This presumably was due to a more uniform density in the boards from hammermilled chips which is a typical effect of smaller particles. The IB of the board from hammermilled chips of mixture B at 5% resin was significantly lower than the IB of the mixture C board but not different from mixture A. However there were no significant differences at the 8% resin level. There was no significant difference between the boards from steamed and unsteamed ring-flaked chips at either resin level. The planer shavings boards had somewhat higher IB values than those from ring-flaked chips which probably was due to the former's smaller average particle size. An increase in resin content resulted in a significant increase in the IB of the boards from the three hammermilled furnishes and planer shavings but not in the boards from the ring-flaked chips. IB also increased with an increase in board density.[6]

The LE's of the urea bonded boards adjusted to 45 pcf are shown in figure 5. The superiority of the ring-flaked furnishes in producing panels with excellent linear dimensional stability is quite evident. The relatively short, chunky particles of the hammermilled furnishes probably accounted for their greater LE. The boards from planer shavings exhibited LE's intermediate to the boards from ring-flaked and hammermilled chips. The LE of all board types decreased with an increase in urea resin content, but the effect was statistically significant only for the boards from the hammermilled mixture C furnishes. Board density had a negligible effect on LE.[6]

Total and irreversible thickness swellings of urea bonded boards (50% to 90% to 50% RH) are in figure 6. Irreversible thickness swelling of all six board types was reduced significantly by an increase in resin content, and this in turn was reflected in the total thickness swellings of the boards. The boards from planer shavings exhibited the least total and irreversible thickness swelling and the boards from hammermilled chips the greatest at either resin level. However it is evident from figure 6 and table 1 that the differences among board types at a given resin level were not large. As was the case with linear expansion, there was not a consistent relationship between board density and total and irreversible thickness swellings which is not unusual for either laboratory or commercial particleboards.

The percent water uptake and total thickness swelling of the urea boards at 45 pcf after a 24 hour water soak are in figure 7. Thickness swelling was a linear function of water uptake, and water uptake and

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[6] Not illustrated in figures or tables.

Table 1 Predicted mean values of strength and dimensional stability properties of urea bonded particleboards from Philippine species at 45 pcf (721 kg/m^3).

Chip Mixture	Particle Type	Resin Content (%)	Modulus of Elasticity (1000 psi)	Modulus of Elasticity (MPa)	Modulus of Rupture (psi)	Modulus of Rupture (MPa)	Internal Bond (psi)	Internal Bond (MPa)	Linear Expansion1/ (%)	Total Thickness Swelling1/ (%)	Irreversible Thickness Swelling1/ (%)	Water Uptake (%)2/	Thickness Swelling2/ (%)
A	hammermilled	5	398	2740	2700	18.6	192	1.32	0.37	17.9	12.9	66.2	28.1
A	hammermilled	8	440	3030	3090	21.3	270	1.86	0.31	13.1	8.7	54.6	17.5
B	hammermilled	5	371	2560	2210	15.2	161	1.11	0.37	16.1	10.9	65.7	24.8
B	hammermilled	8	402	2770	2440	16.8	267	1.84	0.30	11.1	7.8	51.2	14.8
C	hammermilled	5	430	2960	2640	18.2	221	1.52	0.38	16.0	11.6	62.8	24.5
C	hammermilled	8	456	3140	3110	21.4	290	2.00	0.27	11.8	8.5	42.9	13.5
A	ring flaked	5	634	4370	4080	28.1	145	1.00	0.18	14.8	10.7	75.1	29.5
A	ring flaked	8	670	4620	4590	31.6	180	1.24	0.15	11.1	7.9	56.7	17.1
A	ring flaked3/	5	614	4230	4100	28.3	146	1.01	0.19	14.2	10.1	77.3	29.1
A	ring flaked3/	8	656	4520	4700	32.4	186	1.28	0.16	11.1	7.1	56.7	15.1
C	shavings	5	470	3240	3090	21.3	164	1.13	0.35	12.6	8.3	66.3	21.4
C	shavings	8	533	3680	3780	26.1	235	1.62	0.33	9.1	5.5	43.6	10.1

1/ From equilibrium at 50% RH to equilibrium at 90% RH

2/ From a 24 hour water soak at 22°C.

3/ Chips steamed prior to flaking.

swelling were greatest at the 5% resin level. The general trend at both resin levels was that the boards from ring-flaked chips had the greatest water uptake and swelling and the planer shavings boards the least. For the boards from hammermilled chips, chip mixture C resulted in the least amount of swelling. It is interesting to note that the planer shavings boards, which exhibited the least amount of swelling, had the same species composition as chip mixture C. The greater absorption and swelling at 5% resin content would be expected since less bonding existed to hold the matrix together. The greater water absorption and greater swelling by boards from ring-flaked chips would be due to the larger internal voids in those boards because of their larger particle size and corresponding less uniform density. Whether or not the above relationships would hold if the boards were soaked for longer periods of time is not known.

The strength properties of the phenolic-bonded boards from hammermilled chips of mixture A at 45 pcf (721 kg/m^3) density before and after ASTM accelerated aging are in table 2 and figure 8. As was the case with the urea-bonded boards from the same furnish, MOR, MOE, and IB all increased with an increase in resin content and panel density.[6] MOR and MOE were reduced no more than 50% by accelerated aging at both resin levels, but IB was reduced an average of 75%. An increase in resin content somewhat decreased the percent reduction in MOR and IB by aging but had no effect on MOE. For some unapparent reason the three strength properties at 5% phenolic resin content were considerably less than those of the urea boards at 5% resin, but were nearly the same at the 8% level. Both thickness swelling and LE were less for the phenolic-bonded boards.

Linear thickness swellings (50% to 90% to 50% RH) and irreversible thickness swelling after accelerated aging of the phenolic-bonded boards are in figure 9 and table 2. Both LE and thickness swelling were reduced by increasing resin content from 5% to 8%. The reduction in thickness swelling for the 50% to 90% RH test condition was due to a reduction in the irreversible component. When compared to the urea-bonded boards from the same hammermilled furnish (fig. 6), the thickness swellings were approximately the same, but the LE of the phenolic-bonded boards was considerably less at both resin levels (fig. 5). Also the effect of the 8% resin level in reducing LE was greater for the phenolic resin. Why these differences occurred between the two resin types is not known.

When the 12 urea boards in this study, with properties adjusted to 45 pcf (721 kg/m^3), were compared to the interior type 1B2 board of Commercial Standard CS 236-66,[7] all boards except the board at 5% resin content from hammermilled chips of mixture B (the high specific gravity mixture) met or exceeded the 2,400 psi (16.5 MPa) MOR and the 400,000 psi (2,760 MPa) MOE minimum requirements. All boards greatly exceeded the 60 psi (0.41 MPa) minimum IB requirement. Only the boards from the ring-flaked furnishes had LE's less than the 0.30% maximum allowable. The other boards all exceeded 0.30% except for the 8% resin board from hammermilled chips of

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[7] Commercial Standard CS 236-66, mat-formed wood particleboard. U.S. Dept. of Commerce.

Table 2. Predicted mean values for properties of 45 pcf (721 kg/m^3) phenolic bonded particleboards from hammermilled chip mixture A Philippine species.

Resin Content (%)	MOE (MPa [1000 psi])		MOR (MPa [psi])		IB (MPa [psi])		50% RH to 90% RH			Irrev. Thick. Swell After Aging
	Control	After Accel. Aging	Control	After Accel. Aging	Control	After Accel. Aging	LE (%)	Total Thick. Swell (%)	Irrev. Thick. Swell (%)	
5	2290 [332]	1340 [194]	15.4 [2230]	7.6 [1110]	0.95 [138]	0.21 [30.6]	0.25	16.6	10.8	52.5
8	3100 [449]	1830 [266]	22.6 [3280]	12.6 [1850]	1.73 [251]	0.57 [83.2]	0.19	12.1	7.0	26.2

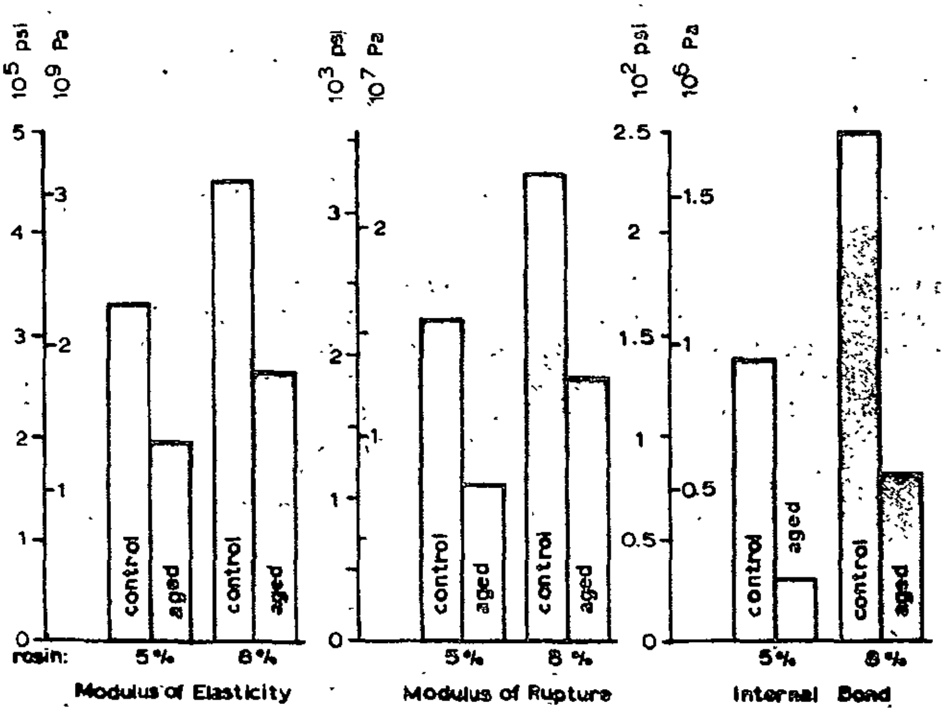

Figure 8.--Predicted mean values for modulus of elasticity, modulus of rupture, and internal bond of control and ASTM accelerated aged samples of 45 pcf (721 kg/m^3) phenolic-bonded particleboards from hammermilled chip mixture A Philippine species.

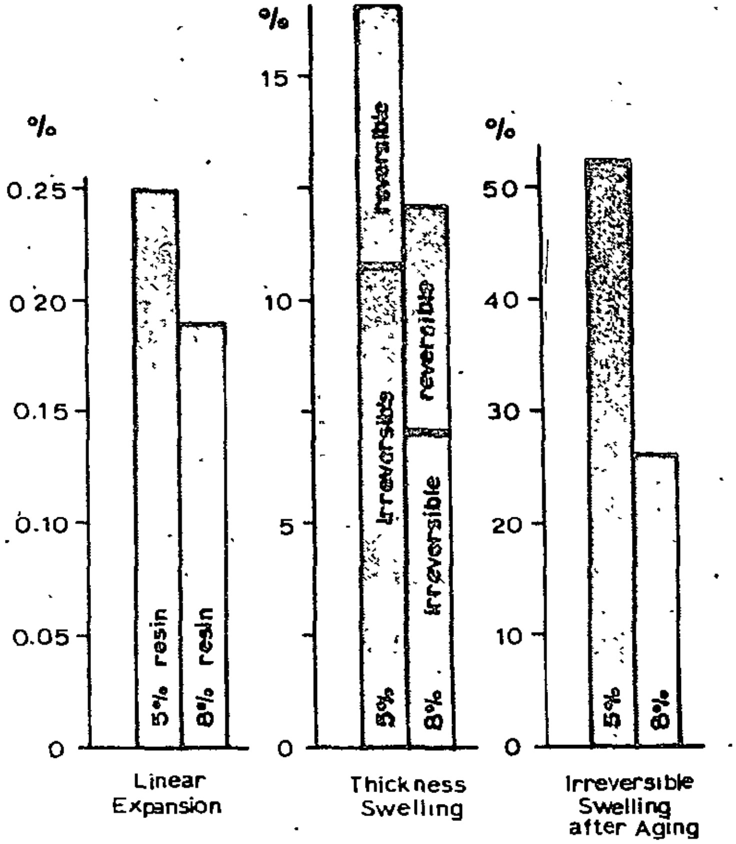

Figure 9.--Predicted mean values for linear expansion and total and irreversible thickness swellings (50% to 90% to 50% RH) and irreversible thickness and swelling after ASTM accelerated aging of 45 pcf (721 kg/m^3) phenolic-bonded particleboards from hammermilled chip mixture A Philippine species.

mixture C. The relatively high LE of the planer shavings boards was not expected but probably was related to its low thickness swelling (fig. 6).

A comparison of the properties of the phenolic-bonded board from hammermilled chips of mixture A to those of the exterior type 2B2 board of Commercial Standard CS 236-66 showed that the boards in this study exceeded all of the minimum requirements at the 8% resin level [2,500 psi (17.2 MPa) MOR, 450,000 psi (3,100 MPa) MOE, 60 psi (0.41 MPa) IB, and 0.25% LE]. However MOR and MOE minimums were not met at 5% resin content, but LE and IB were. A reduction in MOR of not more than 50% after accelerated aging as specified in the Standard was met at both 5% and 8% resin levels.

GENERAL CONCLUSIONS

1. Satisfactory urea-bonded particleboards were manufactured from furnishes prepared from chip mixtures of Philippine hardwoods representing three different wood density distributions.

2. Board properties were influenced by the type of furnish (hammermilled chips, ring-flaked chips, and planer shavings).

3. An increase in resin content improved all board properties. Generally speaking, the minimum property requirements of Commercial Standard CS 236-66 type 1B2 boards were met or exceeded at the 5% resin level except for the LE of the boards from hammermilled furnishes and planer shavings.

4. An increase in board density improved all strength properties.

5. When all properties were considered, boards from ring-flaked chips were superior to those from hammermilled chips of the same chip mixture (mixture A).

6. Boards from hammermilled chips of the high-density mixture (mixture B) were overall of only slightly lower quality than boards from the other two hammermilled chip mixtures.

7. Boards from planer shavings (mixture C) generally had properties intermediate to the boards from hammermilled chips and ring-flaked chips.

INVESTIGATIONS AT TROPICAL PRODUCTS INSTITUTE OF FIBROUS MATERIALS FOR USE IN PULP AND PAPERMAKING

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INTRODUCTION

The Tropical Products Institute is a scientific unit of Britain's Ministry of Overseas Development. Its function is to help the less developed countries derive greater benefit from their renewable natural resources (mainly their plant and animal products); and it specializes in the various scientific, technological, and economic problems that arise subsequent to harvest. It is concerned with the processing, preservation, storage, transport, quality control, marketing, and utilization of such products, including the use of waste and byproducts.

The Institute started as a very small laboratory within the Imperial Institute in 1894. Most of the work of the Institute was then focused on Britain's colonies and Commonwealth countries but today as part of the Ministry of Overseas Development, its work encompasses the needs of less developed countries generally.

The purpose of the paper is to review briefly the past work of the Institute and to make known the work in progress and something of the philosophy behind it.

Work to evaluate fibrous materials for use in pulp and paper started early in the history of the Institute. The first report, on the value of megasse (the fibrous residue from sugar cane more commonly called bagasse) from Trinidad, was published in 1910. Since that time, the results of many investigations have been published.

WORK BEFORE 1935

A dividing line in the work of the Institute can be drawn at 1935 because in that year the Institute acquired a British Standard sheet former. Prior to that time most digestions were by the soda process, and pulps were evaluated by feel and appearance after forming hand sheets approximately 8 inches by 10 inches.

During this period, more than 100 nonwood species and 50 wood species from 36 countries were examined. There did not appear to be any overall policy for deciding which species should be examined: anything sent in was examined. Most of the samples were sent by people working in tropical countries in a nontechnical capacity. Thus missionaries and administrators, often with an amateur interest in the abundant flora of a locality, would send samples. Others would be attracted by the possibility of finding a use for a waste material. The only attractive feature apparent for all the samples was that they appeared to be available in large quantities. During this period, some rather unpromising materials were examined. For example, rice husks from Egypt, examined in 1918 were found to have an ash content of 14.7% and fibres between 0.5 and 0.7 mm long; the paper obtained was very weak and brittle. The Institute examined also a number of materials that were promising and some are now very well known to papermakers: for example bagasse (1910), various species of bamboo (from 1912), Arundo donax (1912), Imperata arundinaria (Lalang grass 1914), and rice straw (1918).

The Institute has never been innovative in the development of techniques for pulping, or of new ways of processing pulps. However, and particularly when evaluating wood species, knowledge has often been acquired many years before there was any commercial exploitation. One example of this is the trials involving more than 20 species of hardwoods from Guyana which were the subject of three reports in 1924, 1928, and 1930. Although there have been a number of trials since then and work completed in the last three years is now being published, when a project was proposed in 1974/75 to exploit hardwoods from Guyana, these 50-year-old reports were the most complete published information.

An investigation, which led to further studies and exploitation in a shorter period, was the examination of Pinus radiata, P. larico, and six hardwoods from New Zealand. In 1921 it was reported that both these pines yielded strong pulps, but they were difficult to pulp because of the number of knots. The pulps were more difficult to bleach than pulps obtained from the hardwoods. The report concluded with a number of suggestions for further investigations necessary before commercial exploitation. In this case, it is well known that a successful industry has been built on the Institute's preliminary work.

To conclude this section reviewing old work at a time when increasing the use of the whole biomass is the vogue, it is worth noting that as long ago as 1924 the Institute published a report in which the effect of pulping before and after the removal of bark from a hardwood was studied, and in 1929 and 1930 a number of studies were completed in which the various parts of the sisal plant were examined with the intention of using all parts of the plant either separately or together.

WORK AFTER 1935

The year 1935, with the acquisition of the standard sheet machine for sheet forming and pulp strength testing equipment, marked a major change in the work of the Institute: instead of assessing the quality of the pulp by its appearance, it was now possible to quantify quality on the basis of standardized testing procedures. Although details of methods used have changed and new tests have been added, no further changes of comparable significance have taken place since that time.

Prior to 1952 most digestions were by the soda process, with a few by the sulphite process and all bleachings were by use of hypochlorite. The increasing number of wood samples led to the inclusion of the kraft (sulphate) digestion process in the Institute's experimental work. Now the sulphate process is the chemical process used most frequently. This change led to the inclusion of multistage bleaching: initially successive applications of chlorine, alkali, and hypochlorite, and more recently, the inclusion of chlorine dioxide.

To the Institute's facilities has been added the machinery necessary for experimental semichemical pulping. Currently a new refiner to produce, on an experimental scale, refiner groundwood and possibly thermomechanical pulps is being commissioned.

When introducing new techniques, every effort is made to ensure that results obtained before the change are comparable with those obtained after it. However, there are some changes in standards which have such an effect on the values obtained that direct comparison of results before and after the change are not possible. One such change was that of the conditions in which pulp sheets are tested, from the old British standard of 68° F and 65% relative humidity to the more widely used new standard of 23° C and 50% relative humidity. One advantage of this change is that it is easier to compare results obtained in the Institute with those obtained in American laboratories.

There has been a marked change in the type of fibrous material examined. In the early period reviewed the number of nonwoods to the number of woods was in the ratio of 2:1. In the period since 1935, the ratio is reversed with fewer than 40 nonwood species being examined against more than 100 wood species. In the last twenty years about 95% of the Institute's time has been spent examining wood samples.

Another change has been in the strategy of the work and, therefore, in the source of the samples. Most samples now are sent by professional foresters, who are very careful to select samples as representative of the growing stock, and frequently there is consultation with Government departments concerned with the promotion of local industry.

Examination of reports from the early period shows that the primary object was to assess the value of a raw material for export to Europe for processing. Now the object is to promote local industry. In most cases this means processing at least to pulp, if not to paper, in the locality where the trees are grown. However, there are some places where local conditions make this impossible, and the end product is likely to be chips for export.

The samples examined by the Institute originate from both natural forests and plantations, but a decision was made to concentrate work on plantations. The main reason for this decision was that, in the opinion of the Institute, a mill based on a uniform raw material is more likely to be successful, both technically and economically, than one based on a heterogeneous material.

Consequently, it was thought that the facilities available could be used to greater effect by influencing the choice of species to replace the natural forest. It should be emphasized that plantations do not necessarily mean plantations of exotic species. Often the species chosen will be exotic, but there is no reason why native species, with the potential to grow fast in plantations, should not be included in the studies.

At present the work of the Institute has three principal aspects:

1. Evaluation of plantation-grown coniferous species;
2. evaluation of plantation-grown hardwood species; and
3. evaluation of potential seed trees.

EVALUATION OF PLANTATION-GROWN CONIFEROUS SPECIES

This is the subject that has received most attention in the last 10-15 years. Reports have been published giving the results of evaluations of *Pinus caribaea*, *P. kesiya*, *P. patula*, *P. elliottii*, *P. merkusii*, and *P. oocarpa*. Studies now in progress include four of the above species and *P. occidentalis*, *P. tropicalis*, and *P. cubensis*. The samples have come from 11 different countries.

The results of all these examinations have been or will be published elsewhere, and only some principal features need be emphasized here.

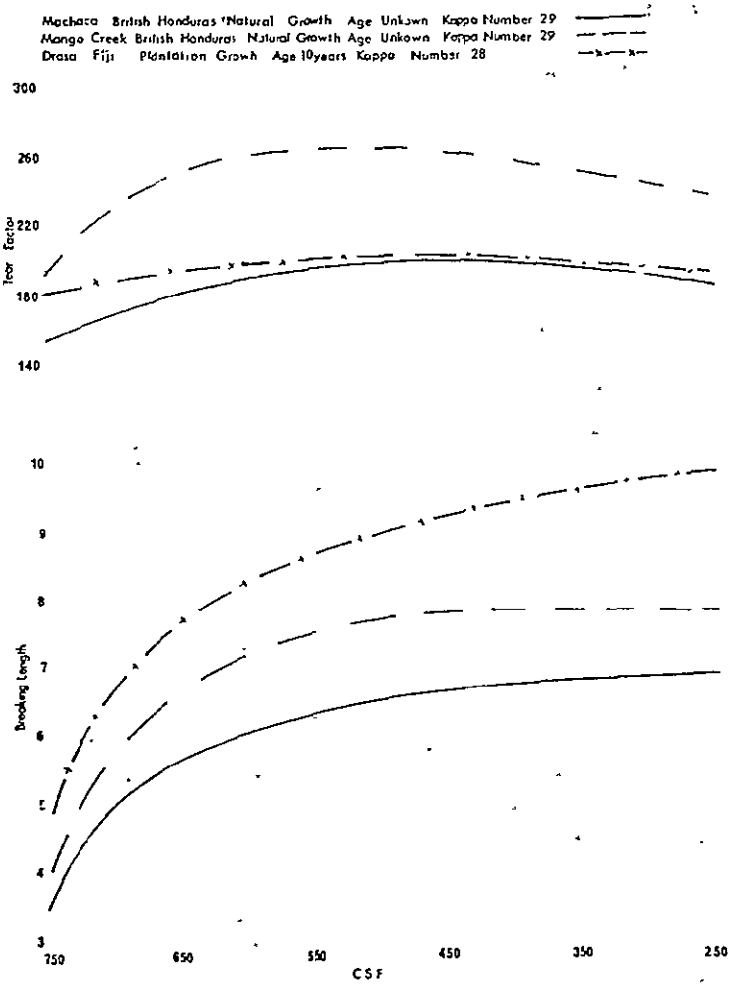
The results of the first two examinations of *P. caribaea* showed that there could be a considerable difference between samples of the same species. Pulp prepared from old samples from a natural stand in Belize gave sheets that were very bulky, had a very low bonding strength but a very high tearing strength. Pulp prepared from young trees grown in plantations in Fiji and Sabah gave more dense sheets with much better bonding strength and lower, but still good, tearing strength. Initially this difference was ascribed to age of trees. Subsequent examinations have shown that this is not the only factor because the differences in the wood from the plantations of the same age was also great. For example, the mean density of a sample of 20 trees of *P caribaea* variety *hondurensis* grown in Fiji was 502 kg/m^3 with a range of 378-696 kg/m^3, whilst a sample of the same variety of the same age grown from seed from the same provenance in Uganda had an average density of 374 kg/m^3 with a range of 329-447 kg/m^3. These results indicate that other factors than age and seed source are important. The range of difference for pulp quality is illustrated in figure 1.

Even after examinations of 36 samples of *P. caribaea* from 11 countries, quality still cannot be predicted, and it is necessary to test all samples.

A second important finding was the variation within a plantation of uniform age, for example in a sample of 32 10-year-old trees of *P. caribaea* from Seaqaqa in Fiji the range of density for individual trees was

COMPARISON OF THREE SAMPLES OF PINUS CARIBAEA

Unbleached Sulphate Pulp



340-610 kg/m^3. This has meant that considerable care has to be taken in selecting a representative sample; the observation was also the stimulus to the work on the evaluation of seed trees.

One investigation has given a result that is very encouraging to those who select trees for vigour. In each of two plantation areas in Fiji, a group of 300 trees were measured and divided into three groups: 100 with the largest girth, 100 with the smallest girth, and 100 between the extremes. From each of the extreme groups 10 trees were selected at random and examined. The main findings, which were the same for both areas, were:

1. The volume of wood produced by trees selected as fast grown was approximately twice that produced by the slow grown trees;
2. there were no significant differences in the density of the wood;
3. there were no significant differences in the chemical composition of the wood;
4. when cooked by the sulphate process, there were no significant or consistent differences in the ease of digestion;
5. the yield of pulp, when compared as weight of pulp per volume of wood, was higher for the slow grown samples, but the much higher volume increment of the fast grown trees more than compensates for this disadvantage; and
6. there was an impression that the pulps from the slow grown samples were more difficult to beat and were stronger, but the differences were no greater than might have been found in replicate beatings of the same pulp.

The wood properties of _P. caribaea_ are well known for their great variability caused by seed source, growing conditions, climate, age of trees, and the interaction of these factors. In the work at the Tropical Products Institute much less variation in other pine species has been experienced, but workers in France, examining two samples of _P. patula_ from Swaziland and Madagascar, have found differences in the tensile and bursting strength of more than 25%, and differences in the tearing strength of more than 10% when evaluating pulp at constant kappa number and freeness. Consequently, it is possible that some variation is likely with most pines grown in the tropics.

EVALUATION OF PLANTATION-GROWN HARDWOODS

Fewer samples of hardwoods have been examined at the Tropical Products Institute. In a period when 16 reports were published about softwoods, there were only four reports concerning one sample of each of the four species of hardwoods. The proportion will change when current work, involving 21 samples from 11 species, is completed.

The main advantage of the plantation-grown hardwoods is their very fast growth rate. Although it is difficult to get accurate figures, none of the samples we have examined is estimated to have a rate of growth lower than 17 m^3/ha/a and some are as high as 50 m^3/ha/a. Unfortunately, many of these species examined have low densities (for example 230 kg/m^3), but others are higher (for example Gmelina arborea, 400 kg/m^3 and some Eucalyptus spp., over 500 kg/m^3). This means that where high growth rate and high density are combined, yields of dry wood can reach 25 tonnes/ha/a, and yields of 16-20 tonnes/ha/a are attained more frequently. These quantities can be compared with 15-20 m^3/ha/a (10 tonnes/ha/a) for many plantations of Pinus caribaea, although a yield of 28 m^3/ha/a has been reported in most favourable conditions.

To present an assessment of the quality of hardwood pulps, table 1 gives a comparison of pulp yield and strength compared with two commercially accepted pulpwoods, mixed U.S. southern hardwoods and beech.

To make the comparison, all the woods have been digested using the same sulphate conditions; the pulp strengths are all compared of 300 Canadian Standard freeness after beating in a P.F.I. mill; and the values for southern hardwoods are taken as 100. The species grown in the tropics were four species of Eucalyptus grown in Kenya and Gmelina arborea grown in Fiji. The two results for G. arborea were the highest and lowest obtained when pulping six samples from different localities. The yield of pulp from all the samples grown in the tropics was higher than the yield from beech, and for most of them was higher than the yield from U.S. southern hardwoods. Most of the tropical species yielded pulp with a lower kappa number than was obtained from U.S. southern hardwoods, indicating that less severe digestion conditions were required.

A comparison can be made between pulps from (a) species grown in the tropics and (b) U.S. southern hardwoods. The former gave dense sheets with equal or greater tensile strength and, in most cases, greater bursting and lower tearing strengths. All the strength characteristics were higher and in some cases very much higher than those of the pulps from beech.

All of these results indicate that for uses where a dense sheet is acceptable, and the highest tearing strengths are not required, the establishment of plantations of hardwoods should be considered.

EVALUATION OF POTENTIAL SEED TREES

The work to evaluate potential seed trees arises from that on plantation species. In many of the investigations completed, a wide variation in the wood properties of individual trees was found. Consequently, it was thought that if it were possible to select the "best" tree from a plantation as the seed source for future generations, then it would be possible to produce a plantation with more uniform wood of higher quality. It was decided to try to select trees on the basis of both their growing characteristics and their potential industrial usefulness. In this work the Institute is co-operating closely with the Commonwealth Forestry Institute at Oxford.

In the first trial completed, the trees examined were Pinus caribaea from plantations in Fiji. Increment cores were taken from the large number of trees with above-average vigour and satisfactory form. The cores were scanned by X-ray densitometry to determine the mean density and the variation of density within the core. From these results 20 trees were selected which represented the full range of mean density and a variety of density patterns. The selected trees were felled for further examination but before felling were propagated both by sexual and vegetative methods.

Each tree has been examined to determine its mean density and the variation of density within the tree, tracheid dimensions, main chemical constituents, and pulping characteristics.

The final results are still being evaluated and a full report should be available later this year, but some preliminary findings have been published and are worth reporting. Firstly, the differences in pulping characteristics between trees were larger than expected: at constant digestion conditions the pulp yield varied from 45.7-50.3% and the kappa numbers between 40 and 64. The high yield pulps were not necessarily those with high kappa numbers. At the same digestion conditions and beating-point there were considerable differences in pulp strengths: for example, for one set of conditions the tear factor varied from 125-200 and the breaking length from 8.0-10.3 km. Although statistical analysis showed, as expected, that tearing strengths and tensile strength were inversely related, the relationship was not constant. Ranking all the trees according to their yield and strength characteristics, it was found that four trees were in the top ten for yield, bursting, tensile, and tearing strength. Therefore, it would appear possible to select trees with superior use characteristics for breeding purposes.

The data obtained in these trials are being carefully analyzed to seek correlations between the physical, chemical, and microscopic characteristics of the tree and properties. Present indications are that although general relationships exist, they are not sufficiently precise to be able to predict pulp quality from tree characteristics. However, the information obtained will be very valuable in monitoring progeny by taking increment cores.

INFORMATION WORK

In addition to its investigation work, the Institute replies to many enquiries each year. It is well equipped to do this because its library subscribes to more than 40 journals which publish information about pulp and paper from many parts of the world. There are very long runs of some journals: Indian Forester from 1876, Paper from 1905, Pulp and Paper Magazine of Canada from 1924, and a complete set of Tappi since it was published in its present form in 1949 as well as many earlier Tappi publications in Paper Trade Journal. Additionally there are many reprints as well as annual and technical reports from many forestry departments and research institutes.

Table 1

Comparison of Pulp from Commercial Pulpwoods

and species grown in the tropics.

Based on pulp from Mixed U.S. Southern hardwoods = 100

	Southern hardwoods	Beech	Eucalyptus saligna	Eucalyptus camaldulensis	Eucalyptus regnans	Eucalyptus fastigata	Gmelina arborea highest	Gmelina arborea lowest
Screened Yield	100	95	107	96	110	100	108	96
Kappa No.	100	84	86	103	66	99	135	90
Pulps evaluated of 300 Canadian Standard Freeness								
Density	100	102	102	103	114	111	124	115
Tensile Strength	100	90	105	99	119	114	118	103
Bursting Strength	100	87	104	92	115	117	115	97
Tearing Strength	100	79	89	87	89	94	100	89

Naturally the Institute has established close personal contacts with many countries through the many visitors received in our London laboratory, and senior members of the Pulp and Paper Section spend several weeks every year on liaison visits to the countries for whom we are doing work. Consequently, we may not be unique in our ability to provide information on the prospects for pulp and paper developments, but we are in a very good position to do so.

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Pulping characteristics of *Pinus caribaea* from Fiji. Effect of rate of growth.	1977	L46
Pulping characteristics of *Pinus oocarpa* grown on Mountain Pine Ridge, Belize.	1976	L44
Pulping characteristics of *Pinus caribaea* from Belize.	1976	L43
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Pulping qualities of plantation grown *Pinus patula* and *Pinus elliottii* from Malawi.	1974	L37
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	Year	No.
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SECTION VI

INDUSTRIAL PLANS AND PRACTICES

TROPICAL HARDWOOD PULPS

By

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TROPICAL HARDWOOD PULPS

By

Georg Petroff

The first research carried out in France for the purpose of putting tropical raw materials to use, dates from the beginning of the century.

Between the two world wars about 50 woods originating from Africa, Guyana, Vietnam, and Madagascar had already been tested.

These first works led to the setting up of a pilot plant in the Ivory Coast which was in use from 1950 to 1955. This plant which produced 10T/day of chemical unbleached pulp and paper from tropical heterogenous mixed hardwoods proved that it was possible to use clearcut tropical forests for this purpose.

Unfortunately this experiment was stopped as the capacity of the mill was too low to enable a sufficient level of profitability to be reached, even with high French Government aid.

The reorganization and extension of the mill were overwhelmed by more urgent problems due to the Ivory Coast becoming independent. Nevertheless it was decided to entrust the CTFT with the pursuit of the research in the form of laboratory experiments, semi-industrial or purely industrial tests, and economic studies. These different works led finally to the drawing up of some industrial projects for implementation in Africa and Guyana.

The following is a short synthesis of the knowledge acquired by the CTFT.

GENERAL CHARACTERISTICS OF TROPICAL WOODS

Nature of Forests

Table 1 gives some examples of low-altitude tropical forests studied by the CTFT. These forests are composed essentially of hardwoods, although in tropical America and in the Far East a few softwoods are to be found. For each forest the number of species varies between 200 and 300 which belong to about 50 botanical families. The average volume of the trunks excluding the branches varies from 200 to 400 m^3/ha. This volume corresponds to trees with a diameter of 10 cm to 1.50 m. The average diameter of the trees is 50 to 55 cm for the forests on the West African Coasts, 35 cm to 45 cm for the Amazonian forests which are characterized by slightly smaller dimensions.

Table No. 1 : Characteristics of a few tropical forests studied by the C.T.F.T.

Geographical situation	Gabon	Ivory Coast	Cameroon	French Guyana	Ecuador
Surface areas surveyed (hectare)	150,000	255,000	100,000	80,000	680,000
Survey rate (%)	1.33	0.125	1	1	0.2
Registered species	308	234	342	277	307
Botanical families registered	53	–	–	37	–
Botanical genera registered	235	–	–	149	–
Kind of woods :					
Hardwoods (%)	100	100	100	100	98
Softwoods (%)	0	0	0	0	2
Trunk volume excluding branches (m3/ha)	260	205	340	360	260
Average diameter (cm) (1)	55	55	50	44	36

(1) : Volume of woods lower than the average diameter = volume of woods higher than the average diameter.

Wood Costs

Our evaluations have been made for forests in Africa and Guyana where the cost of labour is relatively higher than in the Far East or in South America. They correspond to modern harvesting with heavy engines.

The cost of road construction, excluding one or two important axis, is charged to the logging companies. The distances between the forest and the mill do not generally exceed 30 to 40 Km. Logging is geared to the feeding of modern plants with 250,000 T/year of pulp with a wood consumption of approximately 1 million m^3/year.

In these conditions the price of wood per cubic meter at the yardmill could reach $15 to $18 in 1977. These costs are reasonable compared with European costs but they remain probably higher than those of certain developing countries where wages are low.

Individual Characteristics of Tropical Hardwoods

Each paper characteristic of hardwoods which make up a tropical forest varies considerably from one species to another. Nevertheless when we consider the different tropical forests studied in Africa, America, and the Far East, we find a fairly even statistical distribution for each characteristic when the individual species are taken as a whole.

We should not conclude that tropical forests have the same value where paper is concerned, because in each forest the dominant species may correspond to good or bad species, which fact can seriously affect the final results.

Table 2 illustrates, for more than 1,000 samples of tropical hardwoods tested at the CTFT, the statistical distribution of a few physical, chemical, morphological, and paper characteristics.

Figure 1 shows as an example the statistical distribution for fibre length.

Taken as a whole and compared with European hardwoods, the registered tropical hardwoods show the following particularities.

Wider range of results
Lower pentosan content
Higher lignin content
Slightly longer fibres
Lower pulp yield
Slightly higher tear

In certain forests the wood is of a higher density, which leads to a shortening of the breaking length and of the burst of papers and to an increase in the bulk and the porosity.

Table No. 2 : Statistical distribution of a few characteristics for 1000 samples of tropical hardwoods.

Statistical distribution	Minimum	Main class	Maximum
Density of dried woods	0.15	0.5-0.8	1.3
Chemical composition.			
Alcohol benzene extract %	< 0.2	1-3	> 15
Water extract %	< 0.2	1-3	> 10
Lignin %	< 20	28-32	> 35
Cellulose %	33	42-50	58
Pentosans %	10	14-18	22
Silica %	< 0.001	0.01-0.1	> 3
Morphological characteristics.			
Fiber length mm	0.7	1.2-1.4	3.7
Width (mu)	12	20-30	73
Flexibility ratio %	< 5	40-60	90
Paper characteristics.			
Pulp yield (kraft-Kappa 25)	33	44-50	60
Breaking Length (40 °SR)	3000	6000-9000	14000
Burst (40 °SR)	10	25-50	100
Tear (40 °SR)	50	80-120	325
Bulk (40 °SR)	1	1.25-1.50	2

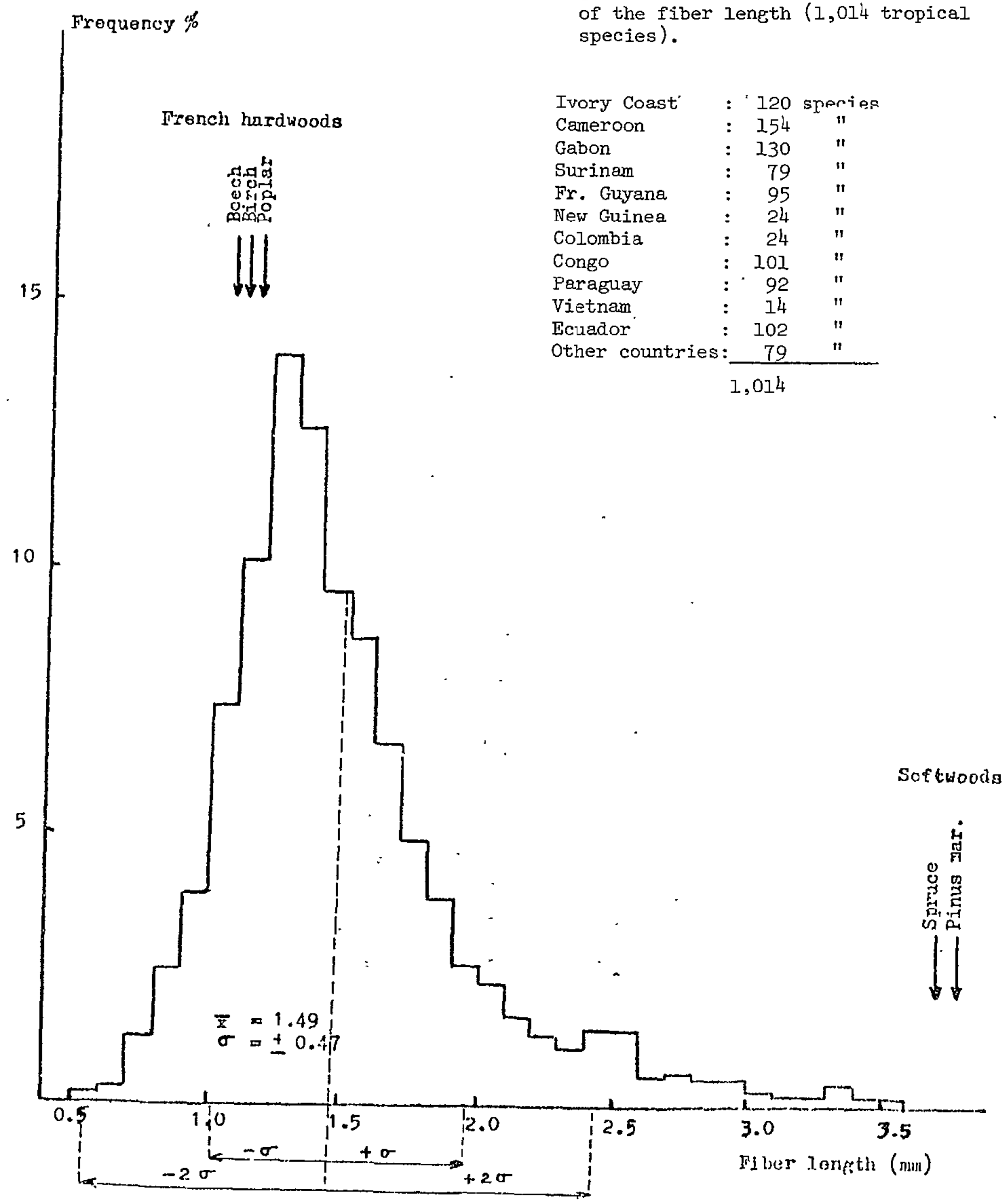


Figure 1. Statistical distribution of the fiber length (1,014 tropical species).

Ivory Coast	: 120	species
Cameroon	: 154	"
Gabon	: 130	"
Surinam	: 79	"
Fr. Guyana	: 95	"
New Guinea	: 24	"
Colombia	: 24	"
Congo	: 101	"
Paraguay	: 92	"
Vietnam	: 14	"
Ecuador	: 102	"
Other countries	: 79	"
	1,014	

Appropriate Processes

It is possible to obtain unbleached or bleached chemical pulp by the soda process (Kraft) from any tropical wood.

The acid sulfite process gives less consistent results. In fact, although most tropical species could be treated by this process some hardwoods are difficult to impregnate and give less delignified pulps. We even find a few species apparently uncookable by this process.

Unbleached neutral sulfite pulp can be obtained from all woods, but the pulp quality varies considerably from one species to another. These pulps remain generally very lignified and consume prohibitive quantities of chlorine when bleaching.

Only low density and clear woods are able to give cold soda pulps or mechanical pulps of acceptable quality.

Correlation Between Wood and Pulp Characteristics

Theoretically, methematical relations exist between wood density and certain morphological fiber coefficients. For example, the relation between wood density and the flexibility ratio is a second degree function, of which graphic representation is a parabole (see annexes).

Experimental results reveal a distribution of points similar to the theoretical distribution.

The use of wood density or of the flexibility ratio leads, in the end, to almost equivalent results during research into correlations between pulp or paper characteristics. Taking our experience into account, we believe it is advisable to retain the density as the evaluation criterion.

We observe correlations of a relatively high level (r equal to or greater than 0.7) between wood density and the following characteristics:

Breaking length
Burst
Folding endurance
Porosity
Bulk
Pulp freeness before beating
Dryness of pressed pulps

Tearing resistance is in correlation with both fiber length, which defines felting, and cell wall thickness, which resists breaks during beating. On the other hand it is necessary to make a distinction between initial tear before beating and tear after beating.

It is more difficult to establish close correlations between chemical wood composition and cooking results (yield, kappa, chemical consumption). At the present time the correlation values r are rather low (r includes between 0.3 and 0.5).

METHOD FOR STUDY OF TROPICAL HETEROGENEOUS FORESTS

The first laboratory cookings of heterogeneous mixtures from Gabon and the Ivory Coast woods were made in 1946. It very quickly became apparent that any wood mixture originating from these regions could be treated by the Kraft process. Since this time, new forests have been tested by the CTFT according to techniques which were progressively improved.

Constitution of a Representative Mixture of the Forest

Initially, we only studied a wood mixture which was representative of the forest, by grouping the main species in proportion to their forest volume. One of the first problems was to decide on the number of species to select. The more we increase the number of species, the more asymptotically we approach the final result.

Theoretically, we should use all the woods, that is to say 200 to 300 species. Practically, we can considerably limit this number. Table 3 gives as an example the evolution of the breaking length for an Ivory Coast forest depending on the number of selected species. We see that the margin of error hardly exceeds 1 percent for 40 woods representing 70 percent of the forest volume. For 80 woods representing 85 percent of the forest volume, the margin of error is practically nonexistent.

Finally, we think it is possible to constitute a sufficiently representative forest mixture by selecting a number of species corresponding to 70 to 80 percent of the total forest volume to be represented.

Incidence of Heterogeneity on Pulp Quality

The representative mixture of the forest can only represent a theoretical case of wood harvesting. Practically, the woods which arrive every day at the mill represent a variable mixture, and it is important to calculate the extent of this variability which thus results, so as to determine the variability of the pulp quality.

For the forests which were first tested, we tried to calculate this variability by selecting specific wood mixtures which correspond to an increase in the percentage of good or poor quality species. It quickly became apparent that this method was imperfect and that it was preferable to use statistical methods linking the results obtained from forest inventories to paper studies carried out in the laboratory.

An important fact has facilitated this kind of study. We have in fact observed that when we treat a tropical wood mixture, the final result could be calculated with a small margin of error from the individual results of each selected species treated under the same conditions.

We do not state that experimental values and calculated values coincide with each other; on the contrary, we think that during a treatment in mixture, the distribution of the reactives and the reactions are rather complicated and difficult to explain. We are simply saying that the final

Table No. 3 : Evolution of the breaking length at 40 °SR for an Ivory Coast forest vs. the number of species selected to make up the mixture.

Number of species	Forest volume represented %	Breaking Length	Difference % with the final value (234 species)
1	8	6300	− 12.5
15	40	7500	+ 4.2
20	53	7400	+ 2.8
40	69	7100	− 1.4
60	79	7250	+ 0.7
80	84	7220	+ 0.3
234	100	7200	0

Table No. 4 : Mixture of 10 woods. Comparison between the experimental values and the values calculated from individual tests.

Characteristics	Pulp yield	Rejects	NaOH in black liquor	Index MnO_4K	Breaking Length	Tear
Calculated	47.5	0.61	5.4	21.7	7280	111
Experimental	47.5	0.62	5.1	20.8	7350	119

<u>Table No. 5</u> : Correlations between the experimental values of a wood mixture and the values calculated from individual tests on the species constituting this mixture. (Study carried out by J. NAVARRO, FAO)

Characteristics	r
Yield	0.986
Kappa	0.973
Breaking Length	0.947
Burst	0.946
Bulk	0.984

<u>Table No. 6</u> : Standard deviation of the delignification index and of the breaking length, when we take from the forest at random the necessary quantities of woods for the provision of a 250.000 T/year pulp mill during a few hours or a few days.

Provision time units	Standard deviation e %	
	Delignification index	Breaking Length
8 h	4.91	5.21
16 h	4.01	4.42
24 h	3.54	4.19
48 h	3.12	3.80
72 h	2.76	3.49

result is not very different from the calculated value as shown in table 4. Table 5 shows that a very close correlation exists between calculated and experimental results (r practically = 1).

In these conditions we can introduce both forest data and data provided by individual paper tests of woods into a computer. We are thus able to resolve all sorts of problems relating to the variability of pulps.

We have therefore established, for African pulp mills producing 250,000 T/year, the standard deviation of a few characteristics when the necessary woods for a few days or a few hours of production are harvested at random in the forest. The standard deviation under these conditions is between 2 and 4 percent, which values are considered as acceptable by manufacturers (table 6).

KRAFT PULPS--COMPARISON OF VARIOUS TROPICAL FORESTS

Laboratory Tests

Among the forests studied by the CTFT, nine were selected so as to carry out fairly extensive comparisons. The forests are located in the Ivory Coast, Gabon, The Cameroons, Guyana, Indonesia, Ecuador, Colombia, Surinam, and New Guinea.

As a reference test, we also studied a French hardwood mixture including birch, poplar, beech, and oak.

Table 7 gives some of the principal results obtained during these studies.

The tropical mixtures tested are composed of wood, of which the average specific gravity is variable. The New Guinea and Ecuador mixtures are characterized by a lower density than that of the French mixture, while the other tropical mixtures are of a higher density, particularly those of Guyana and Surinam.

All the tropical mixtures have longer fibers than the French mixture. They are richer in lignin and contain much less pentosan.

The tropical pulps can be bleached by classical processes; with CEDED bleaching some mixtures show a lower degree of brightness than that of French mixtures. Nevertheless, with the exception of the New Guinea mixture the differences are very small.

When CEDPD bleaching is used, a method which seems to be more suitable for tropical woods, very good results are obtained, and it is possible to exceed 90° brightness.

All the tropical mixtures are characterized by greater tearing resistance than that of the French mixture, particularly those from Africa, Guyana, and Surinam.

Table No. 7 : Comparative results of nine tropical forests and of a French hardwood mixture.
(kraft treatment - Laboratory tests)

Origin	Ivory Coast	Gabon	Cameroon	French Guyana	Indonesia	Ecuador	Colombia	Surinam	New Guinea	France (1)
Average wood density	0.68	0.60	0.71	0.83	0.65	0.54	0.66	0.76	0.46	0.59
Fiber length	1.50	1.45	1.70	1.50	1.30	1.25	1.30	1.40	1.40	1.00
Alcohol benzene extract %	1.7	2.3	2.3	2.8	3.0	2.1	1.2	5.8	1.5	2.2
Water extract %	2.2	2.1	1.8	2.2	2.7	2.7	2.7	2.7	1.0	3.3
Lignin %	30	29.5	32	29.9	31.8	27.9	28.6	27.1	28.8	23
Pentosans %	15.7	14.9	14.5	13.6	15.9	16.3	14.7	14.5	15.0	25.6
Cellulose %	43.3	47.1	45.6	47.4	43.1	44.6	47	43.9	47.7	40.0
Ashes %	1.5	0.6	1.4	0.9	1.1	1.2	1.2	1.0	1.6	0.5
Na_2O when cooking (Kappa 20-25)	17	16	17	17	17	17.5	15.5	17	15.5	14.5
Bleached pulp yield %	42.3	44.1	40.4	42.4	43.0	46.0	46.5	43.7	46.7	48.3
Brightness CEDED	87.5	90	87	89.5	88.5	89.5	87	89.5	84	89.5
Brightness CEDPD	90.5	90.5	90	91.5	90	90.5	90	90.5	86	91
Bleached pulp characteristics (40 °SR) :										
Breaking length	7200	8000	6900	6500	7200	7300	6800	6700	7300	7700
Burst	45	50	39	33	38	43	40	36	44	53
Tear	120	116	110	128	108	90	100	118	90	78
Opacity	64	63.5	62	65	64	65	60	63	60	63

(1) Mixture of Birch, Beech, Poplar, Oak.

The breaking length and bursting vary from one mixture to another and sometimes give lower values than those obtained from French mixtures.

If the curves of the tearing versus tensile strength are considered (fig. 2), the tropical mixtures are classified somewhere between the European hardwood and softwood pulps. The mixtures from Africa, Guyana, and Surinam are particularly well placed in these types of curves.

Many tropical mixtures containing dense woods produce bulky and porous paper.

Storage of Tropical Woods

Tests were made on storing tropical woods in the open air in a tropical climate. In all cases they concern round logs stocked in small piles in the forest, unprotected, for 13 months.

Many logs had a normal level of resistance to decay but certain very alterable species showed a high weight loss in woods considered to be anhydrous. This loss is noticeable after 1 or 2 months, and can reach 30 percent after 13 months.

At the same time as a weight loss, a decrease in the paper quality was noticed, the tearing resistance and folding endurance being the most affected characteristics (loss can reach 50 pct of the initial values with the most alterable species).

Nevertheless it is possible for a heterogeneous mixture of woods to be stocked for 3 months without any serious damage but it is better not to exceed this period.

Until the present time it has not been possible to attempt storage of woods in chips.

Industrial Tests

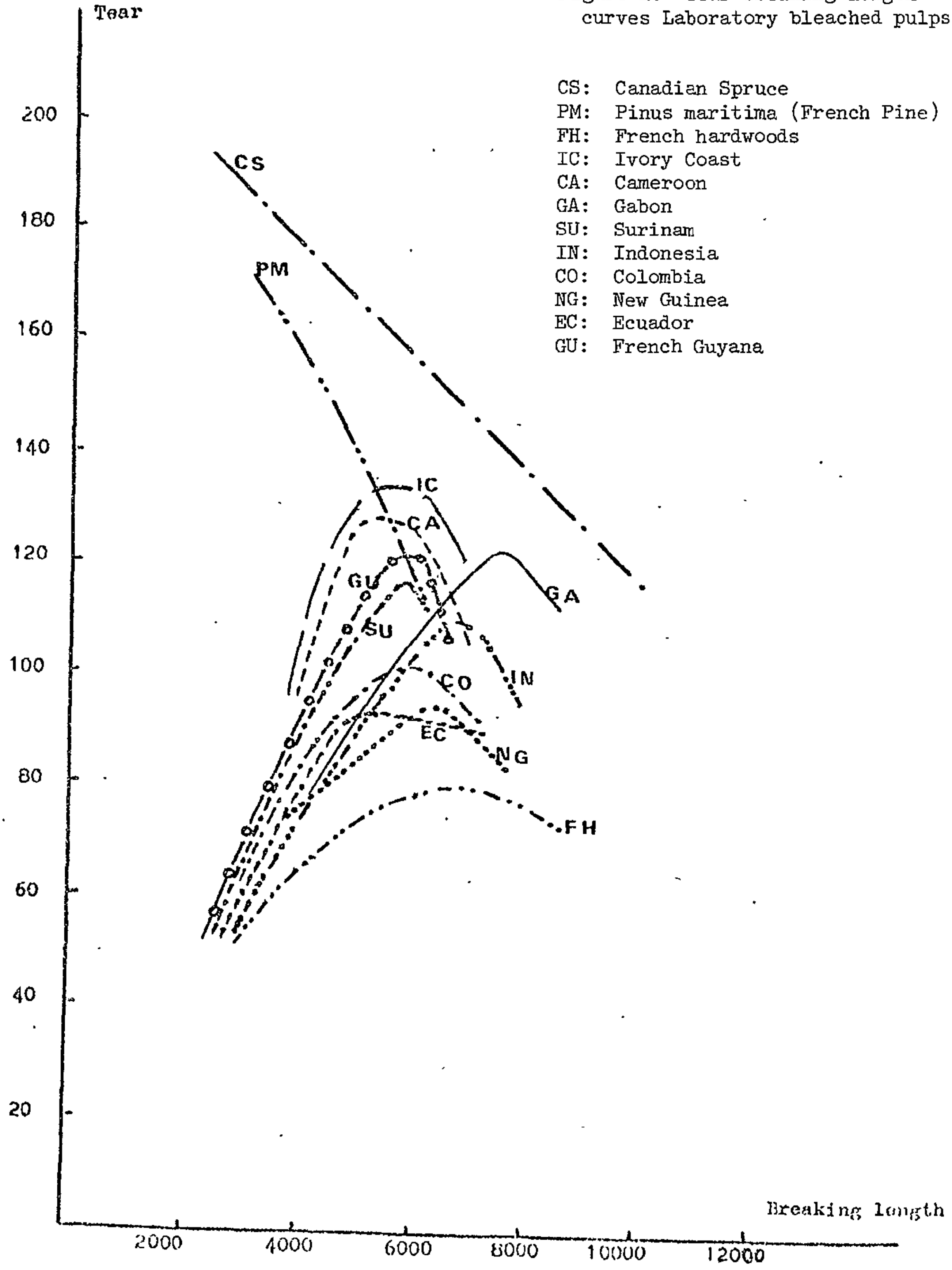
After some semi-industrial pilot tests we took part in some industrial trials using representative mixtures from a few tropical forests. Apart from the RICC experiment which lasted for 4 years, these are generally experimental manufactures of a few days' production from 1,000 to 5,000 tons of wood in various plants producing hardwood pulps. Three to 6 months were left between the felling of woods and the industrial tests.

In the case of unbleached production we also produced wrapping paper on integrated paper machines.

In the case of bleached production the pulp was put into bales and marketed.

The bleaching sections were modern and enabled the use of chlorine dioxide with the exception of the Indonesia mixture for which the bleaching was CEHH.

Figure 2. Tear-breaking length curves Laboratory bleached pulps.



CS: Canadian Spruce
PM: Pinus maritima (French Pine)
FH: French hardwoods
IC: Ivory Coast
CA: Cameroon
GA: Gabon
SU: Surinam
IN: Indonesia
CO: Colombia
NG: New Guinea
EC: Ecuador
GU: French Guyana

Table No. 8 : Quantity of wood chipped with the same set of knives on a modern chipper.

Epicea	600 m3
European hardwoods	400 m3
Gabonese hardwoods	100 m3
Guyana hardwoods	20 à 80 m3

Table No. 9 : Characteristics of unbleached wrapping paper obtained on an industrial scale.

Characteristics	Weight/m2	Breaking length $\frac{(M+C)}{2}$	Burst	Tear $\frac{(M+C)}{2}$
Tropical papers.				
Ivory Coast mixture	72	6120	30.5	125
	40	5400	27.5	122
Congo mixture	75	5750	28	114
Reference papers.				
80 % beech - 20 % pine	72	4400	28	72
French Maritime pine	60 à 85	5400 à 6200	30 à 39	95 à 140
Swedish Epicea (cement bag)	72	5270	34	158

During these trials various equipment was used, which enabled a few observations.

On the whole, drum debarking was difficult to adjust. It was necessary to shorten it in order to avoid too much broken wood. So, large pieces of bark were allowed through.

The cambio debarkers were more efficient for logs of small and medium sizes but it was not possible to use them for wide diameter logs.

During these different tests, the logs with wide diameters were either eliminated or sawn in quarter and more or less treated with bark.

Difficulties during chipping were observed with African mixtures, and above all with those from Guyana which included heavy woods. It was necessary on the one hand to increase the angle of the knives to avoid turning the edge, and on the other hand to change the knives for sharpening very frequently (table 8.).

The cooking, bleaching, wet lap section, drying, and baling gave rise to no difficulty, but it was necessary to make some adjustments relating to the nature of the wood tested.

Neither foam problems or bad drainage were noticed. The speed of the pulp in the different sections was normal and in a few cases even higher than the usual speeds. The elimination of bark residues was done correctly with centricleaners.

It was not possible in so short trials to make worthwhile observations on the regeneration of black liquors. We can simply say that for a running period of a few days no particular difficulties arose.

No irregular variations of pulp quality were observed although samples of pulp were often taken during production.

Tables 9 and 10 give the main characteristics of unbleached papers and bleached pulp obtained during the course of these tests. These tables also compare the paper and pulp characteristics obtained from European or North American woods.

The tropical wrapping papers are of higher quality than those of paper including 80 percent beech. They showed a slight resemblance to some French pine papers but nevertheless cannot attain the quality of Scandinavian Kraft papers.

Tropical bleached pulps can be compared with the European or North American hardwood pulps. The breaking length and burst are sometimes a little poorer, but the tearing resistance remains higher, though lower than the values noted in laboratory or semi-industrial tests. This is due to the short amount of time allowed for the tests which do not enable an optimum adjustment to manufactures. In spite of this handicap, the pulps were marketed

Table No. 10 : Characteristics of bleached industrial pulps.
(samples taken from bales of dried pulp - Jokro beating)

Characteristics (40 °SR)	Brightness	Breaking Length	Burst	Tear	Bulk	Opacity	Alcohol ether extract
Tropical pulps.							
Gabonese mixture (2)	92	7800	53	76	1.30	65.5	0.10
Ivory Coast mixture (3)	89	7000	39	87	1.40	67	0.20
Guyana mixture (4)	90.5	6000	35	80	1.45	69	0.10
Indonesia mixture (5)	80 (1)	6100	33	102	1.45	67	0.50
Reference pulps.							
French beech	90	6000	39	65	1.40	67	0.15
Canadian hardwoods	90	6800	42	66	1.45	64	0.20
Scandinavian birch	90.5	9100	64	64	1.10	55	0.25
Southern hardwoods (U.S.A)	89	7500	42	73	1.33	63	0.40

(1) CEHH bleaching
(2) Test realized in Sweden at the Skutskar mill (Stora Co.)
(3) Test realized in Taiwan at the Chung Hwa mill
(4) Test realized in France at the Cellulose d'Aquitaine mill
(5) Test realized in Indonesia at the experimental L.P.S. mill (Bandoung)

with success and gave good results for the manufacture of printing, writing, tissue, duplicata, coated papers, etc. It was possible to substitute traditional hardwood pulps with an equivalent amount of tropical pulps without seriously altering the beating conditions and the final paper characteristics. We even frequently noticed that the wet sheet reacted better on the machine when tropical pulps were used.

SEMI-CHEMICAL AND MECHANICAL PULPS FOR THE MANUFACTURE OF CORRUGATED PAPER

Our experience is more restricted in the field of manufacturing semi-chemical pulps.

The laboratory tests show that the tropical mixtures treated with neutral sulphite are more difficult to delignify than the European hardwoods.

When treated equally, they give pulps with a higher Kappa number which necessitates in a few cases a little more energy when defibering. Nevertheless, it is generally possible with 16 percent sulphite to obtain 70 to 75 percent pulp yield and to manufacture corrugated paper which is strong enough for making cardboard boxes.

Difficulties can appear when fluting as shown by the following industrial test using material from Gabon forest.

The Gabon woods were grouped into three mixtures:

- Mixture No. 1 - Representative of the forest (average density 0.60)
- Mixture No. 2 - The proportion of dense and hardy woods was increased (average density 0.70).
- Mixture No. 3 - The very hard and dense woods were excluded (average density 0.50).

Each mixture was treated under the same conditions using 16 percent mono-sulphite. The pulp was defibered, refined, and paper was produced in 118 g/m^2.

There were no difficulties up to this stage of manufacture.

If we consider characteristics such as bursting, breaking length, and ring crush, the three papers can be classified in the same order as wood density--the selected mixture with low density species gave the best paper, and the mixture of dense woods gave the poorest, though the characteristics should be theoretically sufficient for use in cardboard boxes (table 11).

It was surprising to observe that during the fluting, the papers were classified in reverse order. The paper from selected woods evidenced flute breaks and it was necessary to greatly reduce the speed of the machine. On the other hand, the paper from hard and dense woods passed through at maximum speed and produced very good corrugated paper.

Table No. 11 : Characteristics of corrugated papers obtained from 3 Gabonese wood mixtures.
- No. 1 : Representative mixture of the forest
- No. 2 : increase in dense wood proportion
- No. 3 : excluding dense woods

Wood mixture	No. 1	No. 2	No. 3	Reference paper(1)
Wood density	0.6	0.7	0.5	–
Weight/m2	118	119	118	115
Breaking length : M	7140	6640	9850	–
C	2465	2400	3230	–
Aver.	4800	4520	6540	4700
Tear : M	55	50	46	
C	80	81	58	
Aver.	67.5	65.5	52	53
CMT : M	25	25.7	24.1	20
Ring crush : C	13.1	13.1	15.5	13.7
Max. speed when corrugating	200	>200	160	180

(1) French hardwoods + paper wastes.

It was supposed that this result was due to the presence of longer fibers in the dense mixture, but this hypothesis was not entirely verified, because the introduction of softwood fibers into the selected wood mixture did not improve the passing through of the corrugating machine.

Taking this odd result into account, we intend in the near future to make an experiment with the wood mixture from Guyana which is particularly hard and dense.

With regard to the mechanical pulps we do not think that it is possible at the present time to use tropical forests without selection of the species. But an industrial test made using a light wood often found in natural forest, the Umbrella tree, gave relatively acceptable results, in spite of the fact that the pulp was a little dark and needed to be lightened.

PAPER INDUSTRIALIZATION IN FRANCOPHONE COUNTRIES OF AFRICA AND FRENCH GUYANA

The action of local governments in conjunction with the CTFT research has facilitated the drawing up of some projects in the Francophone countries of Africa and in Guyana. Four of them concern the setting up of modern mills for the production of bleached pulp from natural forests. The greater part of the pulps would be designed for export. Two projects have already been decided on and are in progress in the Cameroons and in Gabon. Medium term decisions could be taken in the Ivory Coast and Guyana.

CONCLUSION

The research into the use of paper produced from tropical forests has considerably improved during the last few years. Transformation into chemical or semi-chemical pulp seems to be technically possible. The use of natural forest only represents the period of a few years in the mill's life because it is recognized that in the long run it is more advantageous to replace this forest with artificial reafforestations. But inversely, it appears that it would be unreasonable not to profit from the existence of this forest, particularly when new land is not available for plantations.

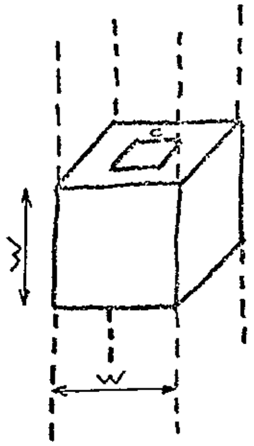
The first projects which will be carried out in the tropical regions will meet some difficulties, in particular with regard to the lack of substructure and the training of workers. However, there is a lot at stake and it therefore deserves serious efforts.

Appendix 1

Relationship and correlation between the wood density and the flexibility ratio.

Theoretical Relationship

Supposing that a fiber has a square section and neglecting the rays and the vessels, we have:



w = fiber length
c = lumen width
F = flexibility ratio = $\frac{c}{w}\%$

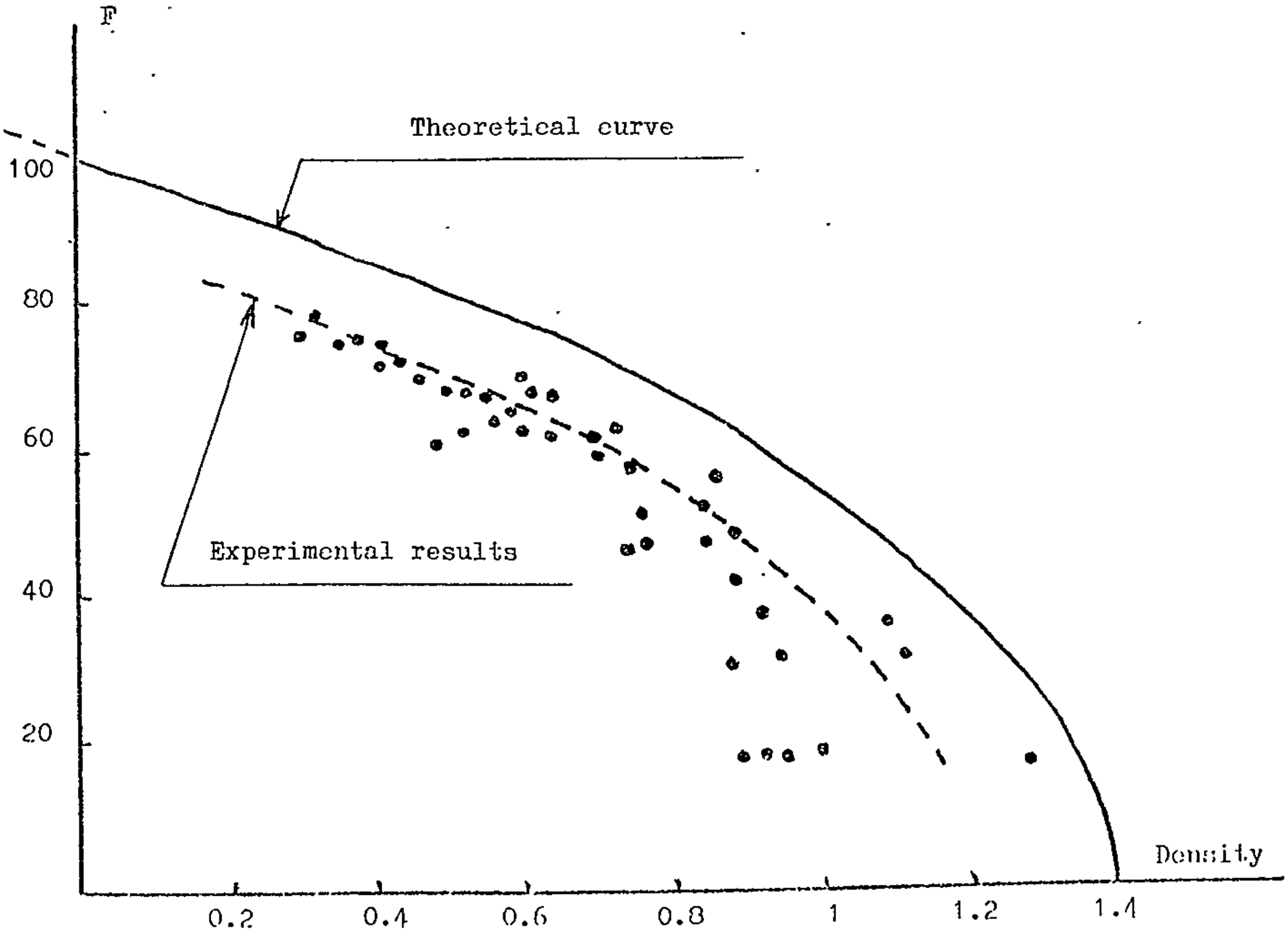
d = wood density
k = density inside the fibers

$$d = \frac{(w^3 - c^2 w)\ k}{w^3} = \frac{(w^3 - w^3 F^2 10^{-4})\ k}{w^3} = k - F^2 10^{-4} k$$

The calculations based on cylindrical fibers lead to similar results.

Correlation

The following graph represents the experimental results from about 40 woods (k = 1.4):



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UTILISATION OF BLEACHED SULFATE TROPICAL HARDWOOD PULP

By

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INTRODUCTION

Guyane is a French department situated in South America, close to the Equator and to the north of Brazil. Its total surface area is 35,000 square miles, and it is overgrown with a hetrogeneous hardwood forest 31,000 square miles (19,840,000 acres) in area. France imports more than one million tons of pulp per year, and the building of a French mill would allow this deficit to be reduced and would develop this department where the only activity is a shrimp fishery and a missile launching base.

DESCRIPTION OF THE FRENCH GUYANA FOREST

A forest inventory was made on 1,600 square miles. Five botanical families represent 35 to 45% of the totality of the forest. About 10 families form about half of the woody potentiality. The dense forest on solid ground extends over 78% of the total forestry zone, of which 73% has a slope of less than 20% and 84% has a slope of less than 30%. In the dense forest, there are 280 m^3 of trees to the hectare, of which 13 to 15 m^3 are lumber and 180 m^3 are pulpwood.

Eighty percent of the trees are between 10 and 20 meters tall, and 36% have a diameter of between 30 and 50 cm.

FULL SCALE LOGGING EXPERIMENT

A full scale logging test was performed over 10 hectares (24.71 acres) in a zone as representative of the totality of the forest as possible, in so far as concerns relief, nature of the soil, and composition, during a period of mean rainfall. The operational method employed was to fell the trees with chainsaws, to cut them to long lengths (less than 17 m), and to skid them with rubber-tired articulated skidders on skidding roads built with bulldozers. Loading onto trucks was performed by means of a grapple loading crane.

The productivity revealed that a site capable of producing 82.77 cords of wood per day, i.e., 20,693 cords per year, requires the following personnel and equipment:

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The productivity revealed that a site capable of producing 82.77 cords of wood per day, i.e., 20,693 cords per year, requires the following personnel and equipment:

Personnel	Equipment
1 Site supervisor	1 Pick-up – 1 office – 1 radioset
1 Assistant supervisor	1 Pick-up – 2 huts
	1 water cisterne, petrol and gas oil
6 Cutters	9 motor-driven saws
6 Buckers-choker setters	9 motor-driven saws
2 Bulldozer operators	2 140 hp bulldozers
3 Skidder operators	3 175 hp skiders
2 Landing chasers and buckers	
2 Chainsaw operators	3 saws
1 Loading crane operator	1 grapple loading crane
1 Loading crane assistant operator	
2 Mechanics	1 workshop van

WOOD CHARACTERISTICS

The characteristics of Guyanese wood are as follows, in comparison with those of other African, European, and American hardwoods.

Density

	(dry weight, dry volume basis)
Guyana	0.83
French hardwood	.59
White birch	.56
Gabon	.60
Ivory Coast (Africa)	.68

Micrometric Characteristics of the Fibers

	Guyana	Beech	Blue gum	Slash pine	Gabon (Africa)	Douglas-fir
Fiber length (L microns)	1500	1050	1000	2200	1450	4000
Fiber width (1 micron)	22.3	19	19	36	22	41
Thickness of walls (2p microns)	14.3	12	11.8	7.6	10.5	8
Cavity (c microns)	8	7	7.2	28.4	11.5	33
Flexibility ratio (c/1 %)	36	38	38	79	51	80
Felting ratio (L/1 %)	68	54	52	64	66	98

Chemical Composition

	Guyane	French hardwoods	White birch	Gabon (Africa)	Douglas-fir
	---In percent---				
Alcohol benzene extract	2.85	2.2	2.8	2.2	4.4
Hot water extract	2.25	3.3	1.5	2	5.6
Sodium hydroxyde extract	14.4	18.5	14.1	--	15.1
Lignin	29.9	23	20	29.5	27.2
Pentosans	13.6	25.6	22.6	14.9	6.8
Cellulose	47.45	40	--	47.1	--
Ashes (425° C)	.92	.5	.4	.6	.2
S_iO_2	.31	.005		.4	
Fe_2O_3	.002	.0005		--	
$Fe_2O_3 + Al_2O_3$	.02	.035		--	
CaO	.18	.14		--	

The values listed for Guyana and Gabon correspond to a representative composition of the forest. Guyanese wood fibers are longer than those of European and American hardwoods, but their lignin content is higher. The density of Guyanese wood is particularly high, which is an advantage from the point of view of wood transportation and the capacity of the pulp manufacturing lines.

PULP MANUFACTURE

Laboratory Tests

Laboratory Tests Performed at Tropical Forestry Technical Center at Nogent-sur-Marne

The tests were performed on a representative composition of the Guyanese forest. Cooking was performed with percentages of total alkali (measured in NaOH), in relation to the wood, which varied from 20 to 24%, and white liquor sulfidities of 20 to 30%. The time taken for raising the temperature from 20° to 170° C was 2 hours, and the 170° C temperature was maintained for 1-1/2 hours. Bleaching was performed in accordance with the following sequences and conditions:

CEHH - CEHD - CEDED - CEDPD - CPDPD

- chlorination at high density (30%) for 5 minutes,
- treatment with low density (5%) chlorine dioxide at 60° C for 4 hours,
- treatment with low density (5%) hypochlorite at 35-40° C for 6 hours,

- treatment with low density (5%) peroxide at 60° C for 1 hour,
- alkaline extractions at low density (5%) at 60° C for 1 hour.

The standard pulp was obtained under the following conditions:

. total alkali in relation to the wood	22% in NaOH
. sulfidity	30%
. raw permanganate number	17.6
. screened pulp yield	45.6%
. photovolt on brown pulp	21%
. DP on holocellulose	1035
. bleaching	CEDED
. chlorine consumed	5.1%
. soda consumed	1.45 + 0.1%
. chlorine dioxide consumed	1.85 + 0.5%
. bleaching yield	96%
. bleached photovolt (on sheet)	91
. bleaching stability	90%
. DP on bleached pulp	965
. copper number	0.45

This pulp was refined in a Jokro mill up to 40° SR (303 CSF) and formed into hand sheets on a Rapid Köthen machine. The comparative characteristics of European hardwood and softwood pulps and the laboratory pulp thus obtained were:

	Guyane	Birch	Beech	Spruce
Refining time (minutes)	40	38	30	45
Breaking length (meters)	6300	9600	7900	11500
Burst	33	64	54	85
Tear	118	75	75	110
Double folds (1000 g load)	16	180	110	1300
Porosity	25	2	8	1.8
Bulk	1.40	1.15	1.25	1.15
Opacity	65	57	63	55

In conclusion, the resistances to tensile breaking, to bursting, and to double folds of the Guyana pulp are low, but the tearing resistance is extremely high and the same applies to the bulk. The breaking length-tear curve of Guyanese pulp places it in a zone which is intermediate between hardwood and softwood pulp.

Laboratory Tests at European Cellulose Group Research Center at St. Gaudens, Performed in April 1976

Cooking was carried out under the following conditions:

- composition of wood representative of the Guyanese forest identical to that employed by the C.T.F.T., but stored for 1 year, thus very dry.
- liquid to wood ratio: 2.8.
- time duration of the increase in temperature from 80 to 170° C: 2 hours. Maintained at 170° C for 1 hour.

. total alkali in relation to the wood (as NaOH), %	23	21
. sulfidity, %	20	20
. kappa number of the screened pulp	23	26.5
. yield of the screened brown pulp, %	45	46
. DP on holocellulose	820	1050

Bleaching was performed under the following conditions:

	Concentration (%)	Temperature (°C)	Duration-hour
. chlorination	3.5	35	0.5
. alkaline extraction	10	40	1
. dioxide 1	5	70	2.5
. alkaline extraction	10	50	1.5
. dioxide 2	5	80	4

The results of the bleaching were as follows:

. kappa number brown pulp	23	26.5
. $KMnO_4$ number brown pulp	15.8	17.4
. chlorine consumed	4.7	5.6
. soda introduced	1.8 + 0.6	2.1 + 0.6
. chlorine dioxide consumed	1.2 + 0.42	1.4 + 0.40
. bleaching yield	93.8	96.3
. bleached pulp yield	43.8	46.2
. brightness	87.6	88
. DP on bleached pulp	680	810

These pulps were refined in a Jokro mill up to 40° SR (303 CSF) and formed into hand sheets on a Rapid Köthen machine. The characteristics of the sheets obtained were:

. kappa number brown pulp	23	26.5
. refining duration (minutes)	39	52
. breaking length (meters)	5510	5135
. stretch (%)	1.5	1.9
. burst	24	27
. tear	98	124
. porosity	17	16
. bulk	1.49	1.46
. opacity	74.8	73.6

The results of the laboratory tests at St. Gaudens are similar to those obtained at the Tropical Forestry Technical Center.

Laboratory Tests Performed at the St. Anne Nackawic Pulp and Paper Company Mill (Canada) in September 1975 and September 1976

1st series of tests:

Cooking was performed under the following conditions:

- logs of wood of marked families which can be separated in two classes--high density families and low density families.
  - active alkali adjusted to give a permanganate number of 20

sulfidity	25%
liquid to wood ratio	3.5
duration of the rise in temperature to 174° C	80 minutes
duration maintained at 174° C	30 minutes
density of wood	0.73--high density 0.48--medium and low density
active alkali in relation to the wood (in Na_2O)	15.1--high density 14.5--medium and low density
$KMnO_4$ number	20.8--high density 20.4--medium and low density
yield of screened pulp (%)	45.68--high density 49.92--medium and low density

Pulp refining tests were performed in a PFI refiner (CPPA-C7 method) and formed into hand sheets in accordance with the CCPA-C4 method. The results obtained were as follows, and are listed in comparison with a *Eucalyptus deglupta* pulp.

Freeness test number 300 CSF (40.3° SR).

	High density Guyanese wood	Medium and low density Guyanese wood	Eucalyptus deglupta
Fiber length before refining (mm)	2.02	1.89	1.52
Number of rotations	6400	6845	7400
Breaking (ml)	8450	9750	11700
Burst	54	64	77
Tear	121	112	95
Double fold TMI	250	464	1200
Bulk	1.74	1.60	1.30

2nd series of tests:

Cooking was performed under the following conditions:

- wood chips from the industrial test performed at the St. Gaudens mill, a representative sample of the Guyanese forest without the very high density wood part,
- active alkali adjusted to obtain a permanganate number on brown pulp of 19.3

. sulfidity	25%
. liquor to wood ratio	3.5
. temperature rise	80 minutes
. maintained at 174° C	30 minutes

Bleaching was performed under the following conditions:

Brown pulp permanganate number	18.7	19.3
- chlorination		
Cl_2% on pulp (including 20% ClO_2)	10	12
Temperature (°C)	20	20
Time (minutes)	30	30
Cl_2 (% consumed)	94.9	85.6
Final pH	1.8	1.7
- 1st alkaline extraction		
NaOH (% on pulp)	4.5	4.5
Temperature (°C)	74	74
Time (minutes)	90	90
Initial pH	11.5	11.6
Final pH	10.9	10.8
Kappa number after extraction	2.7	2.5
CED viscosity	22.5	22.7
- Chlorine dioxide 1st stage		
ClO_2 (% on pulp)	0.95	0.95
Temperature (°C)	74	74
Time (minutes)	120	120
Initial pH	6.2	5.2
Final pH	5.3	3.6
ClO_2 (% consumed)	78.2	88.7
Elrepho brightness	85.1	87.8

- 2nd alkaline extraction

NaOH (% on pulp)	0.8	0.8
Temperature (°C)	74	74
Time (minutes)	90	90
Initial pH	11.0	11.0
Final pH	10.6	10.6

- 2nd chlorine dioxide stage

ClO_2 (% on pulp)	0.5	0.5
Temperature (°C)	74	74
Time (minutes)	180	180
Initial pH	5.8	5.5
Final pH	4.8	4.5
ClO_2 (% consumed)	85.6	75.2
Brightness	90.0	90.6
Viscosity	18.9	17.6

Conclusions of the Laboratory Tests

All these tests show that it is possible to manufacture good quality pulp with a 90-91 Elrepho brightness by:

- cooking the pulp to a permanganate number of 19.
- performing a first bleaching stage with chlorine-chlorine dioxide.
- maintaining a permanganate number of less than 3 after the first alkaline extraction.
- maintaining a brightness of 85 to 87 Elrepho after the first chlorine dioxide stage.

The main characteristics of this laboratory pulp are very good tear and very high bulk, but fairly low tensile resistance and bursting.

Semi-Industrial Tests Performed at Paper Technical Center of Grenoble in July 1975

The tests were performed under the following conditions:

- wood representative of the Guyanese forest under the condition of the tests at the Tropical Forestry Center

- active alkali in relation to the wood	22%
sulfidity of the cooking liquor	30%
liquid/wood ratio	3.8
duration of the temperature rise	60 min from 30° to 120° C 60 min from 120° to 170° C
duration maintained at 170° C	90 min
brown pulp kappa number	20
screened pulp yield	44.3%

- Bleaching conditions

chlorination

. Cl_2 (% on pulp)	5
. temperature (°C)	20
. duration (minutes)	60
. Cl_2 (% consumed)	98
. Final pH	1.9

1st alkaline extraction

NaOH (% on pulp)	2.5
Temperature (°C)	60
Duration (minutes)	60
Final pH	12.2
D.P.	990

1st chlorine dioxide stage

ClO_2 (%)	1
Temperature (°C)	72
Duration (minutes)	180
Final pH	2.1
ClO_2 (% consumed)	98
Elrepho brightness	70.7
D.P.	895

2nd alkali extraction

NaOH (% on pulp)	0.8
Hydrogen peroxide (% on pulp)	.3
Temperature (°C)	75
Duration (minutes)	90
Final pH	11.1
D.P.	835

2nd chlorine dioxide stage

ClO_2 (% on pulp)	1.2
Temperature (°C)	72
Duration (minutes)	180
Final pH	2.6
ClO_2 (% consumed)	66
Elrepho brightness	89.4
D.P.	805

SO_2 treatment

pH	3.5
Elrepho brightness	89.5
Brightness stability (%)	92
°SR	16 (690 CSF)

The mechanophysical characteristics of brown and bleached pulp are, after refining at 40 SR (302 CSF) in a Jokro mill and forming into handsheets on a Rapid Köthen, as follows:

	Brown pulp	Bleached pulp	Canadian hardwood pulp
Duration of refining (minutes)	39	42	--
Breaking length (meters)	7100	6900	6000
Stretch (%)	2.9	3.1	---
Burst	39	37	42
Tear	112	104	66
Double folds	45	25	20
Opacity	--	60	64
Porosity	20	22	6
Photovolt	---	89.5	90
Bulk	1.46	1.40	1.45

The first chlorination was insufficient and bleaching, after the first chlorine dioxide stage, was not up to the 85 to 87 values required. It was necessary to add hydrogen peroxide to obtain an 89.5 brightness. However, the characteristics of the bleached pulp obtained compare very favourably with those of Canadian hardwood pulp.

Full Scale Mill Run at Saint Gaudens

This test was performed at the St. Gaudens mill of the Groupement Européen de la Cellulose d'Aquitaine in May 1976 on 1000 tons of wood, replacing Pyrenean hardwood with Guyanese hardwood and minimizing the oxygen bleaching stage according to the following conditions:

- active alkali in relation to the wood (in NaOH) %	22
- sulfidity of the cooking liquour	20 to 21
- duration of the temperature rise (minutes)	120
- duration maintained at 170° C	60
- loading density (kg bone dry per cu. meter)	268
- KMnO4 number before oxygen stage	16 to 18
- kappa number before oxygen stage	23.5 to 28
- yield on screened brown pulp	45.5
- polymerization degree	865
- KMnO4 hardness index after oxygen stage	10.6 to 11

. Bleaching conditions:

	Concentration %	Temperature °C	Duration time Hr
Chlorination	3.5	25-30	0.50
1st extraction	9	40	2.30
1st chlorine dioxide stage	12	65	.6
2nd extraction with peroxide	9	70	2
2nd chlorine dioxide stage	12	78	.7

Quantities of chemical products consumed in relation to the pulp:

- chlorination	4 to 5% of chlorine (remainder in chlorine 0.5%)
- 1st alkaline extraction	1.6% of soda
- 1st chlorine dioxide stage.	1%
- 2nd alkaline extraction	0.3 to 0.6% NaOH - 0.3% H_2O_2
- 2nd chlorine dioxide stage	0.5 to 0.6% ClO_2
- final brightness	89-90
- degree of polymerization	695
- copper number	0.47

The bleached pulp was refined in a Jokro mill and formed on a Rapid Köthen machine. The results obtained were as follows:

- freeness number	40 SR (302 CSF)
- breaking length (m)	4150
- stretch (%)	2.65
- burst	22
- tear	88
- bulk	1.70
- brightness	88

One obtains the same characteristics as those of the pulps obtained in the laboratory, but the tear has considerably dropped, in a manner which is, up till now, inexplicable.

COMPARISON OF GUYANE PULP CHARACTERISTICS WITH OTHER HARDWOOD PULPS

Table 1 gives the comparison between Guyanese wood pulp and hardwood pulp found on the French markets. The refining was performed in the Escher Wyss refiner of the Cellulose d'Aquitaine laboratory, which reproduces fairly faithfully the results obtained during mill refining. The standards used were as follows:

TABLE N°I

COMPARATIVE RESULTS BETWEEN GUYANA HARDWOOD PULPS AND COMMERCIAL HARDWOOD PULPS.

kWh/100 kg	Pulps	°SR	Permeability	Tear	Break lenght	Stretch	Burst	bulk	Cont. opacity	R	S	K	Dennisson	Initial wet strength	Taber rigidity	Creep	Scott cohesion	CSF
0	SCANDINAVIAN BIRCH	16,2	79	81	2620	1,76	12	1,70	81				4,8					683
10		25,3	21	97	4400	3	24	1,51	77,8				10,2				--	500
20		37,8	8,1	84	5050	3,6	30	1,42	76,5				12,9					328
0	EUCALYPTUS CACIA	17,5	109	57	2760	1,40	11	1,90	82				2					650
10		23,3	52	110	4050	2,60	21	1,62	79,8				7				1	533
20		33	19,5	103	5100	3,40	28	1,50	78,7				10					468
0	GUYANA INDUSTRIAL TEST UNBLEACHED K:19,5	13	188	47,4	1760	1,40	6,8	2,16	79,3	88	383	3,2	2	43	5,50	115		763
10		20	60	85	3350	2,40	17	1,90	78,1	87,8	379	3,3	5,8	100	5,92	71		600
20		33	22	85	4100	2,65	21,5	1,72	77,9	87,1	375	3,8	9,4	130	5,91	51		488
0	GUYANA INDUSTRIAL TEST UNBLEACHED K:26,5	14	227	44,1	1615	1,49	6,7	2,18	78,8	88	378	3,6	2	58	5,70	115	1	738
10		23	44	85	3350	2,49	17,5	1,88	78,7	87,8	374	3,6	5,8	107	6,15	69	1	531
20		35	16	86	4150	2,65	22	1,70	77,9	87,1	368	3,6	9,4	130	5,50	46		363
0	CELLULOSE D'AQUITAINE (FRANCE)	15,5	97	51	1800	1,30	7	1,91	82,6	87,8	449	4,0	2,5	81	4,80	91		700
10		23	35	71	3200	2,60	16,5	1,70	80,7	87,3	418	4,2	8,1	115	5,30	57		531
20		34,5	15,5	66	4125	3,20	23	1,55	79	86,9	394	4,5	10,6	140	4,30	38		369
0	SAINTE ANNE (CANADA)	16	56,3	51,5	2098	1,20	8,5	1,78	82,7	89	466	3,1	3	88	4,70	75		668
10		26	18	67	3600	2,60	19	1,56	81,6	89	430	3,1	8	–	4,30	44		466
20		40	6	68	4450	3,30	24,5	1,45	80,6	87,7	405	3,5	12	–	4,30	30		303

Escher Wyss Refiner: 0.100 and 200 kWh per BD ton of pulp
Forming into sheets, Rapid Köthen, 70 g/m^2 (100 g/m^2 for rigidity)
Conditioning: 20° C, 65% moisture content
Mechanophysical characteristics:

. air permeability	AFNOR standard	Q 03 001
. tearing index	" "	Q 03 011
. breaking length and stretch	" "	Q 03 004
. resistance to bursting	" "	Q 03 014
. bulk	" "	Q 03 017
. contrast opacity	" "	Q 03 006
. R reflectivity		ISO
. S specific dispersion coefficient		
. K specific absorption coefficient		
. wrenching:		Dennison method
. rigidity		Taber method
. absorbency		Klem method
. wet strength: GEC method - force in g, for rupture of a 15 mm broad strip, dryness 20%		

The Guyanese pulp is refined like the Aquitaine pulp, but with greater difficulty than Scandinavian birch pulp and Canadian birch and maple pulps, for an equivalent degree of refining:

- from the point of view of resistance (breaking length and burst) Guyanese wood pulp is slightly better than the Aquitaine and Canadian wood pulp, but inferior to birch and eucalyptus pulp;
- from the point of view of tear, Guyanese pulp is equivalent to Scandinavian birch pulp;
- from the point of view of opacity, Guyanese pulp is slightly inferior to other hardwood pulp, except for Scandinavian birch pulp;
- from the point of view of bulk, Guyanese wood pulp is very much superior to all hardwood pulp on the market.

FULL SCALE PAPER MANUFACTURE

Conditions of Manufacture

The pulp delivered to the client was strictly required to be:

- clean, i.e., to contain less than 30 black dots to the square meter: Guyanese pulp contained a maximum of 12.
- as white as standard 89-90 Aquitaine pulp. Guyanese pulp had a brightness which varied between 88.5 and 90.
- delivered with at least 90% dryness: Guyanese had a dryness which varied between 90 and 94%.

Choice of Paper Manufacturers' Clients

The characteristics specific to Guyanese pulp being the bulk, the tear, and the porosity, the tests were performed on the premises of the following paper manufacturers:

France:

. wood free bulking paper for books	Papeteries de Gorges de Domène - Domène mill
. wood free coating paper	Papeteries Job - Sept Deniers mill
. white front for multiply board	Papeteries Navarre Champ-sur-Drac mill
. paper for printing, writing, and offset	Papeteries Aussedat-Rey - Cran-Gevrier mill
. waterleaf paper for parchment	Papeteries Dalle & Lecompte - Saint Severin mill
. tissue	Sopalin - Sotteville-les-Rouen mill

Germany:

. high bulking paper for books	Peter Temming AG mill - Gluckstadt mill
. high bulking paper for books	Salach Papierfabrik GmbH - Salach mill

Great Britain:

. tissue paper	Sterling International - Stubbins-Bury mill
. paper for printing and writing	Wiggins Teape - Dartford mill

Running of Tests

The Guyane pulp was introduced during manufacture so as to provide a reference, both with regard to the manufacturing parameters and to the finished products. Samples of the paper, tape, and manufacturing recordings were performed once the paper machine was running in a stabilized way.

During the various tests, the Guyanese wood sulfate pulp replaced, partly or totally in the furnish, the following sulfate pulp:

- Cellulose d'Aquitaine (St. Gaudens): blended hardwoods
- Landaise de Cellulose (Tartas): bleached pine
- Aussedat Rey (Saillat): chestnut
- St. Anne-Nackawic Pulp and Paper Company: birch and maple
- Brunswick: softwood
- Algerian esparto grass pulp
- Portuguese eucalyptus pulp

Tests in France

Industrial Manufacturing Tests of Bulk Paper for Books at Papeteries Gorge de Domène

Domène mill - Isère, 15th June 1976. Manufacturing started with the normal composition (mark No. 1). During stage one, Caima pulp (50% of the fibrous composition) was replaced by Guyanese pulp (mark No. 2). Later, all short fibres (80% of the fibrous composition) were replaced by Guyanese pulp (mark No. 3).

This test made it possible to confirm certain points which had already been brought to light by the laboratory studies performed before the industrial test.

- Guyanese wood pulp requires more energy for refining than European hardwood pulps.
- it bulks more than the pulp of the Cellulose d'Aquitaine (C.A.) and also more than that of Caima (eucalyptus sulfite disulfite pulp), very much in demand on account of its bulk.
- it provides a paper which is extremely permeable to air.
- its breaking length is very much the same as that of Caima, and slightly inferior to that of C.A.
- the tear index is practically the same as for Caima and for C.A.
- the paper obtained is less opaque than with the normal composition.

The recordings of the adjustments and the laboratory measurements on the paper obtained are given in tables 2 and 3.

Industrial Manufacturing Test of Coating Paper at Papeteries Job

Sept Deniers mill, 23rd June 1976.

- the tests bore on two manufactures of coating paper, 95 g/m^2 and 169 g/m^2. In both manufactures, the Guyanese pulp was used to replace the Cellulose d' Aquitaine pulp: 24% in the 95 g/m^2 and 48% in the 169 g/m^2.

The characteristics of the paper obtained during this test confirms what the laboratory tests could anticipate that:

- Guyanese wood pulp is more difficult to refine than that of European hardwood.
- it has more bulk.
- its use results in a paper more permeable to air and less opaque.

In this test, it was also noted that there was an improvement in the mechanical characteristics, but, in our opinion, this must be attributed

TABLE N° 2

GORGES DE DOMENE - PAPER MILL

SETTING STATEMENTS

BULKY BOOK PAPER

ITEM	REFERENCE	TEST N°I	TEST N°2
Composition :			
Iggesund flash (long fibers)	20%	20%	20%
Caïma (eucalyptus)	50%	-	-
Cellulose d'Aquitaine	30%	30%	-
Guyana wood pulp	-	50%	80%
Refining:(blended pulps)			
I DD Beloit 20" kw	160	160	160
Approximative flow kg/h	2000	2000	2000
kwh/I00kg	8	8	8
Consistency	3,5	3,5	3,5
° SR screened stock	25	24	22
Machine :			
Machine head refining			
2 Jones intensity A	60 A	60 A	60 A
Output kg/h	2210	2210	1967
Speed m/mn	191	191	170
headbox consistency g/l	8,7	7,3	6,8
headbox ashes %	24	24	25
Suction boxes vacuum mm Hg	115	95	80
Millspaugh vacuum I "	230	180	170
2 "	360	300	240
Ist press vacuum	250	250	220
Pressure Ist press kg/cml	17	21	21
2nd press "	22,9	28,6	28,6
3rd press "			
Steam flow t/h	6,8	6,8/7	6
Steam consumption t/t	3,08	3,08/ 3,17	3,05
Reel humidity %	4,5	4,5	4,5

TABLE N° 3

GORGES DE DOMENE - PAPER MILL

LABORATORY MEASUREMENTS

BULKY BOOK PAPER

Characteristics were measured by G.E.C. St Gaudens laboratory
conditioned paper 24 h 20°C RH 60%

ITEM			REFERENCE	TEST N°I	TEST N°2
Composition :					
Iggesund flash (long fibers)			20	20	20
Caïma (eucalyptus)			50	-	-
Cellulose d'Aquitaine			30	30	-
Guyana wood pulp			-	50	80
Basic weight	g/m2		102,9	101	99,0
Ashes at 600°C	%		9,9	9,9	9,9
R ∞			81,5	83	83,2
R 0 brightness			77,5	76,7	76,6
S cm2/g			475	410	415
K cm2/g			9,9	7,1	7,0
Contrast opacity			90	87,8	87,8
Bulk			1,75	1,73	1,85
Air permeability			16,4	21,9	26,8
Burst			13,9	14,5	13,5
Breaking length	m	MD	4124	4114	3659
		CD	1943	1947	1915
		Aver.	3034	3030	2787
Stretch	%	MD	2,2	2,2	2,1
		CD	3,6	3,9	3,6
		Aver.	2,9	3,1	2,85
Tear	I/IOO	MD	72,5	63,3	70
		CD	75,1	71,3	72,7
		Aver.	73,8	67,3	71,4
Taber rigidity					
Wire side concave		MD	6,3	6,3	6
		CD	4,1	3,5	3,8
Wire side convex		MD	5,6	5,4	5,2
		CP	2,6	2,8	3,1
Average		MP	5,95	5,85	5,6
		CD	3,35	3,15	3,45
		Aver.	4,65	4,50	4,52
Dennisson			9/II	II/II	II/II

TABLE N° 4

JOB - SEPT DENIERS - PAPER MILL

SETTING STATEMENTS

COATING PAPER

BASIC WEIGHT	95 g/m2		169 g/m2		
	REFERENCE	TEST N°1	REFERENCE	TEST N°2	
				Begining	End
<u>Composition</u>					
Norland bleached LF X	23,5	24,5			
Eucalyptus	17,6	18,4			
White birch	5,9	6,1			
Cellulose d'Aquitaine SF X	22	–	49	–	
Guyana wood pulp	–	23		51,5	
Mecanical pulp	3	3	3	3	
Waste	28	25	30	28	
Tarascon bleached LF	–	–	18	17,5	
Refining blended pulps					
3 hydrafiner intensity	3 x 120 A	3 x 120 A	4 x 120 A	4 x 120 A	4 x 120
I twinhydradisc "	250 A	250 A	300 A	300 A	300
°SR virgin pulp	–	26,5/28	36/37	24	29
<u>Paper machine</u>					
Head of machine refining					
I twinhydradisc intensity	290	290	290	290	290
Output kg/h	–	4092		4190	4190
Speed m/mn	–	252	145	145	
Suction boxes vacuum					
before Dandy roll mmHg	150	150	120/180	130	150
after " " "	190	190	170/200	190	190
Millspaugh vacuum "	280/300	230			
Pressure Ist press kg/lcm	18/17	17	13/17	17	17
2nd " "	25/27	27	22/27	27	27
3rd " "	30/36	35	32/40	33	35
Steam pressure before size press	0,9/2,6	1,4	1,5 à 2,8	2,1	2,3
after " "	1,6/2,4	2,5/2,6	1,5	2,2	1,4
Steam consumption	9à10,2T/h	9,6 T/H	8,4/10	9,8	
Size press treatment %	Amisol16,5	Amisol 8	Amisol 16,5	Amisol 8	

X LF long fibers pulp

XX SF short fibers pulp

TABLE N° 5

JOB - SEPT DENIERS - PAPER MILL

LABORATORY MEASUREMENT

COATING PAPER 95 g/m2 - I69 g/m2

CHARACTERISTICS WERE MEASURED BY G.E.C.. ST GAUDENS LABORATORY -
Conditioned paper 24 h 20°C 60% RH

THEORIC BASIC WEIGHT		95 g/m2		169 g/m2	
		REFERENCE	TEST N°I	REFERENCE	TEST N°2
Base weight	g/m2	91,7	97,9	173,4	174,7
Ashes at 600°C	%	16,5	12	10,3	6,3
Contrast opacity		87,2	86,9	95,7	94,5
Brightness.		85,2	84,3	86,1	85,7
Light dispersion power 5 cm2/g		463	416	484	415
Light absorption power K cm2/g		5,9	6,1	5,4	4,9
Air permeability		6,4	7,5	9,1	13,7
Bulk		1,37	1,49	1,43	1,56
Burst		21,4	26,9	16,6	21,1
Breaking length	MD	5520	7036	5049	5965
	CD	3368	3495	2396	3180
	Aver.	4444	5266	3723	4573
Stretch	MD	2,3	2,4	1,9	2,3
	CD	6	5,9	5,7	5,2
	Aver.	4,15	4,15	3,8	3,75
Tear I/I00	MD	69,8	80,3	65,7	85,8
	CD	72,7	88,5	66,9	91,6
	Aver.	71,3	84,4	66,3	88,7
Taber rigidity same basic weight	MD	4,3	4,6	52	66
As reference paper	CD	3,4	2,8	26,5	42,5
	Aver.	3,85	3,7	39,3	54,3
Dennisson felt/wire side		20/20	20/20	19/19	21/21

TABLE N° 6

PAPETERIES NAVARRE - CHAMP SUR DRAC PAPER MILL

SETTING STATMENTS

PAPER BOARD - WHITE RECTO - SUGAR BOX TYPE

	Grey board white recto Glazed sugar box type	
	REFERENCE	TEST
Board structure		
White recto S_I: number of plies	2	2
weight g/m2	7I,3	75,2
Intermediate C_I number of plies	I	I
weight g/m2	4I,5	40,5
Verso S_2 number of plies	I	I
weight g/m2	29,6	32
Total basic weight g/m2	32I	322,4
Recto side composition		
Bleached sulfite long fibers		
Tartas	I8%	-
Strasbourg	60%	60%
Bleached sulfate long fibers		
Tarascon	-	-
Bleached sulfate short fibers		
Aquitaine	22%	-
Guyana	-	40%
Recto side refining	blended	
Duocycle duration	45 mn	60 mm
Applied power kW	2 x 70	2 x 70
Flow l/mn	I000	I000
Consistency %	4,5	4,5
Consumed power kWh/I00 kg	3,9	5,2
°SR	36-43	40
Board machine		
Speed m/mn	47	47

to the modification of the enduction on the size-press rather than to the Guyanese wood pulp.

Industrial Manufacturing Test of White Front for Multiply Board at the Papeteries de Navarre

Champ sur Drac mill, 13th July 1976.

- Guyanese wood pulp was used as a replacement for a blend of bleached softwood sulfite pulp of Tartas and Cellulose d'Aquitaine beech for the glazed white front of a multiply board of the "sugar box" type.

This test brought to light:

- an increase in the power necessary for refining.
- an improvement of the bulk and of the porosity.
- an increase in the rigidity ratio and a reduction of the mechanical characteristics. It is possible that for these two points, the changes observed result from the board itself (which is composed of old papers) rather than from the front.
- the drop in the brightness is most probably a consequence of the low degree of opacity of the Guyanese pulp.
- Guyanese pulp replaced a considerable part of the long fibres pulp of the initial furnish, without giving rise to any problems during run on the machine.

The recording of the adjustments and the laboratory measurement on the papers obtained are given in tables 6 and 7.

Industrial Manufacturing Test of Offset Wood Free Dry Finish Paper and "3 Epis" Offset Paper at Papeteries Aussedat Rey, Cran-Gevrier Mill

Manufacture started with normal composition, then Saillat short fibres pulp was replaced with Guyanese wood pulp.

The mechanical characteristics obtained with the Guyanese pulp were very similar to those obtained with the reference paper.

A slight increase in the bulk was observed after dry finish but also a reduction of the Beck smoothness.

As during the previous tests, a slight higher degree of dye absorption was noted on the size-press: 26 litres/100 kg with Guyanese pulp as against 22 litres/100 kg with the reference paper.

The recordings and the laboratory measurements on the two manufactured papers are given in tables 8 and 9.

TABLE N°8

AUSSEDAT-REY - CRAN-GEVRIER PAPER MILL

WOOD FREE OFFSET DRY FINISH PAPER. I40 g/m2

	REFERENCE	TEST
Composition		
Saillat (pine)	50%	49%
Saillat (chesnut)	37%	–
Guyana pulp		35%
Broke	13%	16%
Refining	blended	blended
Consistency %	3,15%	3,6%
° SR screened pulp	30	31
Paper Machine		
Head box consistency	0,96%	1,0%
Head box °SR	43	42,5
Trimmed width	272 cm	272 cm
Speed	162 m/mn	162 m/mn
Laboratory measurements		
Basic weight g/m2	140	140
Ashes %	21,5	18,5
Breaking length MD	4250	4150
Ratio MD/CD	43%	48%
Burst	24	22,5
Tear I/IOO	88	94
Air porosity	1,96	3,6
Dennisson	12	12
Bulk	1,04	1,08
Beck smoothness	99	62,5

TABLE N° 9

AUSSEDAT-REY - CRAN-GEVRIER PAPER MILL

UNGLAZED OFFSET "3 EPIS" I72g/m2

Composition	
Saillat (pine)	49%
Guyana wood pulp	35%
Broke	16%
Laboratory measurements	
Basic weight g/m2	171,7
Ashes %	22
Contrast opacity	97,3
Brightness R ∞	85,2 (without optical bleacher 81,9)
R 0	84,5
S cm2/g	639
K cm2/g	8,2
Air permeability	4,4
Bulk	1,28
Burst	14,8
Dennisson	14/13

	MD	CD	AVERAGE
Breaking length m	4200	1760	2980
Stretch %	2,3	5,1	3,7
Tear index I00	99,3	109	104
Taber rigidity			
Wire side concave	40	20	
Wire side convex	36	17	
	38	18,5	28

TABLE N°7

PAPETERIES NAVARRE CHAMP SUR DRAC PAPER MILL

LABORATORY MEASUREMENTS

PAPERBOARD WHITE RECTO GLAZED

SUGAR BOX TYPE

	REFERENCE	TEST
Basic weight g/m2	321	322.4
Thickness (microns)	444	478
Bulk	1,38	1,48
Humidity	5,3	5,3
Burst (Mullen index)	15,6	13,3
Kodak rigidity MD	40,2	38,7
CD	13,2	14,5
rapport MD/CD	0.33	0.375
Ashes	9	8,7
Brightness	80/80.5	79/80
Cobb sizing 45" Recto	60	25/40
Verso	110	25/70
Basic weight ply S.I	71,3	75,2
C.I	41,5	40,5
S.2	29.6	32
Air porosity	3,10	5,3
Medium plies adhesion	12/12.2	8.8/13.8
Delaminating level	Int.	S.1-Int.

Industrial Manufacturing Test of Waterleaf Paper To Be Sulphurized and Parchmentized

Papeterie Dalle et Lecompte - Saint Severin (Charente).

During testing, the only difference noted between the Cellulose d'Aquitaine pulp normally used and the Guyanese pulp concerned the refining speed: the Guyanese wood pulp takes longer to refine.

The characteristics given in table 10, measured by the Groupement Européen de la Cellulose laboratory at Saint-Gaudens, did not bring to light any significant differences between the reference and the test, either on waterleaf paper to be sulphurized or on parchment, with regard to the mechanical characteristics.

On the other hand, a considerable increase was noted in the bulk and also better absorbency which is an extremely important quality in the sulphurization operation.

Tests in Germany

The tests took place at the Peter Temming Paper Mills at Gluckstadt and Salach Papierfabrik at Salach, in June 1976. They bore on the manufacture of bulk paper for books. The introduction of Guyanese wood pulp in the composition provided an increase in the bulk of the paper, the elimination of the esparto pulp, and the reduction of the percentage of long fibres pulp.

The recordings of the adjustments and the laboratory measurements on the papers obtained are set out in tables 11 and 12.

Tests in Great Britain

Industrial Manufacturing Test on Facial Tissue at Sterling International Paper Mill

Stubbins Works - Bury, Lancashire - October 1976.

The tests bore on the manufacture of facial tissues, 15 g/m^2. During the initial stage of the test, Arbocel pulp replaced St. Anne hardwood pulp and 50% of the softwood pulp was retained. The results from the point of view of quality were positive, the Arbocel fibre percentage was increased to 60%, thus reducing the softwood pulp to 40%. The speed of the machine was kept at 800 m/min and the quality produced was satisfactory.

The introduction of Arbocel at 50% and then 60% did not affect either the running of the machine nor the quality of the product. The sheet retained its breaking length strength. The tissue was a little more bulked and soft. Unfortunately, no data are available concerning absorption. The replacement of 10% of the softwood pulp shows that some savings may be possible.

TABLE N° IO

DALLE ET LECOMTE
ST SEVERIN PAPER MILL
LABORATORY MEASUREMENTS
WATERLEAF PAPER AND PARCHMENT

	Waterleaf paper		Parchment	
	Reference	Test	Reference	Test
Composition				
Long fibers	35	35	35	35
Cellulose d'Aquitaine	65		65	
Guyana wood pulp		65		65
Basic weight g/m2	43,4	45,5	46,9	46,9
Air permeability	1,37	2	–	–
Bulk	1,66	1,75	1,17	1,22
Thickness	1,93	1,98	1,30	1,32
Burst	23	24	38,3	32
Breaking length MD	5529	5128	7850	7818
CD	3150	3663	4619	4868
average	4340	4396	6235	6343
Stretch MD	2,5	2,3	2,5	2,7
CD	4,8	5,2	10,9	10,7
average	3,7	3,8	–	–
Tear index IOO				
MD	70,7	87,9	51,1	51,1
CD	76,8	84,9	54	51,1
average	73,8	86,4	52,6	51,1
Absorbency				
MD	35	45	0	0
CD	35	45	0	0
average	35	45	0	0

TABLE N°II

SALCH AND TEMMING PAPER MILL

SETTING STATEMENTS

PAPER MILL	TEMMING	SALACH
1. Pulp preparation Refiners		
Mark	Claflin	Dorries
Type	3	3-3C 60K
Consistency bone dry %	5,0	5,0
Refining °SR	20-30	28
Blended pulp refining	yes	yes
2. Paper Machine	Voith	Bruderhaus
Width cm		350
Trimmed width cm	225	340
Speed m/mn	210	230
Head box consistency %	0,8	0,6
Vacuum	N.A.	N.A.
Pressure	N.A.	N.A.
Drying part inlet siccity	30	30
" " outlet "	6,5	6,5
Steam consumption		
T steam/T paper		2,9

TABLE N°I2

SALACH AND TEMMMING PAPER MILL
LABORATORY MEASUREMENTS
BULKY BOOK PAPER

Samples	Salach 1			Salach 2			Temming 90 g/m2			Temming 100 g/m2		
Composition %	soft wood : 28,4 birch : 14,2 eucalyptus: 0 beech/maple 14,2 esparto : 14,2 guyana- : 29			14 14 29 0 0 43			soft wood : 25 beech/maple 50 guyana : 25			25 25 50		
Basic weight g/m2	103,9			98,7			87,8			96,7		
Ashes 600°C %	4,2			3,5			5,8			3,2		
Thickness	I,97			2,02			2,II			2,46		
Bulk	I,87			2,12			I,99			2,31		
Constrast opacity	89,1			88			88			90,5		
Brightness R	81,8			82,8			83			78,9		
Specific absorption K	8,7			7,8			8,4			14		
Specific dispersion S	429			438			484			496		
Air permeability	27,3			45,1			51,2			55,7		
Burst index IOO	23,1			22,3			13,7			13,4		
Dennisson wire/felt	19/19			19/18			9/8			9/8		
	MD	CD	Av.	MD	CD	Av.	MD	CD	Av.	MD	CD	Av.
Breaking length m	5555	2950	4253	5065	2837	3951	3569	1974	2771	3170	2068	2619
Stretch %	2,8	4,5	3,7	2,8	5	3,9	2,1	3,3	2,7	2,3	3,7	3,0
Tear Index IOO	93,6	105,2	99,4	95,9	95,9	95,9	89,6	91,1	90,4	84,1	86,8	85,5
Taber Rigidity												
Wire side concave	8,1	4,8		8,3	5,3		5,5	3,5		7,6	5,2	
Wire side convex	7,1	4,2		7,2	4,2		4,6	2,7		7,1	4,7	
Average	7,6	4,5	6,1	7,8	4,8	6,3	5,0	3	4	7,4	5,0	6,2

The only adjustment recorded was that of the speed of the machine, 2625 ft/min, which was not modified during the test.

The laboratory measurements are given in tables 13 and 14.

Industrial Manufacturing Test of Bulked Paper for Printing at Wiggins Teape Paper Mills

Dartford mill.

The tests bore on the manufacture of bulk paper for duplicating, 70 g/m^2, whose normal fibre composition is as follows:

	(Percent)
. Celbi hardwood pulp	41.7
. Sidi Yahia hardwood pulp	16.7
. Softwood kraft pulp	33.3
. broke	18.3

This quality paper is produced on a 203 cm machine at a speed of 134 m/min, producing approximately 1.14 tons/hour.

The pulp is thus only refined very slightly, which means that the defibering facility is thus of practical importance.

At the request of their research group, the initial change was extremely prudent: only the Sidi Yahia sulphate pulp was replaced by Guyanese wood pulp, i.e., 16.7%. The rest of the composition was unchanged.

The results were good. The basic weight of 70 g/m^2 was retained. The formation of the sheet showed no change.

Following the initial results, the percentage of Arbocel pulp was increased to 33.3%. During this part of the test, the duplicating paper had the following fibrous composition:

	(Percent)
. Celbi hardwood pulp	25.0
. Arbocel hardwood pulp	33.3
. Softwood kraft pulp	33.3
. broke	18.4

The test was a success. The paper had a uniform formation and an excellent lint-free surface.

The laboratory measurements are given in table 15.

TABLE N°13

STERLING STUBBINS LTD – BURY PAPER MILL

FACIAL TISSUE

COMPOSITION												
Softwood pulp	50	50	50	50	50	50	TRANSITION		50	50	50	
Guyana pulp									50	50	50	
Harwood pulp (St Anne)	50	50	50	50	50	50						
												SPEC.
Roll number	1129	1131	1133	1135	1137	1139	1141	1143	1145	1147	1149	
Basic weight g/m2	15.6	15.0	15.1	15.1	15.0	15.5	15.7	15.9	15.8	16.0	16.2	15.0
Bulk 12 plies	.052"	.054"	.048"	.045"	.048"	.046"	.048"	.048"	.049"	.048"	.051"	.050"
Breaking length m machine direction	614	598	632	610	628	612	622	656	618	592	666	500
Breaking length cross direction	252	258	252	268	220	240	240	252	258	262	270	150
Strech MD/CD %	18.8	18.4	15.2	14.6	17.2	14.4	16.6	17.2	15.5	15.2	17.0	15%

TABLE N°I4

STERLING STUBBINS LTD - BURY PAPER MILL
FACIAL TISSUE
LABORATORY MEASUREMENTS

COMPOSITION Soft wood pulp Guyana wood pulp	40 60	40 60	40 60				40 60	SPEC
Roll number	1151	1153	1155	1157	1159	1161	1163	
Basic weight g/m2	15.9	15.9	16.5	15.8	15.5	15.4	15.9	15.0
Bulk I2 Plies	.054"	.053"	.054"	.051"	.053"	.051"	.054"	.050"
Breaking length g Machine direction	564	558	572	490	500	644	662	500
Breaking length g Cross direction	262	292	250	234	244	268	266	150
Stretch %	17.6	17.8	16.7	14.1	17.4	16.6	17.0	15%

TABLE N°I5

WIGGINS TEAPE - DARTFORD PAPER MILL

BULKY DUPLICATING PAPER

LABORATORY MEASUREMENTS

Composition		%
Celbi (Eucalyptus)		25
Guyana wood pulp		33,3
Long fibers Kraft		33,3
Broke		I8,4
Basic weight g/m2		71,2
Ashes at 600°C %		14,3
Bulk		1,75
Thickness		1,82
Air permeability		29,2
Brightness		76,6
Brightness (basic UV)		75,8
S cm2/g		590
K cm2/g		21
Tappi constrast opacity		90,5
Burst		16,5
Breaking length m	MD	4275
	CD	3511
	Aver.	3893
Tear	MD	102
	CD	114,6
	Aver.	108
Dennisson		14/12

Comparison of Paper characteristics Before and After Use of Guyanese Wood Pulp

The Guyanese wood pulp manufactured at Cellulose d'Aquitaine was used to replace European hardwood pulp in the composition of several types of paper:

- bulked paper for book
- base for coating
- wood free offset
- white front for multi-ply board
- waterleaf paper to be sulphurized

These tests made it possible to confirm the results obtained by comparing, in the laboratory, the Guyanese wood pulp with the traditional hardwood pulp of Cellulose d'Aquitaine:

- more difficult refining
- very close mechanical characteristics
- slightly inferior opacity
- superior porosity
- increased absorption power
- highly superior bulk
- more irregular surface condition

The on-machine running of paper with Guyanese wood pulp furnish did not set any problems even at a very high percentage (80%). The following was noted:

- better draining at the wet part
- higher degree of absorption on the size press
- total absence of linting at the wet part, contrary to what we had been led to expect by the presence of large vessels in the pulp.

Quality of the paper:

- bulked paper for printing and writing

  Guyanese wood pulp makes it possible to obtain a better bulk than that obtained with the eucalyptus pulp which has the highest known degree of bulk on the market; a paper which is extremely permeable to air, with a breaking length and tear very close to those obtained with the beech or eucalyptus pulps. With no modification of the filling percentage, absorption on the size press was higher, opacity a little lower, while rigidity remains identical to that obtained with beech or eucalyptus pulps, and the surface finish, although inferior, is above standard.

- base paper for coating

  Guyanese wood pulp provides a less opaque and slightly less regular paper, but it should be noted that the bulk and the tear are of lesser interest in this type of paper, and that the qualities of the Guyanese pulp cannot be valorized.

. multi-ply board with white front

The low degree of opacity of the Guyanese pulp led to a reduction of the brightness of the board, which however possesses a greater degree of bulk and of stiffness. The noted irregularity of the surface would appear to be less favourable for printing; this requires confirmation.

. wood-free dry finish and sized offset printing paper

The replacement of chestnut pulp with Guyane pulp led to an increase of the bulk and absorption and a reduction of the dry finish; the other characteristics remain very similar. No problem was noted during running through the machine.

. waterleaf paper to be sulphurized

The replacement of Aquitaine pulp with Guyane pulp led to an increase of refining, a considerable increase of the bulk, of the tear, and of the level of the absorbency, which is an extremely important quality in the sulphurization operation. The other physical characteristics are fairly similar and no difference in the behaviour on the machine was noted.

. facial tissue

The replacement of St. Anne pulp and of 20% of the softwood pulp with Guyane pulp did not affect either the running on the machine or the characteristics of breaking resistance.

. bulked paper for duplicating

The replacement of the eucalyptus pulp with Guyana pulp provided excellent results. The paper had a uniform formation and an excellent surface without lint.

Guyanese hardwood bleached sulphate pulp is thus commercially acceptable on international markets for the manufacture of a large range of white paper and boards.

SOME POINTS TO CONSIDER IN IMPROVING THE UTILIZATION OF TROPICAL FORESTS

By

Pedro M. Picornell

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SOME POINTS TO CONSIDER IN IMPROVING THE UTILIZATION OF TROPICAL FORESTS

By

Pedro M. Picornell

In the face of a world economy confronted by an ever increasing demand for wood, improving the utilization of tropical forests has assumed importance and urgency. This is because:

1. In many countries where tropical forests were once thought to be inexhaustible, it is now realized that if something is not done right away, these countries may be running out of such forests in the near future. Consequently, the proper utilization of the remaining forests has become essential to increase their value, extend their life, and help pay for extensive reforestation and other remedial programs.

2. In many tropical countries, the timber which could be easily and cheaply extracted is already gone. The remaining timber is located in areas where extraction is difficult and expensive. Consequently, utilization must be maximized to keep costs down, and extraction economical.

3. In many tropical countries, shifting agriculture has not yet been successfully contained, extensive forest lands continue to be destroyed, and effort must be made to curb shifting cultivation, or in the very least, get the timber harvested ahead of the cultivators. One very effective way of controlling shifting cultivation is by increasing the availability of jobs in the area and this can be done by increasing the utilization of tropical hardwoods.

4. Recent technological developments in developed countries have resulted in products which now compete with some of those coming from tropical woods. Consequently, it is now very important to keep the cost of products from tropical timbers at competitive levels.

5. The remote location of most of the remaining tropical timber stands make the transportation of products from these difficult and expensive, this adding to their cost at point of use. Again, improved utilization is the answer to keep costs down.

At the outset, I must point out that because of the diversity of conditions in countries with tropical woods, I will confine my paper to general principles applicable to most areas with tropical forests rather than go into cases specific to any one country. I am using as my base my actual experience in the Philippines and Indonesia, and observations made in other places where such forests exist.

Also, I must stress that I am not a forester and I am not speaking from a strictly technical point of view. However, I have been involved in planning the utilization and marketing of products from tropical forests for over 25 years and I believe that I have some experience in both the marketing and manufacturing fields that may be useful to some of you in these fields. Nothing which I will say will be new to you. You must have heard some points I will bring up at one time or another. What I will try to do is to organize all of these methodically so as to give you a clear picture of the problems we face in improving the utilization of tropical forests, and some possible solutions to these.

There are three fundamental characteristics of tropical forest stands which affect their utilization. These are as follows:

1. Tropical forest stands usually contain a great number of species. The properties of the wood from these vary greatly from species to species, and, in many cases from the point of view of utilization, different species cannot be put into the same uses.

2. Most tropical timber stands are not even-aged. At any one time, there are trees of any one of the species starting to grow, maturing, and beginning to die. A characteristic of an overmature tree in a tropical timber stand is that it starts to rot the moment it reaches maturity, and many tree species start rotting through the center. Consequently, the quality of wood that can be expected to come from any particular species within a particular timber stand can be very varied.

3. Tropical forest stands, from the commercial point of view, have a very diverse species composition with a corresponding wide range of marketability. Timber extraction has tended to be confined to some species favored in the market, leaving inferior residual stands of species with hardly any, or no marketability at all. Likewise, the market has preferred the better grade of logs, leaving the low grades with hardly any market at all.

For many years in the past, tropical woods were considered luxury items, and only the high grades of the most desired species were sold in the export markets. Little effort was made to develop markets for the lower grades and for the less popular species available. This was so because the profit margins earned from the sale of the high grades, due to easy extraction and good demand, resulted in very profitable operations. Also, domestic markets for the lower grades which could not readily be exported were not available because of the remote location of the sources of this timber and their small population with very limited purchasing power.

Thus, for many years only the best wood from a very small number of species available in a tropical forest stand found their way in the international timber market, mostly in the fields of fine paneling and fine cabinet making, this being due to the excellent qualities of these woods as far as grain, figure, and ability of taking finishes. Many other species found in tropical timber stands do not have these characteristics, but do make very good construction timbers. However, it is not easy to export construction-type timber because very many other countries have construction timbers of their own. Moreover, there are many other construction materials which compete with wood such as steel, concrete, aluminum, and others. Also, the very high freight on timber products makes it difficult for tropical construction-type timber to compete with other materials of construction in other countries. All these limited the development of a good market for tropical woods used as construction timber.

Very recently, the development of printing, overlayment, plastic lamination and other prefinishing processes for plywood and composition board have permitted the wider use of other species and lower grade woods existing in tropical forests. It has been found that many tropical woods which have not previously found use in the manufacture of high quality plywood, because these did not have the grain or figure, can now be used because of their ability to take the necessary finishes. A lot of more work still has to be done in the proper gluing of veneers of different species of wood, and in the preparation of surfaces to take on the necessary finishes. Much work is being done along these lines and this has contributed substantially to the increased utilization of tropical woods.

Much work is also being done in the use of mixed tropical species in the manufacture of composition board (particleboard, hardboard, medium density board, etc.). This has met with considerable success by keeping the composition of the mix of raw materials going into the process as constant as possible. More on this later on. However, as almost any country which has any type of fiber can develop some kind of a composition board industry (straw, baggasse, low quality wood, etc.) composition board made out of tropical woods, when exported, is placed at a great disadvantage, because after having to pay high freight rates, it still has to compete with cheaper domestic products.

Recent developments in the use of mixed tropical woods in the manufacture of pulp and paper will greatly contribute to the improved utilization of tropical timber stands. Most of the species found in a tropical timber stand can be pulped although cooking cycles and chemical consumption can vary widely. However, species with characteristics similar enough can be grouped together and pulped together. It is surprising how these groupings can be reduced to a relatively small number considering the very many species that are normally found in the timber stands. What is very important is to have a good record of the distribution of species within the area of forest operations and to plan the extractive operations so that these are distributed over an area wide enough so that by proper planning, the timber coming to the processing area can be blended so as to have a more or less of a constant mix over a given period of time. It may also be necessary to have a number of stockpiles by groups of species and do further blending as the wood is fed to the mill. Considering that extractive operations in tropical timber stands, if properly planned, can be carried over the entire year, these stockpiles need not be very large, and this entire operation can be carried out efficiently and relatively inexpensively. Such an operation is also very handy in planning the wood supply for feeding plywood mills and sawmills where it is also important to insure a uniform feed of raw materials in order to have a reasonable control of the resulting product mixes. The computerization of the recording of the standing timber, the stocks of wood in the yard, work in process, and finished products can be very useful at this point.

Another very recent development which has helped improved the utilization of tropical timbers is the use of waste wood in the generation of steam and electrical energy. Before the energy crisis, it was difficult to justify the additional investment required for the use of wood in the large scale generation of steam and electrical energy, specially when high pressures are used. With the advent of the energy crisis, the situation has definitely changed although the economics of doing this are still quite sensitive to the distance wood has to be transported to get it to the power station. Also, more research has to be done on the design of boilers to burn wood to generate high-pressure steam more efficiently, and it may be that to do so, wood may have to be burned in combination with fuel oil or other fuels. Again, a certain amount of segregation of species may be necessary to insure as homogenous a feed as possible, and waste heat exchangers or dryers could be designed to dry the wood as much as possible before introducing it into the combustion chambers for more efficient combustion. The use of waste wood, and even the growing of certain fast-growing species specifically for use as fuel in the large scale generation of steam and electrical energy, are definite ways in which to improve the utilization of tropical timber stands. This is much more important in developing countries which often do not have their own supply of oil or other adequate energy generating facilities available in developed countries which have extensive and well-developed energy-generating stations and extensive networks for energy distribution.

Another big problem in improving the utilization of tropical timber stands is to find uses for the lower grade wood coming from species which otherwise have acceptable characteristics. The products from tropical timber stands are presently exported in the raw form (logs or squares) or in a semi-manufactured form (rough or dressed lumber or sanded plywood) to developed countries where they are further processed into finished products. The main constraint in shipping the lower grades (of quality) of otherwise acceptable species is the freight factor which forms a substantial proportion of the landed cost of these timber products. As freight is usually based on volume and it is the same for a prime grade piece or a low grade piece, and, as the product recovery from the lower grades is usually substantially below that from the higher grades, the wood from a low grade piece becomes much more expensive than that from a high grade piece, even if the unit f.o.b. price paid at source is substantially lower. As most of the processes involved in finishing a semi-finished piece of wood are labor-intensive, the most logical step to be taken both from the point of view of the supplying country and the importing country is to have as much of the processing done at the source. This has the following advantages:

1. Cheaper, lower quality primary materials can be used.
2. There can be better waste utilization (provided the primary operation has been set up with the necessary installations to do this).
3. Advantage can be taken of the usually lower labor costs in the countries wherein the tropical timber stands are found.

Of course, it may not always be advisable for developing countries to go into the manufacture of completely finished products for export to developed countries but, with the increasing use of standardized components all over the world, countries with tropical timber stands should go more and more into the manufacture of components instead of limiting themselves to producing rough and dressed lumber and sanded plywood. This will result in advantages to both buyer and seller because:

1. The processor can use lower grade wood products that otherwise cannot be sold abroad.
2. Any waste generated can be used right there at point of manufacture, thus improving the utilization of the timber stand.
3. Uses can be developed for species not presently exported, perhaps for hidden parts.
4. The buyer can take advantage of the usually lower labor rates obtaining in the countries where tropical timber stands are located.

On the other hand, developing countries who want to get into the manufacture of components should realize that:

1. Tolerances and standards of quality for components are usually much more exacting than for rough and finished lumber and sanded plywood, hence the need for a very much tighter quality control.
2. Shipping schedules are much more important.
3. Marketing techniques and inventory controls are much more difficult.
4. Mills will have to handle a greater variety of products that require much more sophisticated packaging and distribution procedures.

Consequently, while further processing is one of the most important solutions to the use of lower quality wood from tropical timbers, the sophistication required in further processing must not be overlooked.

Another avenue to help improving the utilization of tropical timber stands, as already mentioned, is to increase the use of both forest and mill waste in the manufacture of pulp and paper and composition board. This opens interesting possibilities even if the products have to be sold mostly in the domestic market for the time being.

In this connection, countries with tropical timber stands must make a serious effort to develop a domestic market for the lower grade products which have no export markets, otherwise, mounting costs will make timber extraction of the remaining stands increasingly expensive as these are pushed back into the more inaccessible areas. A number of possible products have already been discussed. However, the problem is not only one of production, it includes one of marketing where considerable imagination will be needed. The tropical wood industry must come up with product lines which must be attractive, practical for the target market, and must sell at competitive prices.

More work has to be done on the packaging of products coming from tropical forests to lower shipping and handling costs. The use of containerization can be of great help. However, container ships require improved port facilities and good scheduling. This is a factor of greatest importance when planning wood processing facilities in developing countries.

And last, but by no means least, is the critical problem which tropical timber operations face in perpetuating their timber resources. A very large part of the world's tropical timber resources have been squandered but the situation can still be saved if remedial measures are promptly taken. The problem is very complicated and it will take time and great effort to work out a satisfactory program and see it through. Whether we try to perpetuate existing species, or replace all or part of these with other species to be developed for special uses, or go to a combination of these, we do have some control over what can be done and should be done. In temperate countries, the growing of trees as crops has already been in use for many years and getting higher yields from their forest lands. In the tropics, we work along similar lines, taking advantage of climatic and soil conditions very favorable for the development of high-yield forests, and at the same time, working out a proper balance for the preservation of the original species wherever possible. If we act now, the tropics will continue as an inexhaustible source of wood for the benefit of all mankind.

PRACTICAL EXPERIENCES IN PULPING TROPICAL HARDWOODS

By

Jairo Cubillos

Carton de Colombia S.A.
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Carton de Colombia, S.A., is a subsidiary of Container Corporation of America, which manufactures packaging products from board and paper using pulp from short fiber mixed tropical hardwoods, imported long fibers, and locally collected waste paper. The organization begins in the forest and ends with the delivery to users of corrugated boxes, folding cartons, and paper sacks.

Kraft liner, cylinder liner, corrugating medium, boxboard (WPC), and extensible sackpaper of varied weights and qualities are produced.

The pulp plant uses a mix of about 200 species of short fiber hardwoods to produce unbleached and semibleached kraft pulp and semichemical pulp.

The short fiber hardwoods, the pulp plant's main raw material, can be classed in three broadly defined categories:

1. Native hardwoods from the slopes and valleys of the Andean region. Purchased from private land owners and amount to 40% of mill supply.

2. Eucalyptus globulus, an exotic species that has been adapted successfully to the conditions of the Andean Plateaux. Eucalyptus amounts to no more than 10% of the total wood supply.

3. Hardwoods from the tropical forests of Colombia's Pacific Coast.

The forest of the Pacific Coast, which is the source of 60% of total hardwood supply, is a tropical rain forest located 4° latitude north and 77° longitude west 200 m above sea level. Precipitation to 6,000 to 8,000 mm per annum. Relative humidity is about 88% and average temperature is 26° C. The soil is very high in clay, low in percolation. Thus, below surface level there is little water and air, which induces the tree roots to remain at surface level, while rainwater runs off.

The forest contains 267 species. Their distribution all over the forest is almost perfectly homogeneous. It produces very hard, short fiber, high density woods. The average dbh is 12 in., with high values around 40 in. and low values of 3 in. Total volume per hectare is about 160 m^3. Seventy-five percent of the wood is fit to use for pulp making, 8% for construction and other uses, and 5% for sawmill operation.

The remaining 12% is not fit for economic use. A typical distribution of a forest sample is as follows:

Common name	Gen, sp.	%	Density	Fiber length
Caimito	*Himatanthus articulata* *Pouteria caimito* *Crysophyllum* sp.	17.1	0.641	1.57
Cuangare	*Dialanthera otoba*	14.2	.478	1.94
Cuasco	*Schweilera* sp.	5.9	.751	1.64
Guabo	*Inga* sp.	5.1	.575	1.40
Carbonero	*Licania chocoensis*	4.0	.789	1.48
Anime	*Dacryodes colombiana*	3.9	.498	1.23

All other species are represented in very small percentage.

The logging operation is divided into three steps:

1. Felling, bucking, and debarking of the trees. All of the above operations are done manually.
2. High lead transportation using a modified North Bend aerial cable system (300-1,000 m).
3. Road construction. Logs are put on top of the road, with balast on top of the corduroy to avoid sinking of the trucks due to the high rain and the clay content of the soils.

PROBLEMS ASSOCIATED WITH NATURE OF PACIFIC COAST FOREST

Low productivity and low yield (160 m^3 per hectare).

Forest management for this sort of forest is difficult.

It is difficult to construct and maintain roads due to the characteristics of the soil and the intensive rainfall.

There are abundant parasite plants, which embrace the trunk of the trees and tie the trees to one another. These parasites are source of innumerable difficulties in debarking and bucking.

Forests belong to the Nation and are given to the Company through 30-year Concession Contracts. The Company has no private property rights on the land. Thus, forest management policies cannot be adequately enforced.

RELATIVE ADVANTAGES DUE TO NATURE OF PACIFIC COAST FOREST

Good rate of natural regeneration.

High proportion of wood fit for pulpmaking.

Relatively small size of trees makes labor intensive operation feasible.

Fauna not conflictive.

Forest close to urban nuclei, with adequate access roads, which insures the supply of labor.

PULPS PRODUCED

The yearly production is of 120,000 metric tons of pulp, which includes unbleached and semibleached kraft, and semichemical pulps with hardwoods. The kraft line has a capacity of 240 tons per day with hardwoods. The cooking is done in batch digesters. The process for hardwoods is a kraft process, featuring a very short cooking time. The semichemical line has a capacity of 160 tons per day, cooked in a continuous digester. This process features green liquor as cooking agent. Semibleaching amounts to no more than 200 tons per month. The pulp used for semibleaching is a very low yield hardwood kraft. There is also a small production of unbleached kraft pulp from softwoods (<u>Cupressus lusitanica</u> and various pines).

The following are typical properties of the hardwood pulps produced, with some additional information that may be of some interest:

<u>Unbleached Hardwood Kraft</u>	<u>At 400 CSF</u>	<u>At 300 CSF</u>
Tear factor	92	106
Breaking length	7,400	8,400
Mullen test	42	50

Kappa No.	54
Sulphidity	22%
Yield A.D.	62%

<u>Semichemical Pulp</u>	<u>At 400 CSF</u>	<u>At 300 CSF</u>
Concora medium test factor	.49	.59
Elastic modulus	2.5	3.2
Breaking length	6,000	6,700

Sulphidity	23% (green liquor)
Yield A.D.	79%

At 400 CSF   At 300 CSF

Semibleached Pulp

Brightness	53 G.E.
Yield	42%
Kappa No.	36
Sulphidity	22%

TYPICAL FURNISHES

Sack paper	75% unbleached tropical hardwood kraft. 25% unbleached softwood kraft (mostly imported).
Corrugating medium	80% tropical hardwood semichemical. 20% unbleached tropical hardwood kraft.
Kraft liner	80% unbleached tropical hardwood kraft. 20% imported waste (long fiber waste).
Cylinder liner	40% unbleached tropical hardwood kraft. 20% imported waste. 40% domestic waste.

There is some use for the unbleached tropical hardwood kraft pulp in Boxboard. All the production of semibleached pulp is used in Boxboard.

OPERATIONAL PROBLEMS

Pulp and papermaking from tropical hardwoods has posed three operational problems with which one must deal:

1. Control of Input Mix to Sustain Quality of Output

If the composition of the mix of species cooked varies through time:

Consumption of chemicals is very difficult to stabilize.

Yield will be changing permanently.

As the distribution of wood densities changes, the load of dry wood per digester also changes, which does not leave room to evaluate the plant's production.

The quality of some pulps is very sensitive to certain kinds of wood species. For example, semichemical pulp cooked with green liquor yields very low quality indexes when a significant proportion of certain erithrinae is used.

The procurement system solves these problems associated with processing of multiple species, as the wood must mix at several stages. There are several mixing points in the flow of wood from the forest to the digester.

A. Standing Mix

The Company does not purchase or harvest directly any particular species but purchases or harvests lots that contains a number of species.

B. Source Mix

The ratio among different sources of supply through time is not substantially altered.

C. Internal Handling Mix

The wood mix is chipped as it comes in. If one of the ratios is significantly modified due to changes in the country's wood market, wood out of an inventory is used, keeping a rotating scheme, thus sustaining the mix.

D. Chip Pile Mix

A working inventory of a magnitude such that a homogeneous mix can be achieved is maintained through a normal operation of two chippers feeding the same pile and a bulldozer shaping the pile and simultaneously feeding the pulp plant.

Although the fundamental cooking and pulp quality problems have been solved, some additional problems are found as a consequence of the mixing mechanism. The company has to live with changing chipping efficiencies as it does not have the chance to adjust the chipping parameters to the properties of individual species. Thus, Carton de Colombia generates a high level of both sawdust and oversize chips.

2. Restrictions in Using Pulp

Although stable, the properties of kraft and semichemical pulp from mixed tropical hardwoods are relatively low, due to the quality of the fiber. Therefore, a twofold problem is faced here:

A. Productivity of the paper machines.

B. Quality of the paper.

The paper machines have the standard design for papermaking from a furnish rich in high quality fibers. Hence, refining has to be done above average to develop properties, increasing power consumption.

The lower freeness improves the behavior of short fiber hardwoods, but decreases drainage at the forming board, which increases steam consumption in drying and makes it difficult to reach design values in machine speed.

With intensive refining, however, high values of tensile, elongation, and therefore, tensile energy absorption can be achieved with short fibers. Hence, the research program is oriented toward finding a balance of the properties that can be best obtained from short fiber tropical hardwood pulping and studying the behavior of the paper in its final use, in order to determine to which degree high values of properties that are characteristic of long fiber wood pulps can be sacrificed.

The varied nature of the raw material has made it difficult to detect which species have been the source of pitch problems in the paper machine. There exist some undesirable species--those high in latex contents--which we do not acquire. The pitch problem is not a continuous one.

Unfortunately, the pitch problem cannot be detected in the pulp plant because of the alkaline nature of the system which it handles. When it does show up at the paper machines, which in the Company's case occurs very seldom, it is attacked by physiochemical means, but its presence is still trouble.

3. Black Liquor Recovery

Besides the liquor generated in the kraft cook, black liquor is generated in an amount that corresponds to a semichemical pulp production of 140 tons per day using green liquor as cooking agent. This liquor has no residual alkali, is highly viscous at low concentrations, and shows a great tendency to cause scaling problems in evaporator tubes. Due to these properties, although its heating value is not substantially different from that of the kraft process black liquor, semichemical process black liquor is used only to sustain the wood liquor ratio in the batch kraft digesters. The production of kraft pulp is planned in such manner that the liquor balance is satisfied.

Thus, the only liquor that goes to recovery is that resulting from pulping mixed tropical hardwoods by the kraft process, and that resulting from the production of unbleached kraft pulp from softwoods, which, as has been noted above, does not amount to more than 10% of total production.

The liquor is passed through the multiple effect evaporators, keeping the residual alkali around 6 grams per liter as Na_2O. This control figure is most important as liquors below this level lack the desirable flowing properties, and above this point we would be misusing the active alkali.

The evaporating capacity varies with time, as the scaling increases from one boilout to the next. It has been found that, to maximize total evaporating capacity at acceptable economy, boilouts must be conducted with a solution of sulphamic acid (with some corrosion inhibitor) every 40 days, and clean up the tubes with a high pressure pump once a year. The periods have been set up to keep the level of scaling within a range such that, after cleaning, the effective evaporating capacity will go back to 0.95 times its previous post-cleaning capacity. After ten boilouts, rating capacity is reached through mechanical cleaning.

In order for the system to comply adequately to this cycle, the weak black liquor entering it must sustain a solids content of 18%-19%. This parameter is satisfied by means of continuous recirculation of concentrated black liquor.

Since the scale is rich in silica content (55%) due to the high silica level found in tropical hardwoods, and also incomplete debarking, the washing solution used in chemical boilouts must have a low pH.

A GENERAL COMMENT

Although there are problems involved in large scale pulping from mixed tropical hardwoods, it is feasible and has been done. The Company feels that these practical problems do not turn processing tropical hardwoods into a different industry.

During the research stage, a project should be oriented toward detecting those modifications in properties of finished products that result from special raw materials, and design in accordance to the properties of the particular fiber and resulting liquor properties.

INCREASED UTILIZATION OF TROPICAL HARDWOODS BY THE INDIAN PULP AND PAPER INDUSTRY

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ABSTRACT

The present position of conventional raw materials and the necessity to use the Indian tropical hardwoods in the Indian pulp and paper industry is explained. Further, the difficulties encountered in increasing the proportion of hardwoods in admixture with bamboo are discussed. The investigations are being carried out by the joint project of the Government of India and UNDP/FAO entitled "Exploration and Identification of Alternative Raw Materials for Paper and Newsprint Manufacture" to increase the proportion of hardwoods in papermaking furnishes.

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INTRODUCTION

The development of the Indian pulp and paper industry differs from that of most countries as the main supply of papermaking fibers has been derived from non-wood resources. All the integrated mills in India were originally designed for bamboo. The early investigation conducted by Raitt (1) established bamboo as the fibrous raw material for papermaking. The use of bamboo for pulping has been described by Guha (2). Shortage of bamboo has forced the mills to search for alternative raw materials. The obvious choice due to availability was mixed tropical hardwoods; these contained a wide range of hardwood species varying from dense, dark-colored, durable species to relatively low-density, light-coloured ones.

PRESENT STATUS OF HARDWOOD PULPING AND PAPERMAKING IN INDIA

Systematic work done on utilization of mixed tropical hardwoods led to its successful utilization on a commercial scale as early as 1960. As the mills were originally designed for bamboo, mixed hardwoods were introduced in the system along with bamboo in single stream. Later some mills started cooking mixed hardwoods separately. This was done by installation of additional chippers and digesters. Some mills started washing separately. At present, the mills are using one of the following alternatives:

1. Mixed cooking.
2. Separate cooking and washing and further operations in mixture.

No mill in India at present, however, processes the two pulps--bamboo and mixed hardwoods--separately up to refining.

The Indian tropical natural forest contains a variety of species, sometimes 100 to 120. However, 5 to 10 species represent about 50 percent of the growing stock.

Utilization of these complex mixtures poses several problems in all areas of pulping and papermaking, including the soda recovery operation. The most important are those due to the vast difference in basic density, chemical composition, and in the heterogeneity of the mixtures which make it difficult to obtain a uniform quality pulp. Complete segregation of wood species is not economically viable. However, the mills are generally removing some species from the mixture, such as Terminalia tomentosa, Xylia xylocarpa, and Acacia catachu. These woods are generally regarded as unpulpable due to high density and a high percentage of extractives in the wood. Generally the mills in India are pulping 10 to 15 species in mixture (4). Proximate chemical analysis of 21 species of Indian Hardwoods (5) show Klason lignin values ranging from 20 to 32.3 percent, ash content 0.32 to 3.2 percent, and hot water solubility 1.45 to 18.0 percent. The fiber length of hardwood pulps is 0.68 to 1.82 millimeters and fiber diameter 0 to 28 (5) (table I).

The problems presently encountered by the industry during the processing of mixed hardwoods can be summarized as:

1. Debarking.--As the trunks and branches of most of the tropical woods are not straight, no suitable debarking machine is available, indigenously or otherwise. The problems are particularly due to the knots and crooked nature of various parts of these trees. Therefore, debarking is done manually.

2. Chipping.--The general experience of some mills using hardwoods presently is that quite a few pulpable species are chipped more easily than bamboo. However, the dense varieties pose problems in chipping and result in frequent knife changes.

3. Digestion.--Presently, sulphate pulping is the only process used in India for pulping mixed hardwoods. The general experience is that the chemical charge required is slightly higher than for bamboo. Though the sulphidity is maintained around 20 percent, the pulp yield is usually lower for hardwoods. One additional advantage observed while using this material is that more chips could be charged to the digester due to their dense nature. Some dense hardwoods are difficult to penetrate by cooking liquor and this ultimately results in more rejects than for bamboo. Generally, for making bleachable grade pulps, most mills are maintaining the Kappa number of unbleached pulp

TABLE I

PROXIMATE CHEMICAL ANALYSIS AND FIBRE DIMENSIONS OF HARDWOODS

S.NO.	NAME OF THE SPECIES	ASH *	HOT WATER SOLUBILITY	LIGNIN*	AVERAGE FIBRE LENGTH	AVERAGE FIBRE DIAMETER
		%	%	%	mm	mm
1.	Acacia auriculaeformis	0.40	3.12	23.61	0.84	0.014
2.	Anthocenphalus chinensis (A. Cadamba)	1.27	5.32	23.09	1.21	0.028
3.	Acacia decurrens	0.36	2.26	21.24	0.86	0.014
4.	Anogeissus latifolia	2.00	6.50	26.70	0.98	0.010
5.	Bischofia javanica	0.99	4.20	26.14	1.82	0.019
6.	Casuarina equisetifolia	0.90	6.50	23.20	1.08	0.011
7.	Eucalyptus globulus	0.25	3.51	20.27	0.82	0.014
8.	Eucalyptus grandis	0.39	1.45	21.90	1.11	0.014
9.	Eucalyptus hybrid (Mysore gum)	0.32	13.40	24.70	0.73	0.012
10.	Eucalyptus torelliana	0.45	12.05	24.90	0.71	-
11.	Garuga pinnata	0.90	6.50	25.20	0.68	0.011
12.	Hevea brasilensis	0.80	6.90	20.50	1.12	0.021
13.	Moringa oleifera	3.20	8.80	26.40	1.14	0.028
14.	Pterocarpus marsupium	0.60	4.50	25.40	1.05	0.011
15.	Protium serratum	0.90	6.70	22.90	0.91	0.012
16.	Quercus semecarpifolia	0.48	8.58	21.44	1.02	0.015
17.	Quercus dilatata	0.89	8.34	20.02	1.06	0.018
18.	Quercus incana	0.78	9.47	22.26	1.15	0.017
19.	Trema orientalis	0.56	3.16	24.92	1.05	0.028
20.	Terminalia coriacea	3.00	18.0	29.90	1.15	0.009
21.	Xylia xylocarpa	2.90	18.1	32.20	1.12	0.009

* % expressed on oven dry raw material.

between 25 and 35. Jauhari and Bhargava (3) had observed that it is more difficult to blow hardwood pulps than bamboo or pine clean from the digester. Most mills experience a difficult problem of handling rejects at knotter screens, as the quantity is much higher than observed with bamboo. Therefore, the existing rejects handling systems are inadequate to handle these large quantities.

4. Brown Stock Washing.--Hardwood pulps are difficult to wash and require greater washing area even when compared to bamboo. The dilution factors are also higher, resulting in a greater volume of black liquor. The difficulties in washing are sometimes attributed to the lower porosity of the pulp mat due to the fine and short fiber length of hardwoods.

5. Screening and Centricleaning.--No specific problems have been reported in this section of pulp mill while using tropical hardwoods.

6. Bleaching.--The behaviour of pulp during bleaching depends on species present in the mixed hardwoods. Most of the Indian mills use C/E/H/H sequence for bleaching bamboo and hardwood pulps. Generally, the commercial-scale bleaching of hardwood pulps does not pose problems. Difficulties are experienced more when hardwoods and bamboo pulps are bleached in admixture. There seems to be a preferential absorption of bleaching chemicals while dealing with blends of these pulps, which subsequently results in uneven bleaching.

7. Stock Preparation and Papermaking.--In India almost all the mills use conical refiners for refining the pulps. Mixed hardwood pulp and bamboo pulps are refined in mixture. On the paper machine, press picking and fluff on the dryers pose problems. Vessel picking is a problem for printing papers when higher percentages of mixed hardwoods are used in the furnish. Beater additives for increased bonding and surface sizing of the paper are used by some mills to overcome the vessel picking problems. The properties of the commercial papers are satisfactory. Some of the physical strength properties of different grades of commercial papers containing about 30 percent mixed hardwood pulp and 70 percent bamboo pulp are given in table II.

8. Soda Recovery.--The experience in soda recovery when using hardwoods vary for the different mills. This is basically due to differences in species pulped by these mills and in the equipment used. Viscosity of the concentrated black

TABLE II

STRENGTH AND OPTICAL CHARACTERISTICS OF COMMERCIAL PAPER SAMPLES CONTAINING ABOUT 30% MIXED HARDWOODS AND 70% BAMBOO PULPS

CHARACTERISTICS	WHITE PRINTING	WHITE OFFSET PRINTING	M.G. RIBBED KRAFT
Grammage (g/m^2)	60.0	68.6	49.5
Density (g/cm^3)	0.63	0.69	0.56
Burst index $\left(\frac{kPa\ m^2}{g}\right)$	0.90	0.70	1.70
Tensile index (Nm/kg)			
M D	24.0	24.0	29.0
C D	13.5	13.5	18.0
Stretch (%)			
M D	1.2	1.0	2.2
C D	1.9	1.6	1.8
Tear index $\left(\frac{mNm^2}{g}\right)$			
M D	4.55	4.55	7.30
C D	5.20	5.25	7.70
Ash content (%)	13.4	14.9	2.4
% Brightness (Elrepho)	68.3	65.3	-
% Opacity	87	97	-

liquor for hardwoods is higher than for bamboo and pine. The tendency of evaporators to scale is greater when pulping the mixed hardwoods, resulting in increased downtime. In some cases fines and resinous matters are found in these scales.

INCREASED UTILIZATION OF HARDWOODS ESPECIALLY FOR WRITING AND PRINTING PAPERS

Pulping of a selected mixture of hardwoods and manufacture of writing and printing papers from bamboo with admixture of 30 to 40 percent hardwood pulp is an established technology in India. The objective of our Project, which is a joint project of the Government of India and UNDP/FAO, is to explore the possibilities of increased utilization of hardwoods. In the first phase, we are identifying the problems related to pulping of hardwoods which were rejected by the industry, as these hardwoods represent up to 30 percent of the growing stock. Kraft pulping of mixed hardwoods containing these species results in high Kappa numbers (45 to 50) of pulp, which cannot be reduced even by increased alkali charge or prolonged cooking time. In one troublesome species (Terminalia tomentosa), a high content of gallic acid was identified by gas-liquid chromatography (2.1 percent on o.d. wood). Polyphenolic substances are reported (6) to cause increased viscosity of black liquor due to condensation of lignin; this may also be one of the reasons for the high Kappa number. A slight reduction of Kappa number could be achieved by the two-stage kraft process, using alkali extraction as the first stage (20 g/l NaOH, 100° to 110°C). However, the pulp had still a high Kappa number (37 to 40). It was found that the lumen of the Terminalia tomentosa pulp contained a coloured substance. Repeated excessive hot water treatment reduced the Kappa number to 28 to 30. At the present time more efficient extraction processes are being investigated. It is evident that pulping of dense hardwoods containing polyphenols requires detailed research into pulping processes.

Equally important is research on papermaking processes if a high percentage of hardwood pulp in the furnish is required. The runnability and paper properties of a furnish consisting of mixed temperature-zone hardwoods or eucalyptus species and of a low percentage (20 to 30 pct) of softwood fibers could be improved by separate refining of softwood and hardwood pulp. While the hardwood pulp is beaten to develop burst and tensile strength, softwood pulp is only slightly beaten to retain high tear strength and to gain wet web strength. The wet web strength, which is a good measure of runnability on the paper machine, with softwood pulp is 70 to 100 percent higher than with mixed hardwood pulp.

In Indian conditions softwood pulp has to be replaced by bamboo pulps. Unbleached bamboo pulps have generally a good tear strength, but the other strength properties are on the level of hardwood pulps (fig. 1, 2, 3). The freeness, tear strength, tensile and burst index of hardwood-bamboo pulp mixtures are additive; wet web strength is higher than calculated (fig. 4). It was found in preliminary laboratory refining studies, using Central India hardwood and bamboo pulps, that separate beating does not have a distinct advantage over mixed beating. The explanation is in the different response of softwood and bamboo pulps to beating. The maximum tear strength of softwood pulps is high, but decreases rapidly with decreasing freeness. The tear strength of bamboo pulps decreases only moderately by beating; the curve is flat. It is evident that the gain in tear index in separate beating of bamboo pulp is low. On the other hand, it is necessary to beat the bamboo pulp to a lower freeness to increase wet web strength, and this could be done by mixed beating as well. One bamboo species, eta reed (Ochlandra species), available in limited quantites in Kerala (South India), does have an extremely high tear factor and a tear freeness relationship similar to softwoods (fig. 3). The wet web strength is, however, lower than that of softwood pulp.

A serious problem is the low tear strength of bleached bamboo pulps as revealed by analysis of a number of commercial pulps (fig. 5). The loss of tear strength in bleaching is as high as 50 percent of the tear strength of unbleached bamboo pulp. Laboratory bleaching experiments indicate that bamboo pulps are very sensitive to C/E/H/H bleaching sequences. On the other hand, the high tear strength of bamboo pulps could be retained by mild bleaching using sodium chlorite (fig. 6). This indicates a possibility of decreasing the percentage of bamboo in the furnish. Another possibility is using eta reed pulp, which retains tear strength after C/E/H/H bleaching. However, the growth of this bamboo species is restricted to areas with high rainfall and humidity and high temperature.

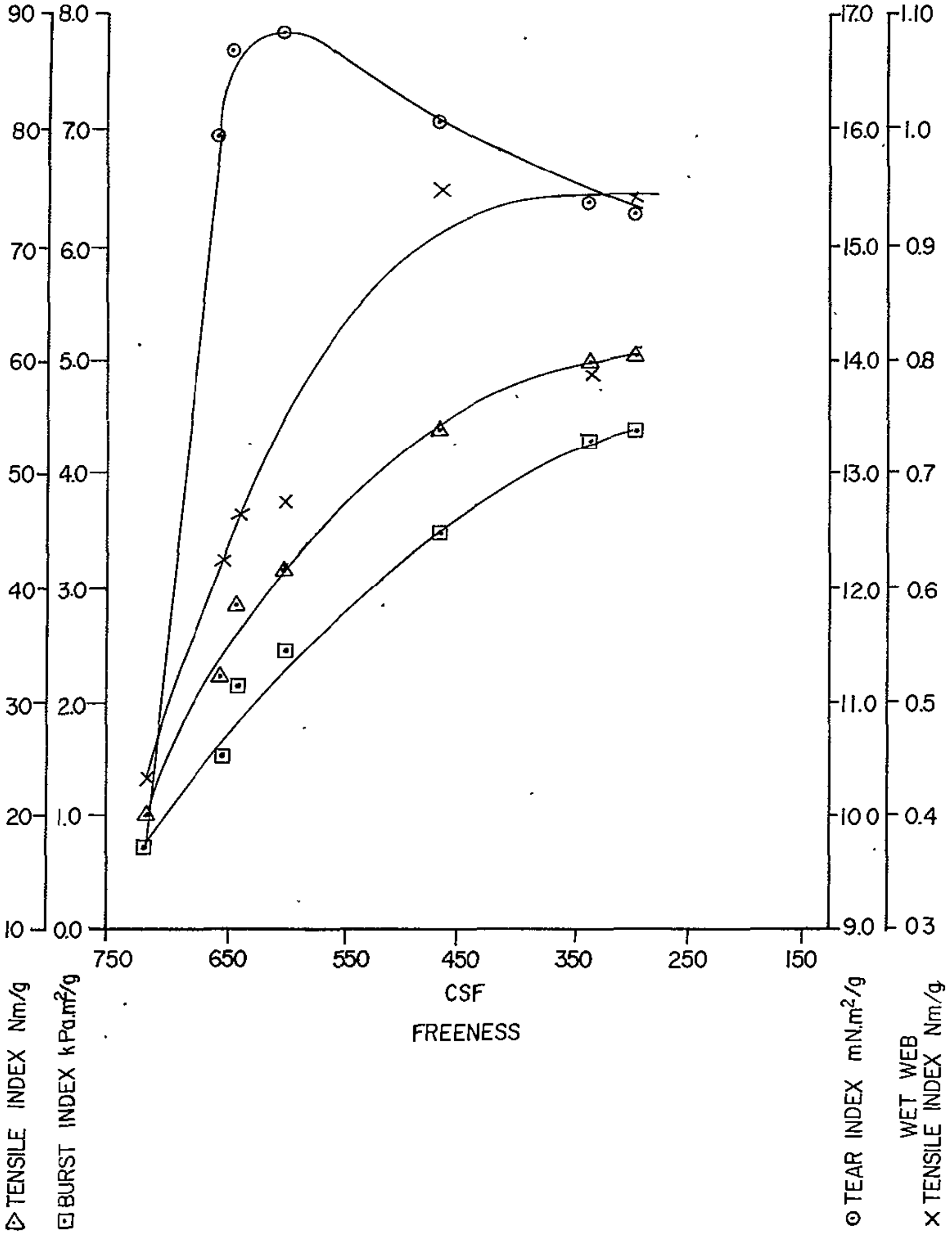

Fig. 1. PROPERTIES OF UNBLEACHED BAMBOO PULP

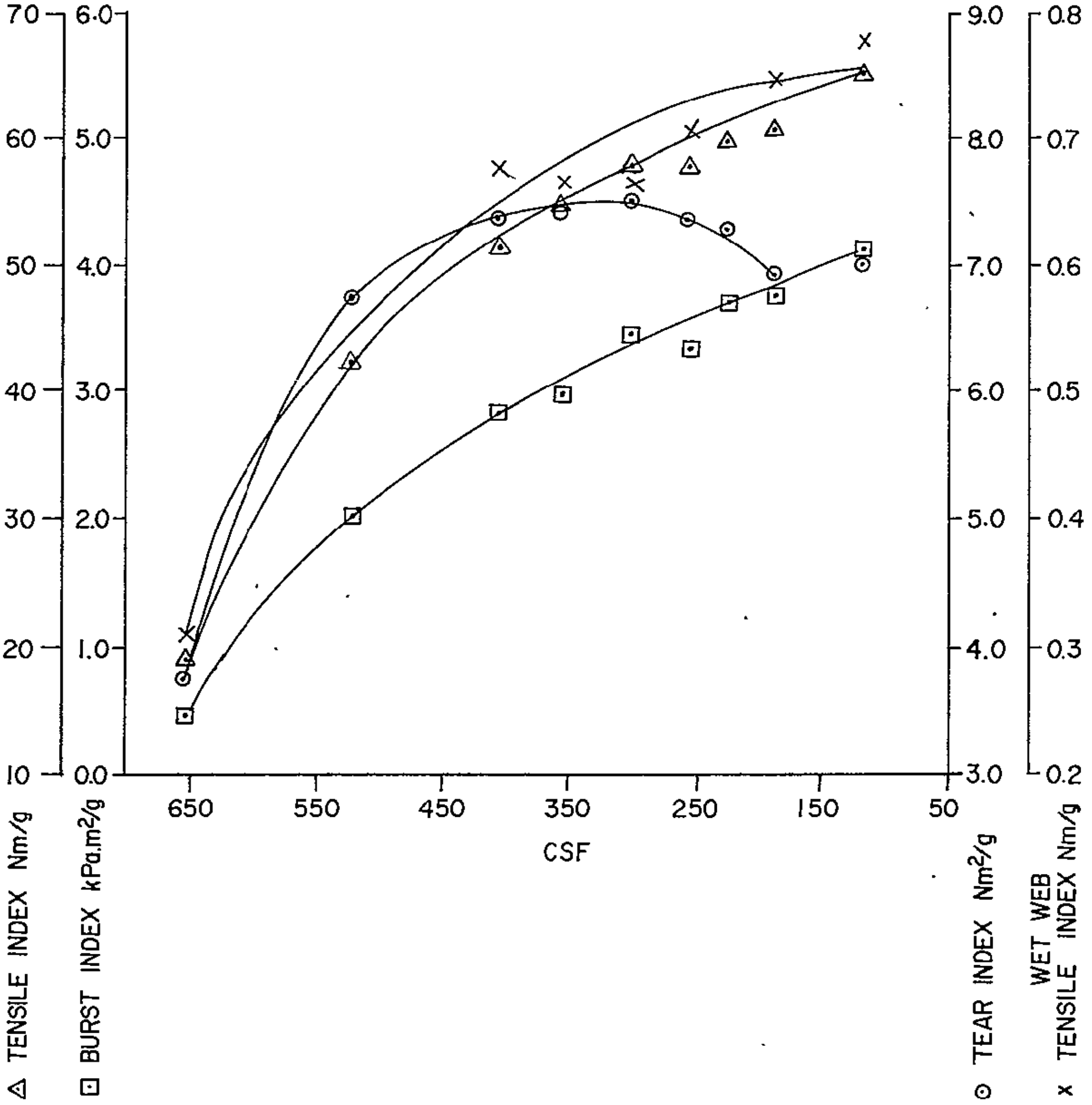

Fig. 2. PROPERTIES OF UNBLEACHED MIXED HARDWOOD PULP

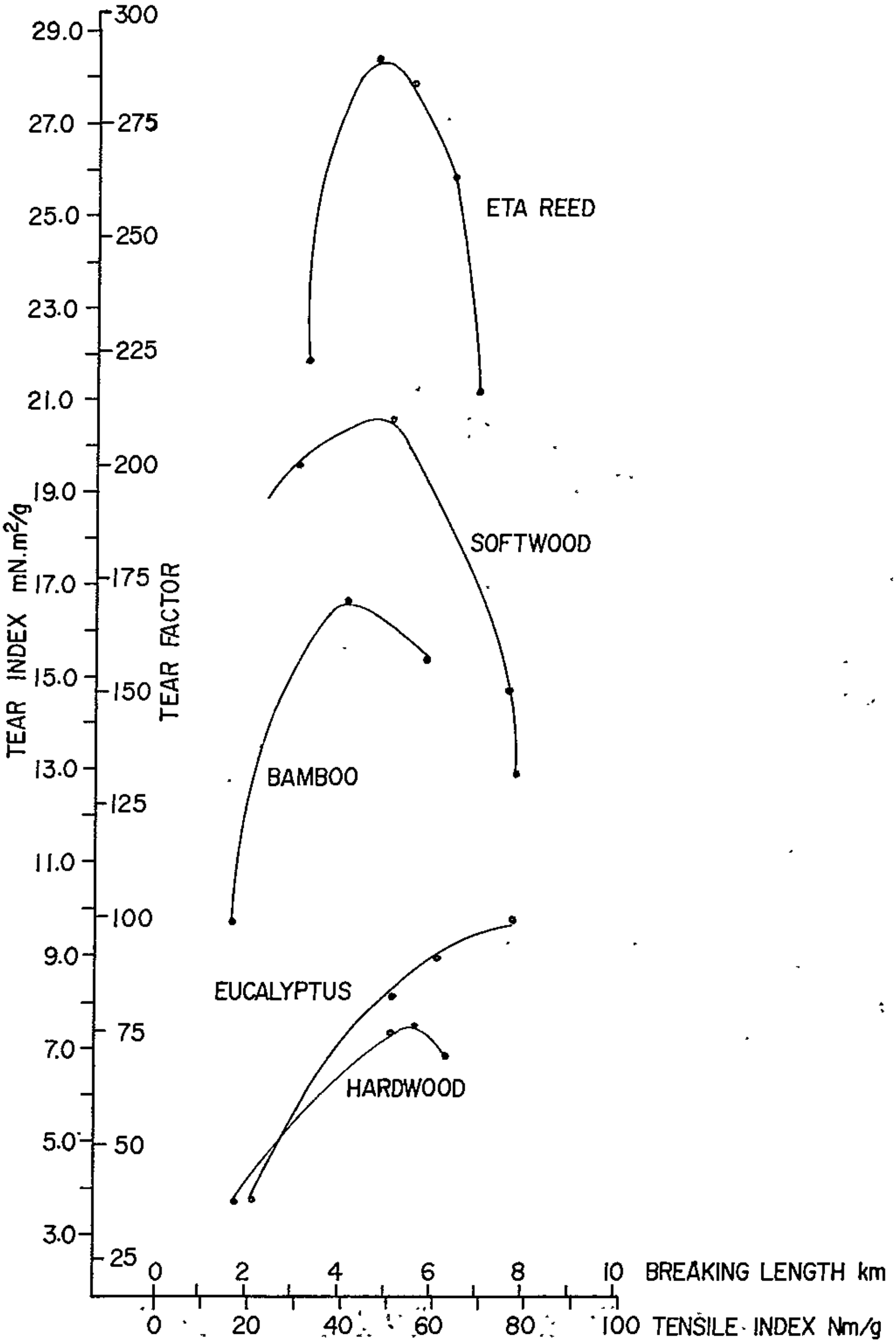

Fig. 3. PROPERTIES OF VARIOUS SULPHATE PULPS

(UNBLEACHED)

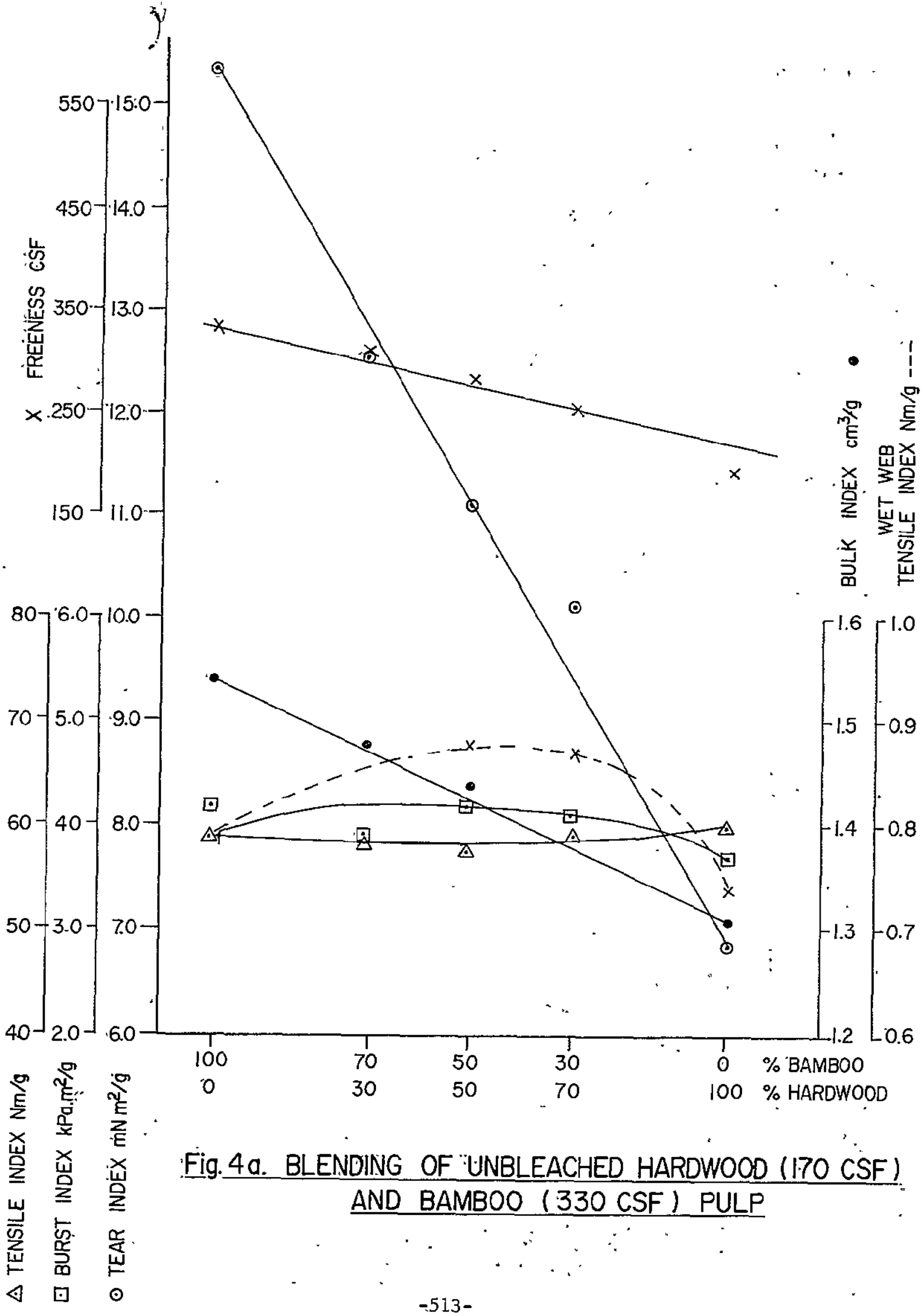

Fig. 4a. BLENDING OF UNBLEACHED HARDWOOD (170 CSF) AND BAMBOO (330 CSF) PULP

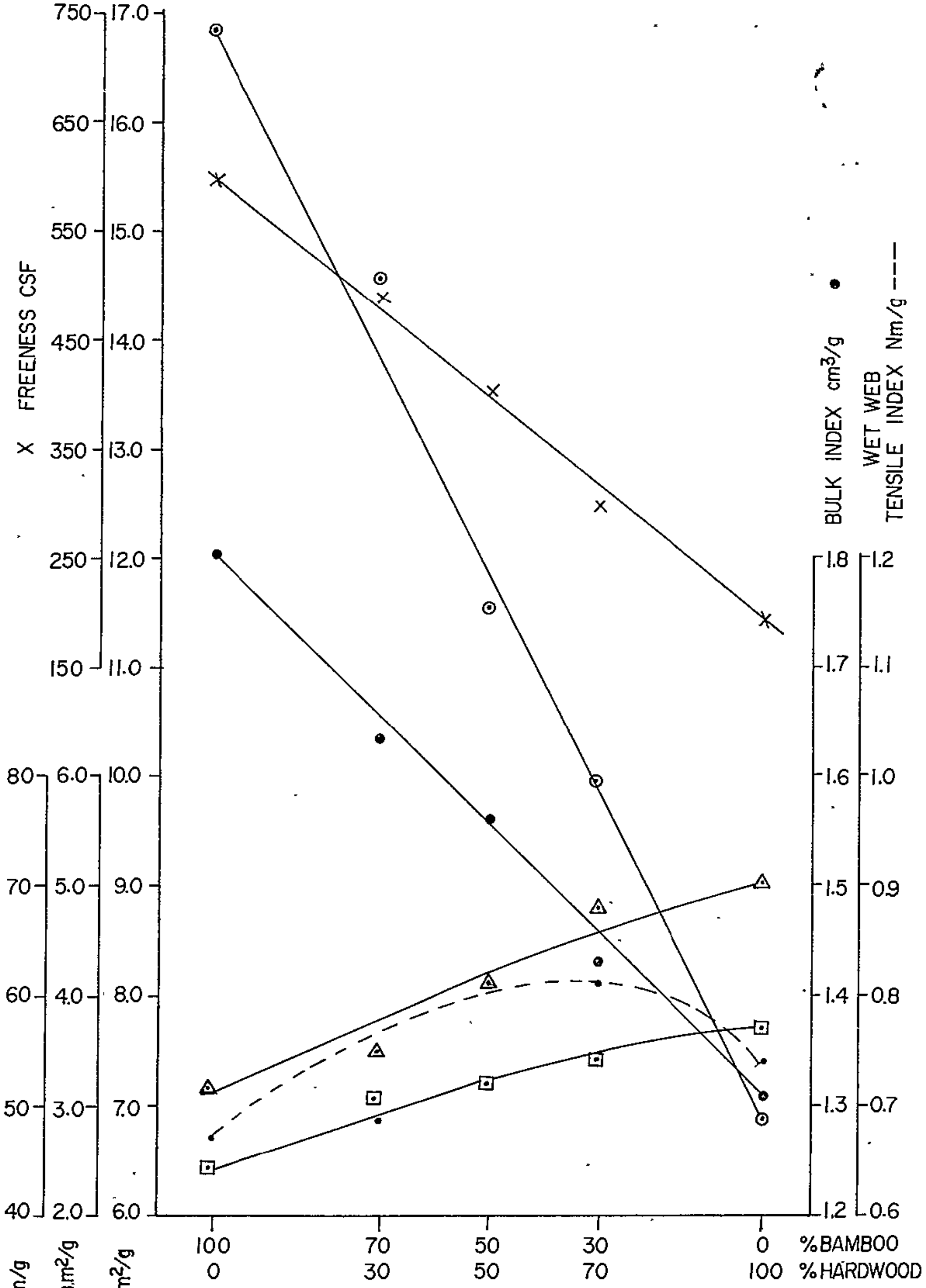

Fig. 4 b. BLENDING OF UNBLEACHED HARDWOOD (170 CSF) AND BAMBOO (595 CSF) PULP

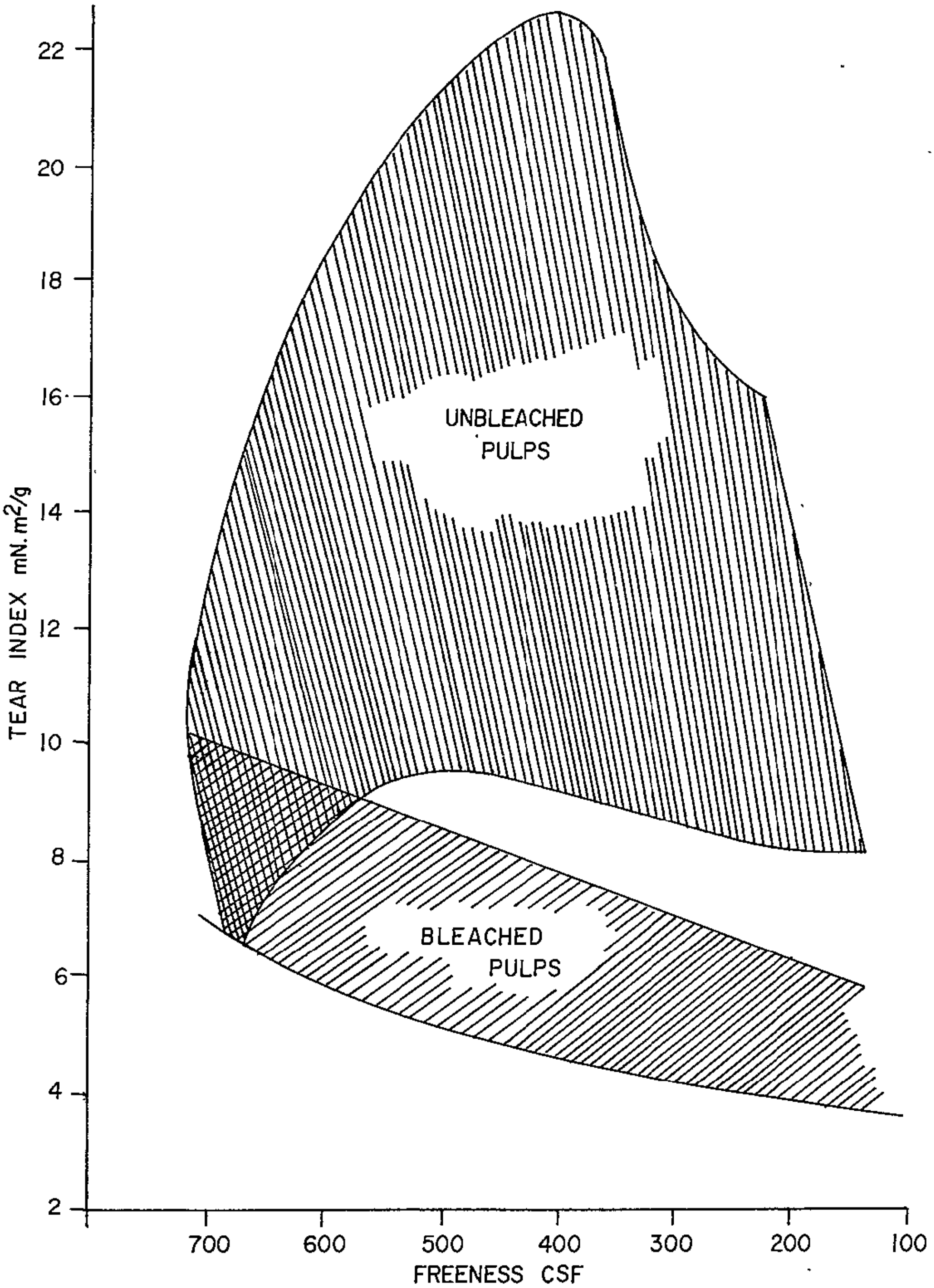

Fig. 5. TEARING STRENGTH OF COMMERCIAL BAMBOO PULPS

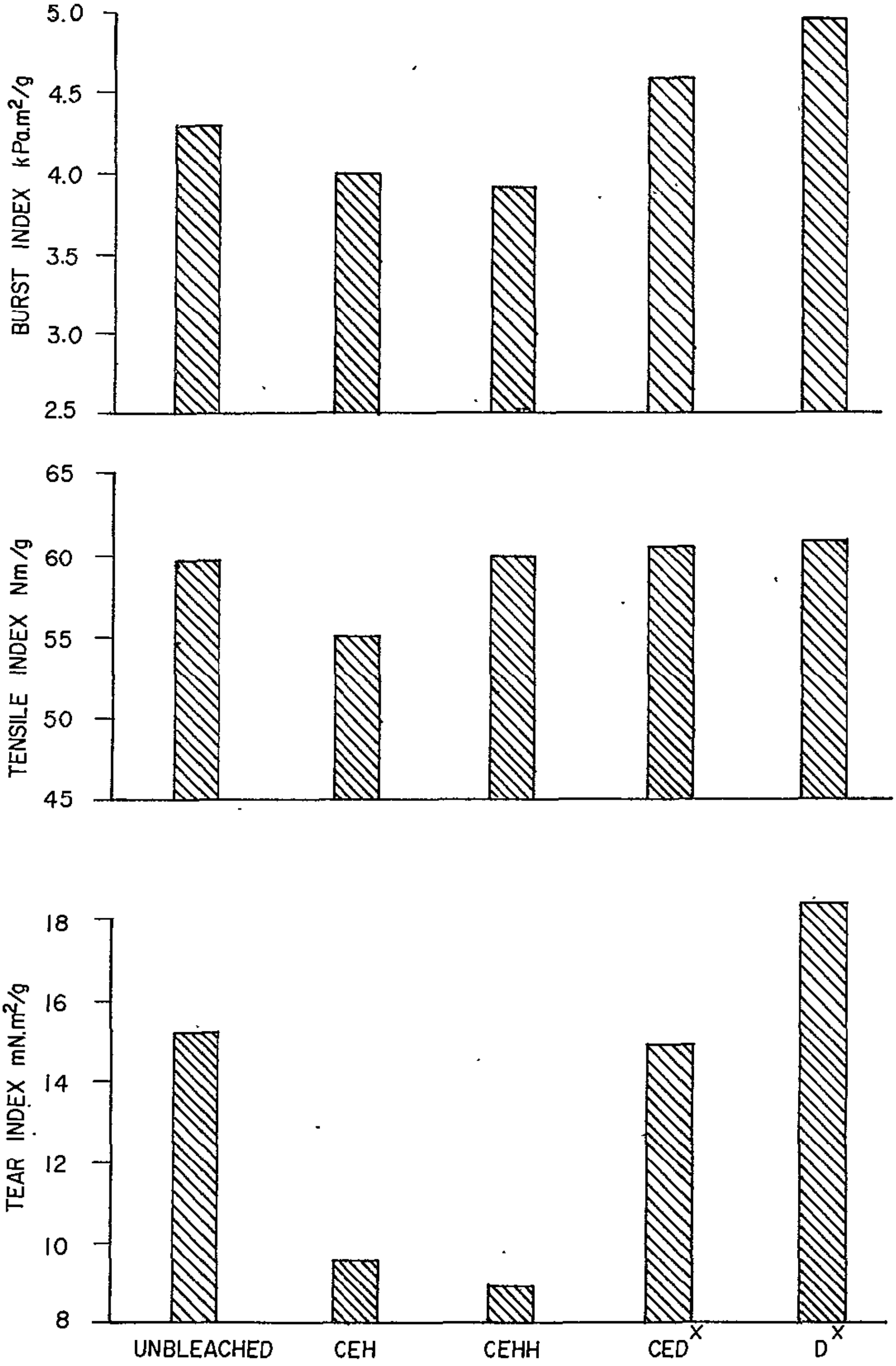

Fig. 6. INFLUENCE OF BLEACHING ON BAMBOO PULP PROPERTIES (AT 300 CSF)

[X] SODIUM CHLORITE TREATMENT

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SECTION VII

INVESTMENT CONSIDERATIONS

PROBLEMS IN PROCESS CHEMICAL PRODUCTION IN DEVELOPING COUNTRIES

By

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ABSTRACT

The problems of establishing chemical process industries in developing countries are considered. The basic chemicals to support the pulp and paper industry are salt, sulfur, soda ash, and the chloralkalis. Problems with the existing infrastructure, costs of construction, processing costs, overhead, support facilities, and markets are analyzed. Fillers and pigments are also discussed; most are not available in the developing countries but must be imported. As a result, the costs of production will be excessive and only a limited domestic market could be served.

PROBLEMS IN PROCESS CHEMICAL PRODUCTION IN DEVELOPING COUNTRIES

By

Haydn H. Murray

INTRODUCTION

Most of the developing countries of the world are located in the tropical and subtropical zones. Parham (1) pointed out that developing nations are not scattered haphazardly across the earth's surface but are concentrated in the hot, humid tropics where the land is covered with heavily leached rock-weathering products. This results in a host of problems including soil fertility, food production, agricultural practices, man and animal nutrition, deforestation, water quality, public health, and rapid erosion of the soils. From a geological and mineralogical standpoint these developing countries will have a very tough job in producing high-protein food because the soils deteriorate rapidly as food production is increased, because the soils have a very low nutrient content and a high alumina, silica, and iron content.

In addition to the basic soils problem, another major problem is that many of the infrastructures in the developing countries, such as education, communications, and industrial activities, are inadequate. Education is insufficient and lacks specialization; labor is largely unskilled; communications are poor, and there is an acute shortage of development capital, cheap energy resources, services, and knowhow to establish profitable industrial activities. Thus, the developing countries rely on the exploitation and export of their natural resources, and even then their principal handicap is that they cannot make full use of their raw materials. The raw materials are not processed sufficiently to gain a reasonable added value, which would permit them to pay decent salaries, obtain necessary savings for reinvestment, and contribute to further development of the country. An example of the above is the processing of bauxite to alumina metal.

4 tons of bauxite --	2 tons alumina -	1 ton aluminum
$80	$240	$1,000

The processing of bauxite to alumina increases the value from 4 to 6 times, and by making the metal ingot the value increases more than 4 times again. To be able to make all these additional gains, the processor has to possess sizable investment capital, adequate technology, and have at his disposal an abundant source of cheap energy, and of course must have a market for the metal. In many instances underdevelopment is characterized by the inability of a country to mobilize sufficient capital investment, technological skills, and market capacity to deliver a processed or refined product rather than the raw material.

The Food and Agriculture Organization of the United Nations (2) has projected an economic growth rate of approximately 4% to 1990 for the world and a growth rate for total paper and paperboard between 3.5 and 4% for this same period. At present over 80% of the world's total raw material requirements are met by wood harvested from the traditional supply areas of North America and Scandanavia. Changes in this market appear inevitable because the recent scarcity of fiber resources in the Scandanavian countries has made fast-growing plantations in such areas as South America, Africa, and Oceana an attractive alternative supply of pulpwood. At present these areas account for only 4% of the world's woodpulp supply, but contain 28% of the world's productive forest area (excluding unstocked and unclassified forest lands and protected forests) (3). Will these countries mobilize sufficient capital to deliver a value added product or sell the wood? If a pulp and paper industry develops in these countries, then satellite chemical industries to supply their needs must also be developed.

Chemical consumption by the pulp and paper industry is enormous. In the United States a total of 6,535,000 tons of chemical were consumed by the paper industry in 1975 (source: C. H. Kline and Co.). The major chemicals consumed were as follows:

	Tpa
Caustic Soda	1,710,000
Salt Cake	1,165,000
Chlorine	1,050,000
Lime	820,000
Sulfuric Acid	555,000
Sulfur	390,000
Limestone	270,000
Sodium Sulfate	170,000
Sodium Chlorate	155,000
Salt	130,000
Soda Ash	120,000

In addition to those listed above considerable tonnages of aluminum sulfate, casein, animal glue, natural gums, rosin, starches, waxes, and synthetic polymers are used in pulp and paper production.

CHEMICAL SUPPLIES

Sodium, sulfur, and chloralkali chemicals dominate the paper industry. Most of the required products are produced from the more common chemicals and minerals, and several are formed or regenerated within the pulping reaction itself. The most significant methods of chemical pulping, accounting for over 90% of the total world production, are the sulfate (kraft) and the sulfite process.

The basic chemicals required are salt, soda ash, sulfur, limestone, and sodium sulfate. From these almost all the chemicals required can be processed. Again, however, capital investment, technical expertise, cheap energy, skilled labor, and a sizable market are required. Very few developing countries can provide these requirements. Another problem is the source of the basic chemicals.

Salt can be produced from sea water so there is no problem as to an adequate resource. Natural soda ash comes from the Trona deposits of southwestern Wyoming and the lake brines in California, Kenya, Sudan, and Botswana. Synthetic soda ash can be produced by the Solvay process using salt and limestone, but energy costs for this process are relatively high so that natural soda ash from Trona and lake brines is growing relative to the synthetic soda ash production. Sulfur is widely distributed around the world but for commercial production is largely restricted to deposits of elemental sulfur and pyrites. The major deposits of elemental sulfur are found in the gulf coast of the United States and Mexico, Poland, Sicily, U.S.S.R., and Iran. Pyrite (FeS_2) is a major sulfur resource. The leading producing countries are Japan, Spain, Italy, Cyprus, Norway, and the U.S.S.R. Australia, the African copper belt, and Chile are small producers at present but have extensive reserves and would be capable of producing large quantities of sulfur from pyrite and other sulfide minerals. Another important source of sulfur is as a byproduct from sour natural gas and crude oil. Important producing countries are United States, Canada, Iran, West Germany, Iraq, Mexico, and the U.S.S.R.

Limestone resources of the world are enormous but high calcium and chemically pure limestone reserves are somewhat limited in certain areas. However, limestone resources are adequate in most of the developing countries and could be utilized for the development of processing operations to produce lime and other chemicals for the pulp and paper industry when feasible. Sodium sulfate, known commercially as salt cake, occurs naturally in Western United States, Canada, Mexico, U.S.S.R., Spain, Turkey, Argentina, Chile, and South Africa. The first four countries listed above are the major producers of natural salt cake. By-product sodium sulfate which supplies about half of the total market is produced in the manufacture of viscose rayon; the manufacture of hydrochloric acid from salt and sulfuric acid in the Mannhein furnace, and in numerous other processes wherein certain sodium salts are converted to acids by reaction with sulfuric acid.

Aluminum sulfate can be produced from the reaction of bauxite or alumina with sulfuric acid. Bauxite is an abundant resource in many of the developing countries because it is an end product of intensive tropical weathering. Many of the organic chemicals such as casein, starch, rosins, waxes, synthetic polymers, animal glue, and natural gums would have to be imported because the total market for these products would not justify building a processing plant just to supply the pulp and paper industry in a developing country.

Even though some of the developing countries have resources to produce the needed chemicals required by the pulp and paper industry there are other factors that would probably negate building chemical process plants in the immediate future. These were mentioned in the introduction and will be included in the summary.

FILLERS AND PIGMENTS

Several types of paper are filled or loaded with a fine mineral powder (almost exclusively white) either to reduce the costs or to give certain physical properties, such as higher opacity, good ink receptivity, improved printing characteristics, and a better feel. The use of too much filler is detrimental to the quality of the paper as it may become weak, abrasive, two sided, and difficult to size. In addition to minerals being incorporated within the body of the paper itself, they are also applied as thin film or coating on the surface. In general, the reasons for coating paper are to improve the receptivity of printing ink, mask the inconsistencies on the original paper, produce a high grade product, apply a moisture resistant film, reduce abrasion, limit fluffing, and to produce a saleable paper of high quality. The choice of white mineral fillers and coaters is wide but about 95% of all the minerals used are kaolin, talc, titanium dioxide, and calcium carbonate. By far the most important mineral filler and coater is kaolin, and it is estimated that kaolin constitutes about 80% or four out of every five tons of minerals used in paper. The minerals that constitute the remaining 5% include barites, calcium silicates, calcium sulfate, diatomite, zinc pigments, alumina hydrate, asbestos, precipitated silicas, and carbon black.

D. A. Clarke (3) has estimated that in Europe the filler and pigment consumption (tons) in paper is as follows:

	Filling	Coating	Total
Kaolin	1,600,000	1,400,000	3,000,000
Talc	300,000		300,000
Calcium Carbonate	100,000	150,000	250,000
TiO_2	50,000	10,000	60,000
Silicates	15,000		15,000
Satin White		20,000	20,000
Alumina Hydrate		10,000	10,000
Barium Compounds	5,000	10,000	15,000

In the United States the filler and pigment consumption in paper (tons) for 1975 was as follows (3):

Kaolin:	Coating	1,029,000
	Filling	775,000
Talc		58,500
Calcium Carbonate:	Coating	56,700
	Filling	41,500
TiO_2:	Coating	31,000
	Filling	117,000
Silicates		39,400
Satin White		1,400
Alumina Hydrate		18,600
Zinc Oxide		5,000
Colored Pigments		3,500

Kaolin is a white hydrated aluminum silicate mineral that is mined and beneficiated from deposits found in several areas of the world (4). The two most important areas are in Georgia and South Carolina in southeastern U.S. and in the Cornwall district of southwestern England. Other countries which supply kaolin for the paper industry are Brazil, Australia, West Germany, Spain, U.S.S.R., Czechoslovakia, and Japan. Talc is a hydrated magnesium silicate and is mined and processed to produce filler quality for paper in Finland, U.S.A., France, U.S.S.R., South Korea, India, China, Italy, Japan, Canada, and Australia. Calcium carbonate is either ground to fine particle size or precipitated to produce a quality acceptable for the paper industry. Presently the countries in which $CaCO_3$ is produced for use in paper are the United States, England, France, West Germany, Austria, Spain, Italy, Denmark, and Sweden. Titanium dioxide is produced using rutile (TiO_2) and/or ilmenite ($FeTiO_3$) as the mineral source. Titanium dioxide pigments are made by two basic processes, the sulfate and the chloride (5). The major production facilities for TiO_2 pigments are located in the United States, West Germany, England, Japan, France, and Italy.

Other fillers and pigments, although used in smaller quantities, are important in that they contribute specific properties to paper that are needed for specialty applications. Barytes (natural barium sulfate) and blanc fixe (synthetic $BaSO_4$) are used primarily in the manufacture of photographic papers. The major producers are: U.S.A., Ireland, U.S.S.R., Mexico, West Germany, Thailand, and China. Diatomite is the siliceous remains of microscopic aquatic plants known as diatoms. They are small in size and have an extremely intricate and porous surface with a low specific gravity of around 2. Diatomite has high water and oil absorption, which is useful in paper manufacture as a filler and pitch controller. Diatomite production largely comes from the U.S.A., Denmark, France, Italy, and West Germany. Satin White (calcium trisulfoaluminate) is a bulky white pigment made from the interaction of slaked lime and aluminum sulfate. The greater portion of satin white is manufactured at the paper plant because of its very high water content and its relative instability. Alumina hydrate ($Al(OH)_3$) is produced by digesting bauxite in caustic to form sodium aluminate. Alumina trihydrate crystals are precipitated by the hydrolysis of the sodium aluminate solution. It is very white and bright and is used in combination with optical brightness. Alumina trihydrate pigments are manufactured in the U.S.A., Germany, and Japan. Zinc pigments are extremely fine and have a high brightness and opacity. Their most important use in the paper industry is in electrophotography. The major production is in the U.S.A., France, Germany, and Japan.

Most of the fillers and pigments that are used in large tonnages are produced by mining and beneficiation of a natural mineral deposit. These pure mineral deposits are generally restricted in their occurrence and most developing countries would have to import these fillers and pigments. Transportation costs then become a very important factor.

MAJOR PROBLEMS

As was mentioned earlier in this paper, the so-called developing countries account for only 4% of the world's woodpulp supply but contain 28% of the world's productive forest area. This undoubtedly means that these areas will supply more wood in the future and hopefully a viable pulp and paper industry will develop. If a pulp and paper industry does develop, then it may be possible for chemical process industries to be built, but there are many problems as listed below:

(1) Lack of infrastructure (transportation facilities, schools, housing, recreational facilities, etc.)

(2) Shortage of development capital

(3) Lack of trained engineers, technical staff, and skilled labor

(4) High construction costs

(5) High transportation and import costs

(6) Erratic deliveries of equipment and supplies

(7) High energy costs

(8) Lack of other industrial activities and support facilities

(9) Lack of service industries

(10) Maintenance of high inventories and replacement parts

(11) Lack of basic mineral commodities

(12) Limited markets

Most developing countries lack the infrastructure to support large and viable chemical process industries. These countries lack good schools at all levels of education and particularly at locations where a pulp and paper industry and its supplier industries would have to locate. An adequate transportation network including roads, railroads, and airports would have to be constructed in most developing countries to support industrial development. Housing is generally inadequate and most companies would have to construct homes for the employees unless they located in or near a major city. This would be an added cost. Recreational facilities are very limited or nonexistent and in order to keep management and staff would have to be provided by the company.

Development capital is exceedingly short in the developing countries, and in all likelihood foreign capital would be required to finance a chemical process industry.

Trained engineers, chemists and other technical staff, and skilled labor are very limited in number in the developing countries. In most instances they are trained in foreign universities and schools so that foreign engineers and scientists would have to be imported to manage and run the plants and in addition train locals to eventually manage and run the facilities. These foreign scientists and engineers are costly so this again is an added expense for a struggling chemical industry.

Construction costs are higher due to many factors including high bids because, in general, local contractors do not have the know-how or equipment to handle a large job. Large multinational contractors with high overhead costs are the only ones capable of handling the construction. Labor is unskilled and turnover is high, so additional supervision is necessary. In general, construction materials such as steel, wood, and concrete are more costly. Most special items of equipment must be imported. These and other factors make the construction costs very high.

Because most of the process equipment must be imported, the transportation costs and import duties are a significant added cost, which again adds to the burden of establishing a profitable chemical process industry in a developing country.

Delivery of equipment and supplies into the developing countries are usually erratic with considerable delays due to many factors. Manufacturing delays in producing the equipment can set off a chain reaction of delays because of port loading schedules, ocean transport, docking delays, unloading difficulties, and transport to the construction site. Also import papers and governmental red tape can cause considerable delays. Delays cost money, and considerable cost overruns can result.

Many developing countries lack petroleum and coal resources and, therefore, their energy costs will be high. In addition, electric power is in short supply, and it takes at least 10 years to develop a new power generating station from its inception. Energy costs range from 10 to 25 percent of the total cost for most of the chemical process industries. If the energy costs are high, this puts the industry at a considerable cost disadvantage, particularly in the export market.

The developing countries have minimal industrial development, and supplies and facilities that we in the United States and Europe take for granted are generally unavailable. This causes processing delays and increased production costs. Machine shops, foundries, and other support facilities are lacking so that additional manpower and shops must be a part of the processing plant. This, of course, increases the overhead costs.

Service industries such as electric shops, telephone service, automotive repair shops, sheet metal fabricators, and others are generally lacking and create additional burdens and costs on the operation.

Spare parts must be adequately maintained so that down time for repairs is at a minimum. This means considerable capital will be tied up in inventory goods. Supplies of all types must be maintained at a high inventory level, all of which costs money. However, if inventories are not maintained, the whole operation could be shut down for lengthy periods of time waiting on parts to be flown in.

Many basic mineral commodities to make the necessary chemicals and fillers and pigments do not occur in the developing countries. Examples are soda ash, sodium sulfate, sulfur, kaolin, talc, and some others. These must be imported at high cost, which would increase the cost of the pulp and/or paper products which would inhibit a successful export market for the commodity.

Another basic problem is the limited domestic market for the pulp and paper and for the industrial chemicals such as soda ash, chloralkalis, and salt cake. To be a successful profitable industry, an export market would be necessary and because of the probability of high costs as indicated by all the problems the products would not compete in the world market.

SUMMARY

The problems in establishing process chemical industries and filler and pigment processing facilities in the developing countries are many. The lack of the infrastructure to support industry is serious and educational facilities, communications, industrial activities, and recreational facilities would have to be improved. Costs of capital, construction, personnel, energy, transportation, overhead facilities, and maintenance of high inventories would add considerable expense in making the product and would limit the sales to domestic customers because a high cost product would not compete in the world markets. Many basic mineral commodities are lacking in the developing countries and would have to be imported at considerable expense. It will take many years and considerable innovation and hard work to establish competitive processing industries in the developing countries.

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ECONOMIC AND POLITICAL ENVIRONMENT FOR INVESTMENT IN NATURAL TROPICAL FOREST DEVELOPMENT

By

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ECONOMIC AND POLITICAL ENVIRONMENT FOR INVESTMENT IN NATURAL TROPICAL FOREST DEVELOPMENT

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INTRODUCTION

The intention in this paper is to briefly review some of the economic and political considerations that can enter into the choice of development projects based on the tropical high forest. The economic orientation of the paper will be more toward impact on the economy as a whole than on the financial economics of the project. In effect an attempt will be madeto try to outline some requisites for investment in this resource from the point of view of how best to realize the contribution of the tropical forest to the social and economic development of the producing countries.

The process of economic growth might be envisaged, in its simplest form, as being made up of three basic parts. The first is growth in production, which is a function of the number of people employed and the productivity of the labour force. In the long run more people can be employed only if new capital stock is brought into use, and productivity can increase only through investing in more productive machinery and equipment. The second component of economic growth must therefore be accumulation of capital and investment. This in itself, however, is not sufficient. Investment, to result in growth, must be allocated to the most productive sectors in the economy. Because the composition of demand changes over time, and technical progress is constantly changing the techniques of production, the nature of the activities with high potential for growth will be constantly changing. The third basic element of economic growth is consequently a transfer of investment capital to the sectors of growing importance from the surplus of other sectors. The transfer of resources from one country to another can be important in this process. However, this importance is mainly limited to the provision of inputs not available in the country. By far the greater part of the wealth necessary to generate economic growth must come from the country's own resources.

The task of identifying and analyzing the contribution of the forest resource to growth and development is thus largely one of perceiving (1) the conditions in which developments in the sector can contribute positively to the process sketched out above and how to achieve these, (2) the conditions which would have a negative impact and how to avoid these, and (3) the additional factors which transform growth into social and economic <ins>development</ins> and how to incorporate these in the analysis. These factors include provision of employment, equitable distribution of income, maintenance or improvement of the quality of goods and services produced (in the sense of their usefulness in meeting basic needs), and safeguarding the integrity of the environment.

EMPLOYMENT AND PRODUCTIVITY

The growth of unemployment in most developing countries in recent years has added an additional dimension to the thrust for development. Production has grown not so much through bringing more persons into the labour force as by raising the productivity of the labour employed. Technological development and the substitution of capital-intensive for labour-intensive methods, in both agriculture and industry, has resulted in growth in output without a corresponding growth in the number of jobs. This process has compounded the problem of how to provide for the rural and urban poor. Though the two cannot be entirely dissociated, as accelerated growth remains one of the most effective tools for creating employment, the provision of jobs and all that goes with employment and wages in the way of an improvement in standards of living has become an important objective in and of itself alongside the objective of growth.

The question of employment is inextricably bound up with the question of technology. The option of developing in a labour-intensive fashion only exists if a labour-intensive technique exists for carrying out the process in question. Many of the processes involved in developing the tropical forests clearly do possess such technological flexibility. Many of the stages of forestry work, harvesting, and primary processing, can be pursued with varying degrees of labour or capital intensity. Other activities do not have much flexibility, notably pulp and paper manufacture, which is characterized by the heavy capital investments required per person employed. On the other hand, secondary processing and manufacturing based on wood, panels, and paper again do tend to present a choice of factor inputs; e.g., in the manufacture of furniture, joinery, packaging, etc., efficient operations can be established with fairly low capital to labour ratios.

The choice, however, involves other factors. There may well be physical or technical constraints. To confine logging of the tropical high forest to hand logging, for example, is likely to confine it to the logging just of river banks. More widespread are the economic limitations. Labour-intensive methods may be less efficient than capital-intensive alternatives for many activities. The question then arises as to how much loss of efficiency can be afforded in return for a gain in jobs created.

Not least among the factors bearing on efficiency is that of availability of skills. It is evident that technologies developed for industrialized economies with high labour productivity in temperate climates are unlikely to be entirely suitable for economies with low labour productivity in tropical climates. Some degree of adaptation and transfer of skills is likely to be required if the transfer from one to the other is to be effective. This may involve adaptation of the technology or adaptation of the procedures for using that technology, or adaptation of the local environment within which the technology is to be used by inserting the skills necessary to operate it.[1]

If extensive training is necessary, or high levels of supervision, in order to achieve this, labour costs can in aggregate prove to be high. Moreover, the process of learning and adaptation requires a certain basic level of knowledge and scientific potential in the receiving country. If a technology is so sophisticated as to be beyond what can be absorbed, it can be adopted only by importing skills in the form of expatriate technicians and managers, or by automating it even further in order to reduce the need for skills. However, a project could become a "technological enclave," bringing very little in the way of benefit to the body of knowledge and skills in the country, and consequently a very low contribution to development.

Another factor which contributes to the tendency toward bias against labour-intensive solutions in most developing countries is the level of wages. In economic terms, the cost of labour is the value of the production foregone by transferring that labour from the previous occupation. The economic cost of previously unemployed labour will therefore be very low, usually much lower than the prevailing level of wages. However, wages reflect the cost that industry has to pay for that labour, and hence influences its decisions about factor use.[2]

Hence there are a number of factors which tend cumulatively to distort factor choice in the direction of capital- rather than labour-intensive solutions. Because the option for substituting labour for capital does exist in many facets of tropical forestry, this could lead to a significant reduction in the economically desirable levels of employment in the sector (Arnold). Therefore more attention needs to be paid to the question of how to exploit more effectively the employment-creating potential of activities based on tropical forests.

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[1] The process of choosing and adapting technology also involves knowledge about the receiving country, and readiness to acquire this knowledge. A recent study relating to forest industry development in Latin America (Gregersen and Contreras) cites two examples of machinery and practices introduced into tropical forestry operations in that region by foreign companies which failed because they were inappropriate to the local conditions. In both cases, local foresters had warned of the unsuitability. The necessary knowledge was thus available. What was lacking was the capacity to adapt to clearly different conditions.

[2] For industry to use labour to the extent that is economically rational it will generally be necessary for government to provide some compensating incentive--tax relief, employment subsidies, etc. This is but one example of how manipulation of market values can influence choice of technology (or of project) toward or away from labour-intensive solutions. An overvalued foreign-exchange rate, for example, by making imported goods relatively cheap, is also likely to encourage an uneconomic and undesirable substitution of equipment in place of labour.

LOCAL IMPACT AND REGIONAL DEVELOPMENT

In addition to the amount of employment created by a development, the type and location of that employment is also important. It has been argued (Westoby) that as forest industries tend to be located close to their raw material source, in the rural areas, they could have an above-average propulsive effect on development. They can bring wage employment and industrial skills to the rural areas, which are generally the poorer parts of the country, and the infrastructure created to support them can provide a base for other industries and services to locate in the rural areas as well, leading to further jobs and development. Through the creation of supporting services and commercial activities, such an investment is likely to result in an above-average "multiplier" impact on the local economy.[3/] This dispersion of industrial and service employment to the rural areas can contribute to the more equitable distribution of income, and can also reduce the social problems of over-rapid urbanization which usually accompanies industrialization.

This is a persuasive hypothesis, but to date little has been done to test it. There has been remarkably little study of whether it is borne out in fact, and if so, what are the factors at play, and nearly all of what little has been done relates to developed countries. Casual observation indicates that sometimes rurally located forest industries in developing countries do become a centre around which other activities develop, but often they do not. One factor may be the extent of the infrastructure and services that come into being with the forest industry: only if these have the capacity to provide for needs over and above the needs of that industry could other industries be encouraged to establish.

If such relationships do exist, and could be established, it would provide an important additional tool in identifying and designing the most effective investments in tropical forest development. The lack of information in this area is therefore a serious impediment.

This lack is all the more important because the huge costs of the associated infrastructure (e.g., power, transport, and social infrastructure) can be a major impediment to developing large integrated tropical forest-based industries. Few can carry such costs, together with plant costs, against

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[3/] Activities which generate income locally through wages and purchases are likely to have some "multiplier" effect, in that this will encourage the development of commercial and service activities to meet the needs of those who in this way have more money to spend. In other words, at least part of the income generated by the initial activities leads to additional, or expanded, activities in the vicinity giving rise to more employment and increased local incomes. For example, it has been estimated (Grant) that development of a pulp and paper mill in a rural area of New Zealand gave rise to at least one additional job locally for every four jobs created in the mill (the employment multiplier was estimated to lie in the range of 1.25 to 1.40).

their production revenues alone. It has thus been common practice for government to shoulder the cost of offsite infrastructural developments, in recognition that such additional benefits could accrue through further development based on this infrastructure. However, as governments and public financing bodies have adopted more rigorous appraisal methods, it has become less easy to justify large investments on unsubstantiated arguments to the effect that such additional developments will materialize. Analysts at the World Bank, for example, have cited this as one of the most important impediments to developing "bankable" pulp and paper projects in developing countries.

The need for a better understanding of local impacts has become more pressing with the growing recognition that not all such impacts are necessarily benign. The opening up of a tropical forest area could seriously disrupt, and even destroy, the way of life of the people living there. Logging roads could lead to severe erosion, or an influx of settlers from outside who could destroy the forest. Plant effluents could adversely affect drinking water supplies, fish resources, and irrigated agriculture. In order to avoid many of these negative effects, it will be necessary to study local conditions. However, the preliminary task of identifying possibilities and constraints will be facilitated if more is known and understood of what happened in similar developments in tropical forestry elsewhere.

A particularly important issue is that of the interaction between industrial use of the tropical forests and other local uses of that forest or forest lands. It is more the rule than the exception that tropical forests are being encroached upon both by the advance of settled agriculture onto forest lands and also through the extension and intensification of shifting cultivation within the forests. These processes can jeopardize the security of supply of wood to industry within any area so affected, and thus discourage investment. Attempts to contain or prevent the encroachment have almost invariably proved ineffective. This could be ascribed to insufficient forest service manpower to carry out the policing function, an inadequate or inappropriate legislative framework to back it up, or political pressures in favour of the squatters, settlers, and shifting cultivators. However, it is increasingly being realized that, even if prevention and eviction could be enforced, this would often be the wrong solution. The people who live in the tropical high forest depend on it for the basic necessities of life: food and shelter. Where population pressures are high, the tropical forest is likely to survive as a source of industrial raw material only if management systems can be devised which combine wood production with the provision of food, and other goods and services, to forest-dependent populations.

This is fast becoming a central thrust of tropical forestry development. The various systems of intercropping food and forest crops, which are commonly termed "taungya" after the original Burmese system, are being re-examined with a view to building on them as a basis for more stable integrated forest community systems, such as the forest village systems being developed in Thailand. The possibilities of exploiting and developing the potential of the forest as a source of products of benefit to forest-based populations is being explored. In Indonesia, for example, developments include the introduction into forest-dependent communities of beekeeping activities, and livestock raising based on grass for fodder grown intercropped with the trees (FAO).

In the Philippines such approaches have already been incorporated into forest industry projects. The Paper Industries Corporation of the Philippines (PICOP), at its integrated operations at Bislig Bay, has set up an operation to encourage and assist local smallholders to use part of their land to grow pulpwood for sale to their pulpmill. Starting in 1968 the scheme had grown by 1976 to include 3,849 small farmers with an average of nearly 4 ha each under trees. Incomes of the farmers have increased significantly. In addition, the Corporation has a number of programmes to assist the nomadic shifting cultivators in the area to take up settled occupations or stable farming. The options offered include (1) the provision of land, building materials, basic agricultural inputs and services in areas set aside locally for settlement, (2) cash payments to enable them to settle elsewhere, or (3) employment with the Corporation. In these ways many more people have benefited from this forestry and forest industry development than just those directly employed by it.

There is good reason to believe that industrial forest developments in tropical forest areas must increasingly follow such innovative approaches. It is unlikely to be enough for forest industry to rely solely on the money they insert into the local economy, through wages to local employees and payments for locally supplied goods and services, to generate an acceptable local impact. It will be necessary for industry to actively promote the development of local communities. This will be necessary in the first place in order to secure the support and participation of the forest-based populations in industrial forestry. It will be necessary more broadly to bring about the proper contribution of tropical forests to social and economic development.

The issue of use of tropical forest land, and the contribution of forestry developments to the optimum use of tropical forest land, extends to more than just accommodating the needs of local people. The alienation of forest land to agricultural use is more than a spontaneous reaction of land-hungry and growing populations. In many tropical countries it is a deliberate element of national policies and plans.

For these countries the task is not only to produce more food, but to do so in a manner which also creates increased employment and better land use. As the intensification of agriculture does not produce many more jobs, the expansion of extensive forms of agriculture is unavoidable. Such an expansion must come largely at the expense of the forest area, which remains the last large reserve of land for new settlement.

The "fortress" approach of many foresters and forest industries in face of these trends therefore tends to be neither effective nor productive in a development context. There are, of course, areas in which the protective function should be paramount, and others where commercial forestry will be the most productive and perhaps only use. But in those large areas of forest where agriculture could be practiced, the prospects for maintaining a forest resource rest on integrating forestry with other land uses (crops, livestock, water management, etc.).

IMPACT ON OTHER SECTORS OF THE ECONOMY

The essence of a development-stimulating activity is that it does not remain an "island" but spreads its effects outwards to the rest of the economy where it expands old and stimulates new activities. Industries that have strong links with other sectors of the economy are therefore more likely to contribute to development than those industries which have few such links or have links predominantly with industries in other countries. Most of the industries which process wood in fact produce intermediate goods for use by other industries (forward linkages)--lumber and panels, builders' woodwork, packaging, printing and writing paper, etc. Furthermore, forest products have a particularly wide range of uses in other industries. At the same time forest industries draw upon locally produced raw material and other inputs (backward linkages). As an intermediate goods industry, the wood-processing sector therefore does have strong linkages to other sectors.[4/] To the extent that these are other industries in the producing country, wood-based industries should be able to provide a positive contribution by stimulating development or growth in the user industries, by providing the latter with lower cost and/or better quality inputs.

The positive impact will be less if the primary product (wood) is destined for export rather than the domestic market. The impact will then be confined to the industry's local purchases of inputs and services, and the encouragement this might give to additional production in the input-producing industries. In the case of the log export industry the "linkage" impact could thus be very small, with the equipment and even the fuel probably imported. Log export developments can, of course, contribute to development in other ways. They can create an infrastructural base for subsequent developments in the forest areas, can earn foreign exchange for other uses, and can create capital which, if it stays in the country, could be invested in other growth-producing activities. However, they have the limitation that they preclude the development in the country of the other activities that otherwise might be based on the log raw material.

Another factor that needs to be taken into account is the quality of the linkage. One measure of this is the usefulness of the product and its end-use. Many forest products contribute to such basic needs as housing, education, communications, and food distribution and presentation, which may be adjudged to have a high qualitative rating. Another measure is the nature of the impact on the industry with which the forest industry is linked. For example, if pulp and paper production is undertaken in

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4/ Forward and backward linkages of different industry sectors are calculated (from national input-output tables), and the linkage effect is discussed, in Yotopoulos and Nugent.

order to supply an existing paper-converting industry in the country, and provides paper which is of higher price or is of inferior quality than the previously imported supplies, then it could have a detrimental rather than positive effect on the development of those industries that have to use its products. The viability of a proposed forest industry project must therefore be assessed not only in terms of its own internal profitability, but also in terms of its impact on the profitability, and hence growth prospects, of those other industries which will use its products, and also in terms of the impact on the final consumer. The desirability of proceeding with a project which would require tariff protection to make it viable may look quite different once the consequences of the higher cost products that would result are evaluated in terms of, say, higher cost schoolbooks or housing.

EARNING AND SAVING FOREST EXCHANGE

Production based on tropical forest resources can contribute to the foreign exchange earnings or savings of the producing country, and hence to its capacity to pay for goods and services that can be purchased only from other countries, or can be supplied more cheaply this way than from domestic production.

Exports of tropical wood products by producing countries grew from less than 5 million m^3 in 1950 to about 16 million m^3 in 1960, and to 53 million m^3 in 1974.5/6/ By 1974 this trade had a value of about $2.6 billion. Development of tropical forests clearly has proved to be an important source of foreign exchange earnings, at least for some countries, and continues to be so. Nevertheless, there are a number of factors which limit its positive impact on development in producing countries.

The most notable is that the greater part of the outflow is in the form of roundwood raw material, from which the proportion of the "value added" in the course of processing which accrues to the producing country is minimal. In 1973, 80% of the tropical wood volume5/ exported left the primary producing countries in log form (Pringle).

Some of the reasons for this structure of the trade are constraints operating at the supply end. There can be a lack of the infrastructure, services, and skills needed to operate processing plants competitively. There can be a lack of appropriate port facilities or shipping links. Existing tax structures may inadvertently encourage export of logs rather than products. In a country with a small domestic demand for wood or wood fibre products, it can be difficult to find outlets for that proportion of the output which is below exportable grades and qualities--an important constrain in sawmilling, plywood, and veneer production. Another constraint on this group of industries can be the absence of commercial outlets for wood residues--i.e., no pulp or board industries--and hence no possibility to generate the economies that come with integrated

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5/ In log equivalent volumes.

6/ Having reached nearly 60 million m^3 in 1973.

full utilization found in so many roundwood importing countries. Industries in producing countries may also lack the marketing organization to place production in overseas markets. In short, a processing industry in the producing country could well be less competitive than an industry in the roundwood-importing country.

A substantial industry to process tropical roundwood has grown up, not only in consuming countries, but also in third countries which import logs and export processed products and manufactures. Most of this intransit processing of tropical roundwood takes place in other developing countries. In 1973 these countries absorbed about one quarter of the logs exported from tropical hardwood-producing countries, and for 37% of the volume of tropical hardwood products (sawnwood, plywood, veneer) exported by all developing countries.

There are also other powerful constraints stemming from the market end. First there are tariffs and nontariff restrictions which discriminate against, or prevent, entry of processed and manufactured products, either to protect competing local products (e.g., temperate hardwood products), or to protect or encourage local processing of tropical wood raw material in the importing countries. In the United States and many other major markets, such impediments have been reduced to minor proportions in recent years, and most of the inflow of tropical wood is in the form of primary processed products (lumber, plywood, veneer). However, in the largest market for tropical wood products, Japan, the greater part of the wood still enters as log raw material.

Constraints on the structure of the trade need not be as explicit as tariffs and quotas. Shipping arrangements and charges may encourage transport of logs rather than lumber, plywood, or veneer. In some parts of the tropical world log production is carried out largely by foreign enterprises which are linked, either formally as part of a multinational organization or less formally through business agreements, to processing plants in other countries. This can result in vested interests in perpetuating the status quo, or at the very least a passive or indifferent attitude towards upgrading into processing.7/ Even where production is in the hands of local enterprises, the same effect can be created by their dependence on the institutions at the importing end for finance for their operations.

Turning to the import-substituting side of the foreign exchange equation, the potentials that arise are mainly in the field of pulp and paper. Because the manufacture of sawnwood and plywood, and most of the manufactures from these products, is relatively simple, small-scale, and inexpensive, these industries usually emerge at an early stage of development of local demand. Generally little is imported. Imports of pulp and paper by tropical countries on the other hand are very large. In 1973 countries with tropical forest resources imported more than 2 million tons of paper and paperboard.

7/ Which tends to be compounded by the fact that processing is usually less profitable than log export and involves more uncertainty, in that a much longer period must usually elapse before the original investment can be recovered.

The main issues constraining development in past pulp and paper production based on tropical hardwoods have been those related to technical and operating problems associated with the heterogeneous nature of this raw material. A major economic factor constraining development of this industry in tropical countries is that of the scale and complexity of operations necessary to achieve competitive production. The small size of most domestic markets conflicts with the pronounced economies of scale associated with pulp and paper production. As has been noted above, a small high-cost mill could have a negative rather than positive impact on development, by burdening paper-converting industries and using industries with expensive inputs. Undoubtedly the challenge in developing pulp and paper industries based on tropical hardwoods is not only to develop viable processes but is also to develop processes that will enable the operation of small economic mills.

In theory, some of these constraints could be relieved or removed by producing for export as well as the domestic market, so allowing a larger scale of production with lower unit costs. However, there are a variety of factors which at present work against the likelihood that export mills in tropical countries would be viable, except within the context of supplies to other countries within certain subregional groupings of countries (e.g., ASEAN). These factors include product quality and price, the global balance between supply and demand, the structure of the existing pulp and paper industry, and the availability of fibre supplies to existing industry.[8/]

Due to the advanced technology involved, most developing countries have to import the equipment for pulp and paper manufacture. Many have also to look abroad for financing to meet part of the huge capital costs involved, and for the technical expertise needed to run the mill, at least for an initial period. Some may also have to import some of the chemical inputs. A further factor that needs to be taken into account in evaluating possible investment in import-substituting pulp and paper developments is that the foreign exchange savings that accrue from producing rather than importing are not offset by continuing foreign exchange costs to operate the plant. If the equipment, chemical inputs, and technical expertise all have to be imported and paid for from foreign exchange, there could be little if any net positive impact on the balance of payments.

DEVELOPMENT POLICIES AND ECONOMIC SOVEREIGNTY

A number of factors thus combine to create in the tropical forest sector in many countries a situation from which developing countries are striving to excape, namely that of being predominantly suppliers of raw mterials to the more developed countries, and dependence on these countries for supplies of more highly processed products. The inequity of this situation is by now too well known to need to be argued here. It includes, in addition to the obvious imbalance in unit values between the

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[8/] For further details, see the Report on the UNDP/FAO Pulp and Paper Industries Development Programme to the Expert Consultation on World Pulp and Paper Demand, Supply and Trade, Tunis, 20-22 September 1977, and the conclusions of the Consultation, in "World Pulp and Paper Supply, Demand and Trade," FAO 1978.

two trade flows, exposure of the exporting countries to the insecurity surrounding the relatively higher fluctuations in prices which afflict raw materials, and the tendency for terms of trade to move against them.

The policies for forestry and forest industry development pursued by most tropical countries hence seek to redress this situation. They are very largely structured around a continuing reliance on foreign participation in the development of the sector:[9/] to secure technical know-how and operating expertise, access to export markets, and investment capital to finance equipment that has to be imported from overseas. These policies include measures to increase the level of domestic processing, the extent of local ownership, and of staffing by nationals, and control on repatriation of earnings. The arguments that surround them are well known. Obviously there has to be an equitable balance between security for the foreign partner and the benefits that accrue to the country. Otherwise investment will not take place. There have, needless to say, on occasion been abuses by both industry and government. But quite clearly the general thrust is now towards greater local control of the country's natural resources, and toward internally located and relatively autonomous processes of growth.

Part of the political framework of tropical forestry development tends to be common to all forms of industrial development and foreign participation. Part is more particular to forestry. As by far the greater part of forest land is publicly owned, the government enters directly into tropical forestry development projects as the supplier of wood. Though there are instances where this is achieved through sales of wood or forest land, the more common practice is through concession agreements of one form or another, which grant rights to work the forest land for log production for a set period of time, and under specified conditions.

To be satisfactory a concession agreement must again strike an equitable balance between the legitimate interests and requirements of the two parties to it. It must also be enforceable, and be enforced. There are many reasons why this is difficult. Either or both parties may lack the knowledge and experience to be able to identify what would constitute an equitable and workable agreement. Forest services usually lack experience with industrial operations, local entrepreneurs probably lack experience in wood-using industries, and foreign companies may well lack knowledge of local conditions. Forest services may well have insufficient manpower and training to adequately monitor concession operations, or to fulfill their own obligations under their agreements. Low salaries may make the system liable to corruption, and so encourage industry to abuse the agreement.

One of the requisites of proper tropical forest development is thus the development of the necessary skills and institutional structures in the producing countries. This is evidently a concern and responsibility of government. In anything but the shortest term, however, it should also

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9/ In the paper-related industry sector in Latin America, for example, majority-owned U.S. corporations accounted for more than half of total sales in 1974 (Gregersen and Contreras).

be in the interests of all involved in tropical forestry development, private as well as public, to ensure that this happens.

CONCLUSIONS

Tropical forests are an important component of the resource base of many developing countries. They can contribute to the economic and social development of these countries in a number of important ways. Particularly in the recent past, developments based on tropical forests have already made significant contributions to the development of some countries. However, the potential remains for a fuller and more effective contribution. If this potential is to be fulfilled, developments need to be consistent with a complex set of interrelated economic and political factors.

The focus in this paper has tended to be on the variety of difficulties that can be encountered in threading a way through this complex framework, and on the shortcomings that may ensue if they are not taken into account. It remains to be said that there is enough experience with successful developments to show that such difficulties actually exist, but can be overcome. There is a need to document and critically analyze such experience more fully, in order to provide more useful guidelines for successful developments in the future.

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UTILIZATION OF TROPICAL HARDWOODS FOR MANUFACTURE OF PULP, GENERATION OF STEAM, AND ELECTRICAL ENERGY--A PRELIMINARY INDUSTRIAL SURVEY

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ABSTRACT

Kraft pulp of satisfactory quality for selected paper grades is presently being manufactured from tropical hardwoods and from mixed tropical hardwoods. Experience with this pulp is now being gained through sales in the world market. Although there is presently an oversupply of pulp, future needs will require additional capacity.

A study was recently conducted into the utilization of mixed tropical hardwoods for the manufacture of pulp.[1] The purpose of the study was to determine the potential for utilization of this existing natural resource in a developing country as a means of creating useful products, providing new employment opportunity, stimulating the economy, and improving the balance of trade, while observing due regard for conservation and ecological factors.

The scope of the study was to conduct a preliminary industrial survey into the technical and financial feasibility of harvesting run-of-the-woods tropical hardwoods for the manufacture of pulp, and for the generation of steam and electrical energy from tropical hardwoods.

Information used in the presentation of this study was gathered from data obtained: at pulp mills presently manufacturing pulp and paper products from mixed tropical hardwoods; from the laboratory results and pilot scale tests done by the U.S. Department of Agriculture, Forest Service, Forest Products Laboratory; from Philippine and Colombian Governmental studies; from the United Nations Food and Agriculture Organization (FAO); and from our in-house information.

The economics of constructing a new kraft pulp mill are adversely affected by currently depressed market prices. This condition can be expected to change as demand catches up to supply.[2]

Incremental earnings benefits can be obtained under specific conditions in an existing kraft pulp mill by the use of mixed tropical hardwoods for pulping and as a fuel substitute for the generation of steam and electrical energy.

UTILIZATION OF TROPICAL HARDWOODS FOR MANUFACTURE OF PULP, GENERATION OF STEAM, AND ELECTRICAL ENERGY--

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BACKGROUND

Utilization of tropical hardwood species for pulping and papermaking has been limited until recently, although research has been carried out for over half a century.

The general forestry practice has been to harvest the best wood selectively and to leave the secondary species standing in the forest. Operations have been established for converting these selected species into lumber and veneer, or the wood has been sold in log form for export. This selective harvesting does not allow for full utilization of the forest resource, nor does it necessarily allow for the most beneficial long term regeneration of the resource.

The concept used here is to employ run-of-the-woods harvesting of all species within a given forest area. The emphasis is on the utilization of secondary species for the production of pulp, with the understanding that wood value will determine the end use of more valuable species. The economics of the study do not reflect the marketing of these species.

Many technical and economic studies have been conducted by The Food and Agriculture Organization of the United Nations (FAO) and others to determine the technical and economic feasibility of producing pulp and paper from tropical hardwoods. It has been generally shown in the laboratory and in mill operation that pulp can be produced, using the kraft process, which is acceptable for use in selected paper grades.

Certain wood species are undesirable due to high silica content or high extractives. Some high density woods are less desirable because of the difficulty in chipping and cooking. Resin or pitch is also a problem which must be dealt with in many areas. For these reasons it is advisable to sort mixed species to cull out the undesirable wood for other purposes than pulping.

It has been reported that pulp yields are lower with tropical hardwood pulps than with North American and other temperate zone hardwood pulps, when pulped to the same degree of delignification.[3]

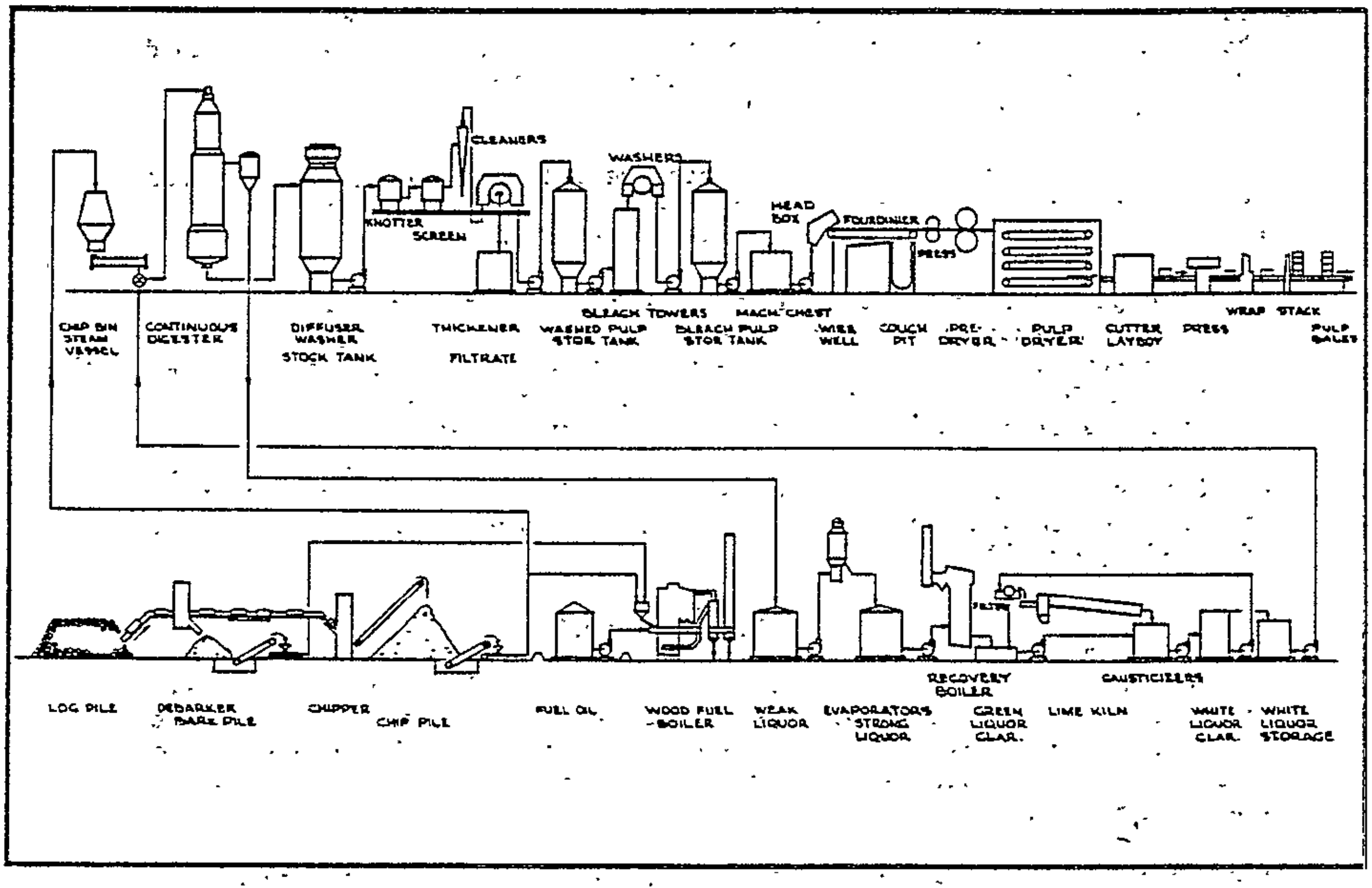


Figure 2.--Mixed tropical hardwood bleached kraft pulp mill process flow diagram.

pulp from MTHW, and for the generation of steam from MTHW. Due to the importance of the energy usage in this mill, a heat balance (fig. 3) has been included for reference.

There is a social obligation to include the latest technology for personnel and ecological protection. This has been accomplished by designing all process and personnel facilities to meet the requirements of the United States Occupational Safety and Health Act codes. Air emission abatement and effluent treatment/containment systems have been designed to meet the latest United States standards of the Environmental Protection Agency.

The mill is designed and the plant arrangement has been established for tropical climate conditions. Allowance has been made for an orderly future expansion. The plant arrangement is shown in figure 4.

Scarce capital is conserved and employment opportunities are increased by using a minimum of automated systems and designing the mill to be labor intensive to the maximum extent possible. The personnel requirements for this MTHW pulp mill are shown in figure 5 and can be compared with manpower requirements for a typical modern North American pulp mill.

A 500 metric ton per day bleached kraft mixed tropical hardwood pulp mill located in Southeast Asia is estimated to require a total investment of US $266,000,000.

Process Systems

The following is a description of the major pulp mill process systems. It has already been said that the sizing of process systems is somewhat different for MTHW than for temperate zone hardwoods. These descriptions include, where applicable, a brief discussion of the principal changes when using MTHW.

Wood Processing requirements are greater than those for a standard temperate zone kraft pulp mill. Approximately 35% more roundwood must be provided. This additional wood is needed to provide pulp wood to the digester and fuel wood to the boiler.

Pulping is based on a continuous digester system with approximately 15% greater capacity than that required for temperate zone hardwoods in order to produce the design tonnage at 40% bleached yield for MTHW. The digester size also allows for two hours of high heat washing. It is important to note that all liquor systems must be increased in size because of the lower yields of MTHW. The digester is followed by a two stage diffusion washing system, pressure knotters, and pressure screens. A three stage cleaning system is added to the brown stock processing equipment in order to remove dirt and pitch (typical in MTHW) from the screened pulp. After thickening, the pulp is stored at high consistency.

Laboratory tests have shown that often tropical hardwood mixtures produce a better quality pulp than many of the individual species. The distribution of fiber dimensions and properties in the mix apparently has a synergistic effect which is beneficial to pulp properties. Pulp strength tests are comparable with those of North American hardwoods. At best, the tear factor approaches that of some long fiber pulp, after suitable beating. The power to beat to the optimum level appears to be higher for pulp from mixed tropical hardwoods (MTHW).[3]

Tests have recently been carried out at the United States Forest Products Laboratory (FPL) in Madison, Wisconsin, to determine the problems involved in making pulp from MTHW, and to compare pulp quality with that of North American hardwoods.[4] This work confirmed earlier testing and added to the knowledge available. Wood samples from various tropical areas were successfully pulped by the kraft and semichemical process. Tests of the pulps and of the paper produced indicated that the physical and optical characteristics were acceptable and comparable with similar products produced with North American hardwoods.

In order to confirm the laboratory results, mills producing kraft pulp from MTHW were visited in the Philippines and in South America. Linerboard, corrugating medium, and sack paper, manufactured at these integrated mills, are sold in the domestic market.

CONSIDERATIONS REGARDING THE CONSTRUCTION OF A NEW MIXED TROPICAL HARDWOOD KRAFT PULP MILL

General

The manufacture of market grade bleached kraft pulp from mixed tropical hardwood (MTHW) is now an established fact both from tests at U.S. Forest Products Laboratory[4] and from commercial operations.

The high cost and uncertain availability of fuel oil has caused many mills to examine the substitution of high percentages of wood waste for fuel oil in the generation of steam and power.

These two features have been combined in the design of a hypothetical 500 metric ton per day bleached kraft MTHW pulp mill for this study. The design criteria for this mill are given in figure 1.

The use of MTHW for pulpwood and the substitution of wood for oil as fuel, in a steam generating boiler requires no new technology. In the design of a new facility, however, there are some important considerations which influence the sizing of processing areas. A lower yield for bleachable grade pulp for tropical hardwoods,[3] as opposed to temperate zone hardwoods, has an effect on the size of the brown stock and liquor systems. The use of fuel wood necessitates a larger chip handling system and lowers the combustion efficiency of a steam generating boiler. The flow diagram included as figure 2 shows the pulp mill processing systems which would be required for the production of market grade bleached kraft

Kraft Pulp Production - From Dryer

Nominal Design Rate - ADT/Year	175,000
Operating Days Per Year	350
Peak Design Rate - ADT/Day	570
Mill Efficiency Factor - % of Peak Rate	88
Nominal Design Rate - ADT/Day	500
Nominal Design Rate - ODT/Day	450

Yield - % Bleached	40

Bleached Pulp Yield Per Cubic Meter Solid Wood

Total OD Lbs. Per OD M^3	373

Heating Value of Fuels

Fuel Oil - BTU/Lb	18,000
*Black Liquor Dry Solids - BTU/Lb	6,300
OD Wood - BTU/Lb	8,500

*Can vary significantly
One Report of 5500 BTU/Lb Dry Solids

Figure 1.--Mixed tropical hardwood bleached kraft pulp mill--general basis of design.

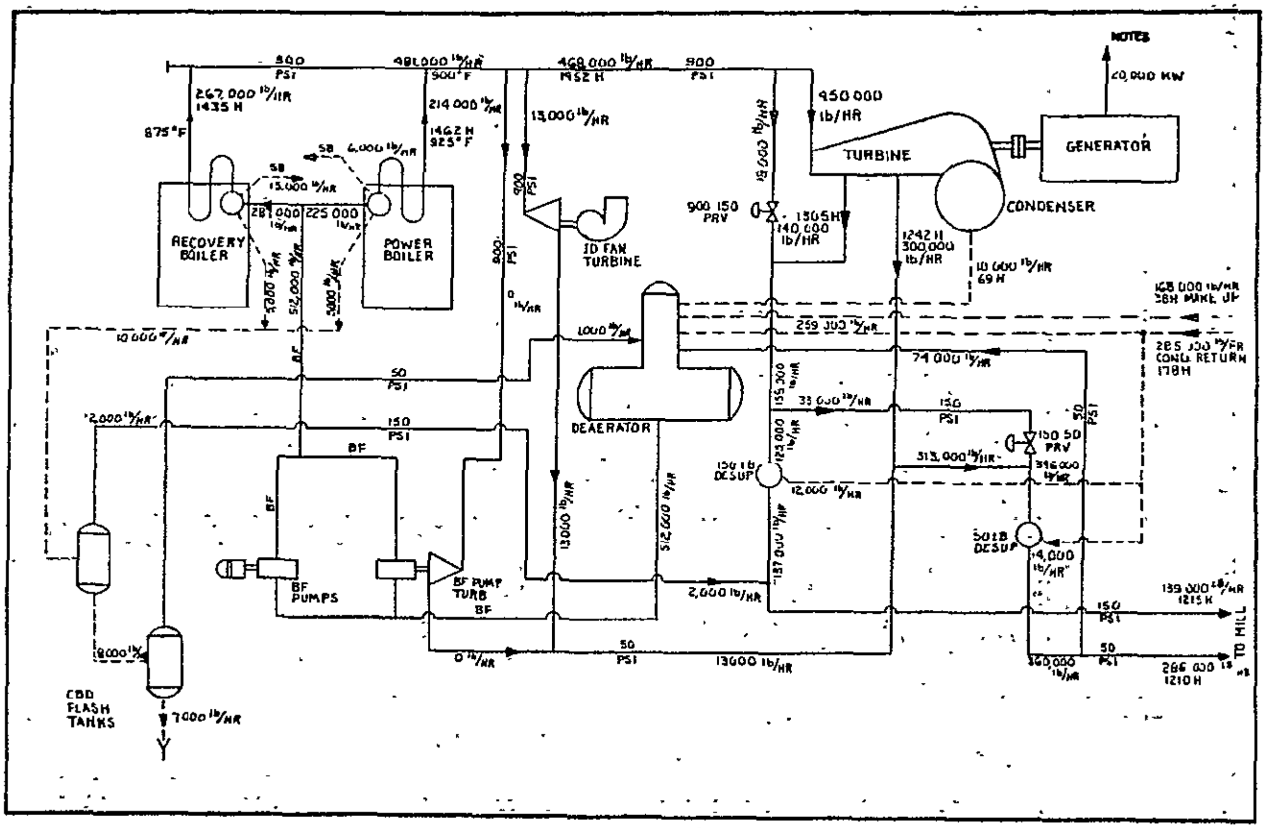


Figure 3.--Mixed tropical hardwood bleached kraft pulp mill heat balance.

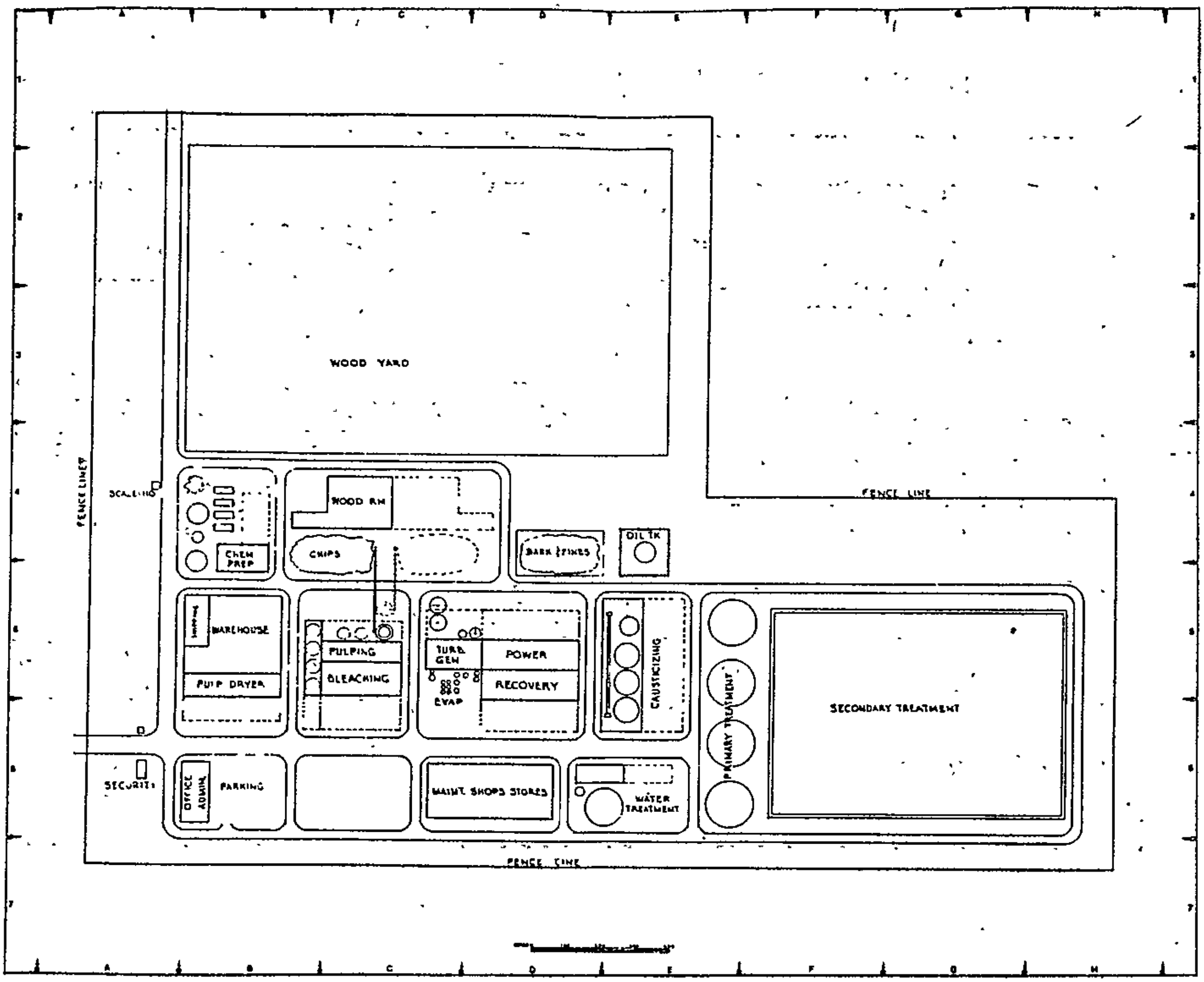


Figure 4.--Mixed tropical hardwood bleached kraft pulp mill plant arrangement.

MTHW Pulp Mill Manpower Requirements - Labor Intensive Design						Labor Saving Design
	Shift	Day			Totals	Totals
Department	Mill	Mill	Office	Managers	MTHW	Typ. North American
Wood Preparation[5]	14	22	6	3	45	46
Pulping	15	5			20	10
Evaporation & Recovery	15	6			21	11
Liquor Preparation	10	3			13	7
Bleach Plant	10	4			14	10
Bleach Chem. Prep.	15	4			19	4
Pulp Process & Finishing	50	7			57	20
Warehouse		13			13	8
Water Treatment & Effluent	20	4			24	8
Wood Fuel Boiler	20	6			26	11
Technical		1	30		31	39
Maintenance & Trans.	40	122			162	124
Office, Clerical, Security	25	100	135	25	285	64
Production Management		10		10	20	12
TOTALS	234	307	171	38	750	374

Figure 5.—Mixed tropical hardwood bleached kraft pulp mill personnel requirements.

Liquor Recovery-Evaporation Weak black liquor from the digester is concentrated to 62% solids content in a six-effect, six-body evaporator set. This system has the capacity for the higher liquor flow rates expected from the MTHW liquor cycle.

Liquor Recovery-Incineration. The black liquor recovery boiler is a modern low odor type unit with large economizer, without flue gas direct contact evaporator, and with a high efficiency electrostatic precipitator. The recovery unit must be carefully sized to handle anticipated liquor flows. The liquor heating value is a wide variable for MTHW and must be determined for each region.

Liquor Recovery-Recausticizing. The liquor preparation system is comprised of conventional gravity type settling equipment for the recausticizing area and a standard rotary kiln with related auxiliaries for the lime reburning process. This system is sized large enough to provide 15% more cooking liquor than would be required for a temperate zone hardwood mill of this size.

Wood Fuel Steam Generating Boiler. The boiler is designed to use wood and wood waste as its principal fuel. Approximately 20% of the steam from the wood fuel boiler will result from the combustion of fuel oil. The fuel oil is required to permit adequate response to rapid swings in mill steam and power demand.

Wood chips along with bark from the woodroom are conveyed pneumatically to a cyclone separator at the wood fuel boiler. From the separator the wood fuel flows by gravity through a chip distributor, chip feeding bin, and chip chutes to stoker distributors.

Nitrous oxide emission control is provided in the design of size and capacity of this boiler. Two-stage mechanical fly ash collectors are included to minimize particulate emission.

This boiler using mixed fuels as described will be approximately 20% larger than one designed for oil due to lower combustion efficiency.

Bleaching of pulp will be accomplished in five stages--chlorination, caustic, chlorine dioxide, caustic, chlorine dioxide. There are no significant differences in equipment type, size and materials of construction for this bleach plant from those used in a standard market pulp bleach plant.

Pulp Dryer. The pulp drying facility includes an essentially conventional machine with a fourdrinier wet end and an airborne dryer.

Electrical. The pulp mill is designed to be virtually self-sufficient for electrical utilities and services. On-site generation of electricity is provided by a steam driven turbine generator. A diesel motor generator provides power during construction, then later is used for mill start-up and emergency purposes.

Maintenance. A maintenance shop is included with the necessary tools and equipment to perform any daily maintenance work and most major repairs.

Infrastructure

The infrastructure requirements and costs constitute some of the greatest variables when constructing a pulp mill in a developing country. If the mill is located near a developed population center, the infrastructure cost could be quite low. In a remote location such as the one selected from this MTHW pulp mill, the infrastructure cost could equal one-half of the total investment. For this analysis, the site is assumed to be in a remote location close to the woodlands, on the sea coast, where flat topography and good soil bearing minimize site preparation and foundation costs.

Since the local government may pay for the development of all or part of the general infrastructure costs, only the mill related infrastructure costs have been included in the estimate of total investment. These mill related infrastructure costs consist of minimum roads, water supply, waste facilities, a communications system, electricity distribution, bulk materials systems, and the on-site services and amenities for the senior staff such as housing, recreational, religious, and medical facilities. These mill related infrastructure costs have been estimated to be $11,000,000 and this has been included in the total.

The general infrastructure requirements can include any or all of the following:

Housing for the community which will develop outside of the manufacturing plant. This community will consist of mill employees and those who provide goods and services to the mill and mill personnel.

Civil services including civil administration, police and fire departments, and a transportation network of roads.

Hospitals, schools, and religious facilities.

Utilities including generation and distribution of electricity, water supply, and waste treatment.

The development costs for general infrastructure could be many times the cost of mill related infrastructure.

500 T/D KRAFT PULP MILL

Financial

Financial considerations for this hypothetical MTHW 500 metric ton per day kraft pulp mill consist of the following components:

1. Total Investment Cost--The estimate of plant capital costs, working capital requirements, startup costs, mill related infrastructure costs, and the cost of capital during construction.

2. Manufacturing Costs--The direct manufacturing costs including wood costs for pulp, cooking and bleaching chemicals cost, materials cost, fuel costs (both fuel oil and fuel wood), and labor costs.

3. Financial Analysis--Translation of the cost data along with various revenue assumptions into a form which will be meaningful to potential investors. Based on a 5 year engineering and construction period, 4 years from startup to full production, 20 year plant life, 15 year loan repayment at 12% interest, 40% equity investment, the following were calculated: profit and loss; cash flow; debt service ratio; and discounted cash flow return on equity.

Cost Estimates--Investment

The total investment is composed of the following:

Total Plant Capital
Working Capital
Startup Costs
Mill Related Infrastructure
Interest During Construction

The total investment cost is summarized in table 1.

A. Total Plant Capital

The capital cost includes the cost of all process equipment and systems described as well as structures, systems, and services indicated in the plant arrangement. The estimate is based on current cost estimates of equipment manufacturers; actual costs of recently completed projects, with adjustment made for size variations; and cost estimates from recent FAO studies.

All costs are in US dollars and have been escalated to the third quarter, 1977.

The spare parts estimate is based on recommendations of equipment manufacturers and actual inventory levels of existing mills operating in developing countries, adjusted for size variation.

It has been assumed that this project would be funded through international financing and, therefore, no import duties have been included in the estimate of costs.

Table 1.--Total investment cost

Plant Capital	
Capital Cost	$159,500,000
Spare Parts	7,000,000
Construction Overhead	6,500,000
Engineering	13,000,000
Contigencies	18,000,000
Total Plant Capital	$204,000,000
Working Capital	11,400,000
Startup Costs	4,000,000
Mill Related Infrastructure	11,000,000
Interest During Construction	35,600,000
Total Investment	$266,000,000

B. Working Capital

The working capital requirement has been based on the amount deemed reasonable to fill the processing "pipelines" and continue operations until receivables have been collected. The basis for determining working capital is: receivables (at cost), 2 months; pulp in warehouse (at cost), 1 month; chemicals and fuel in storage, 1 month; wood in yard, one-half month.

C. Startup Costs

Included in startup costs are: the training in the United States of Nationals from the developing country who will become supervisors in the pulp mill; the U.S. pulp mill operations personnel who will be at the mill during the startup period; prestartup and startup training of all mill personnel; the equipment manufacturers' representatives who will supervise the initial startup and operation of specialized equipment; and miscellaneous items required for startup only.

D. Mill Related Infrastructure

The mill related infrastructure costs included consist of minimum roads, water supply, waste facilities, a communications system, electricity distribution, bulk materials systems; and the onsite services and amenities for the senior staff, such as housing, recreational facilities, a chapel, and medical facilities.

E. Interest During Construction

Financing costs for the mill during the construction period were calculated at a 12% cost of money and based on 60% debt financing over the last 3 years of the 5 year construction period.

Cost Estimates--Manufacturing

The manufacturing cost is estimated as follows:

Wood Costs--Wood for Pulp
Fuel Costs--Fuel Oil/Fuel Wood
Labor Costs
Cooking and Bleaching Chemicals Costs
Materials Costs

The manufacturing costs are summarized in table 2.

A. Wood Costs--Wood for Pulp

The equivalent cost per bleached ton is calculated from the estimated cost per cubic meter of wood for pulp[5] after an allowance has been made for bark and fines removal and is based on an average ovendry specific gravity of 0.48 and a bleached pulp yield of 40%.

Table 2.--Direct manufacturing cost

	US$/Air Dry Metric Ton of Pulp
Pulpwood Cost	
$17.30/M^3$ Wood = $37.16/Ton Chips	$92.90
Fuel Cost	
Lime Kiln: Fuel Oil Cost 9410 Gal/Day @.454/Gal; 350 D/Yr; 175,000 T/Yr	8.60
Wood Fuel Boiler: Fuel Oil Cost 9730 Gal/Day @ $.454/Gal; 350 D/Yr; 175,000 T/Yr	8.90
Wood Fuel Cost $13.55/M^3$ = $25.62/ODT X 276.6 ODT/D @500 T/D Pulp	14.20
Chemicals, Labor, Materials Cost	89.20
Total Operating Cost	$213.80

Pulp Wood Cost/M^3 = $17.30 (Reference 5)

$17.30	M^3	FT^3	2200 LB	1.0 OD	1.0 Equiv Wood	Yield	=$92.90/M Ton Bleached Pulp
M^3	35.314 FT^3	62.4 (.48)LB	M Ton	1.1 AD	0.88 Pulp Chips	0.40	

Fuel Wood Cost/M^3 = $13.55 (Reference 5)

$13.55	M^3	FT^3	2000 LB	= $25.62/Ton Wood Chips
M^3	35.314 FT^3	62.4 (.48)LB	Ton	

B. Fuel Costs

Lime kiln fuel oil requirements are based on actual calculations and have been compared with existing operations. The price of $0.12 per liter of fuel oil has been obtained from existing operating mill records and government sources for the locations selected for this study.

Wood fuel boiler total heat requirements have been determined for this mill, and this information is summarized on the heat balance which has been included.

Fuel oil is assumed to provide 20% of the heat requirement for the wood fuel boiler. The fuel oil cost used is, again, $0.12 per liter.

Fuel wood cost per cubic meter is based on the incremental cost for harvesting, transporting, and processing this additional wood for use as fuel.[5] The equivalent cost is based on an ovendry specific gravity of 0.48 and a heat value of 8,500 Btu per pound.

Wood waste (bark and fines from pulp wood) costs have been included inthe unit cost of pulp wood.

C. Labor Costs

Labor costs are estimated from the manpower requirements shown in figure 1 and are based on labor rates existing in the area selected. This information has been derived from actual mill operations and FAO reports for similar pulp mills.

D. Cooking and Bleaching Chemicals Costs

These costs are based on the totals derived from the prices in mill records and supplier information as applied to the usage rates applicable to each chemical.

E. Materials Costs

Materials cost is based on information received from discussions with pulp mill personnel and examination of pulp mill records.

F. Production

It is anticipated that the design production rate will be achieved in the fifth year of operation. Capacity utilization during this period is estimated to be as follows: 50%, 75%, 85%, 95%, and 100%.

Financial Analysis--The financial analysis examines the feasibility of this pulp mill project to potential investors on the basis of the following financial indicators:

Table 3.--$425/ton-profit and loss-cash flow-debt service coverage--net return on equity

60% Debt 40% Equity
20 yr. Straight line depreciation - $10963/year
15 year financing @ 12%
Equity - $106,160

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Profit & Loss																									
Sales Revenue						37188	55781	63219	70656	74375	74375	74375	74375	74375	74375	74375	74375	74375	74375	74375	74375	74375	74375	74375	74375
Manuf. Cost (-)						18708	28061	31803	35544	47315	37415	37415	37415	37415	37415	37415	37415	37415	37415	37415	37415	37415	37415	37415	37415
Gross Profit						18480	27720	41416	35112	36960	36960	36960	36960	36960	36960	36960	36960	36960	36960	36960	36960	36960	36960	36960	36960
Depreciation (-)						10963	10963	10963	10963	10963	10963	10963	10963	10963	10963	10963	10963	10963	10963	10963	10963	10963	10963	10963	10963
Interest (-)						19200	19200	18685	18109	17462	16738	15928	15020	14004	12865	11590	10162	8562	5770	4764	2522	-	-	-	-
Profit Before Tax						(11683)	(2443)	1768	6041	8535	9259	10069	10977	11993	13132	14407	15835	17435	19227	21233	23475	25997	25997	25997	25997
Cash Flow: Sources																									
Equity	36200	42500	24100	1460	1900																				
Debt	-	-	40000	58000	62000																				
Cash (Operations)	-	-	-	-	-	18480	27720	31416	35112	36960	36960	36960	36960	36960	36960	36960	36960	36960	36960	36960	36960	36960	36960	36960	36960
Total Cash Available	36200	42500	64100	59460	63900	18480	27720	31416	35112	36960	36960	36960	36960	36960	36960	36960	36960	36960	36960	36960	36960	36960	36960	36960	36960
Disposition of Funds																									
Plant Capital	34000	39900	55375	44875	29850																				
Infrastructure	2200	2200	3300	2200	1100																				
Working Capital					11400																				
Test & Start-up		400	625	625	2350																				
Interest	-	-	4800	11760	19200	19700	19200	18685	18108	17462	16738	15928	15020	14004	12865	11590	10162	8562	6770	4764	2522	-	-	-	-
Repayment of Debt	-	-	-	-	-	-	4292	4807	5384	6030	6754	7564	8472	9488	10627	11902	13330	14930	16722	18728	20970	-	-	-	-
Total Dispersed	36200	42500	64100	59460	63900	19200	23492	23492	23492	23492	23492	23492	23492	23492	23492	23492	23492	23492	23492	23492	23492	-	-	-	-
Net Cash Flow	-	-	-	-	-	(720)	4228	7924	11620	13468	13468	13468	13468	13468	13468	13468	13468	13468	13468	13468	13468	36960	36960	36960	36960
Debt Service Coverage Ratio						.79	1.18	1.34	1.49	1.57	1.57	1.57	1.57	1.57	1.57	1.57	1.57	1.57	1.57	1.57	1.57	-	-	-	-
Net Return on Equity (%)	-	-	-	-	-	-	-	1.7	5.7	8.0	8.7	9.5	10.3	11.3	12.4	13.6	14.9	16.4	18.1	20.0	22.1	24.5	24.5	24.5	24.5

A. Discounted Cash Flow Return on Equity

The discounted before tax cash flow rate of return on equity investment was used in this financial analysis to give potential equity investors a useful tool to evaluate this project. The rate of return was determined which balanced discounted equity investment with the discounted stream of net cash flows from the first year of operation through the expected life span of the investment (which in this analysis is assumed to be the 20th year of operation).

B. Debt Service Ratio

This measure was selected in this financial analysis to show the project's ability to meet debt obligations on both the interest and repayment of the debt principal. This ratio is calculated by dividing the estimated gross profit of the enterprise in any year by the payments of both interest and loan repayment.

Profit and loss and cash flow projections were calculated based on several different revenue, and financing assumptions to demonstrate the financial situation under selected alternative conditions. It was seen that at present market prices, this would not be a profitable venture. In order to permit a meaningful financial analysis prices were taken to cover a range which would result in a positive return on equity. This range went from $375/ton to a level which would yield a reasonable return, $475/ton, with a base case taken at $425/ton.

This information has been tabulated in summary form and is shown in table 3.

Variations in revenues, manufacturing cost, and capital cost demonstrate the sensitivity of the return on equity to these assumptions. Sensitivity tests have been made and are presented in graphical form in table 4.

Analysis of these data shows that the return on equity is marginal at $375/ton, 8%± at $425/ton, and 12%± at $475/ton. The return on equity is most sensitive to changes in revenues.

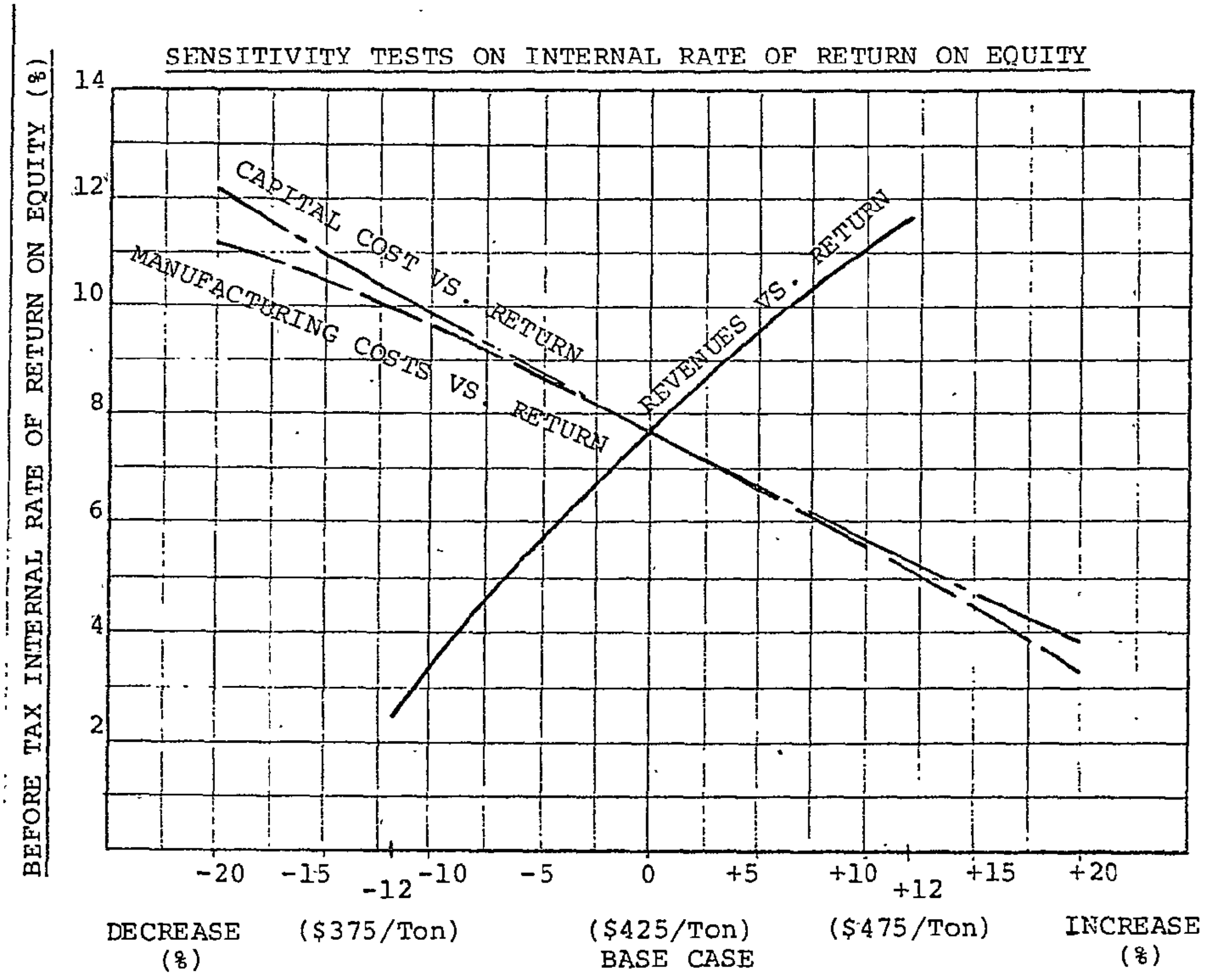
Assumptions for financial analysis:

A. Sales price for pulp is assumed to be $425 per metric air dry ton, f.o.b. pulp mill. Results were also calculated using $375 and $475/ADT as the sales price. (For exported pulp the applicable cost, insurance, and freight must be added.)

B. Manufacturing cost is based on the following rates as a percentage of design production: year 6, 50%, year 7, 75%, year 8, 85%, year 9, 95%, and year 10, 100%.

C. Depreciation is based on straight line over a 20 year plant life. Depreciable assets are taken as total investment less spare parts, working capital, infrastructure, and site related costs. For depreciable assets of $219,260,000, the annual depreciation is $10,963,000.

Table 4.--Sensitivity tests--internal rate of return on investment.



D. Financing is based on equity capital of $106,000,000 and debt capital of $160,000,000 (60%). The loan is repaid over a period of 15 years with payments starting in the second operating year. The constant finance charge (principal and interest) or annuity is calculated based on 12% interest.

IMPACT OF THE USE OF MIXED TROPICAL HARDWOODS ON AN EXISTING PULP MILL

One of the purposes for using MTHW in an existing mill would be to increase profitability. Consequently, it is important to examine carefully the impact of using MTHW as it effects revenues, production, and costs.

The impact on an existing mill of using MTHW may be assessed on the following five bases:

Impact on Pulp Quality and Marketability
Impact on Production Rate
Impact on Capital Costs
Impact on Operating Costs (Fuel Cost)
Impact on Optimization

1. Impact on Pulp Quality and Marketability

These have been dealt with previously. Summarizing that information, it was stated that quality will be comparable to single species hardwood pulps for certain grades of paper. In the case of an existing mill, some initial price discounting may be necessary to satisfy present customers.

2. Impact on Production Rate

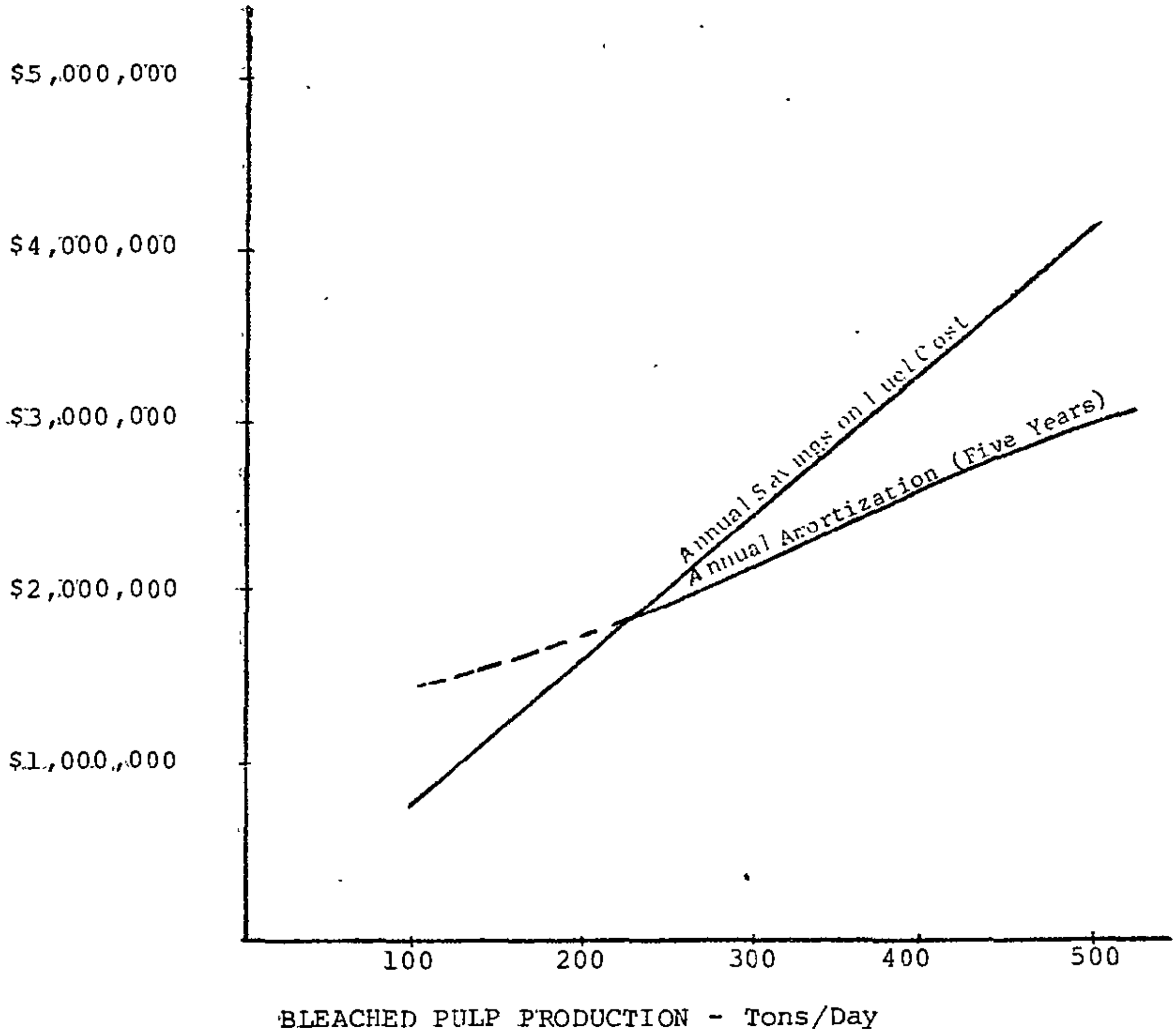
In order to maintain production rate when MTHW is used (in a kraft pulp mill of traditional design for temperate zone hardwoods) for pulping and when wood is substituted for oil in power boiler, the following new design conditions must be considered:

A. Wood harvesting requirements increase by 35%. This results from the use of more wood for pulping to a lower yield; and the requirement to harvest wood for use as fuel.

B. Wood processing requirements increase to handle the incoming roundwood. Fuel wood does not require debarking or screening. However, three times the wood and waste handling to the boiler is required than that for a standard mixed fuel boiler.

C. Pulp digester, evaporation, recovery boiler, and liquor preparation system requirements increase by 10% to 15% to maintain the original unbleached pulp production rate. Most mixed tropical hardwoods have a higher percentage of noncellulosis organics than North American hardwoods, therefore, a lower unbleached yield results. All processing areas

Table 5.--Annual savings versus annual costs



Assume: 500 T/D Bleached Pulp Mill
$15,000,000 Capital Investment required
5 Year Amortization period

Saving would equal $1,000,000 annually for 5 years, then increase to $4,150,000 thereafter.

* $ 830,000 for a 100 T/D Pulp Mill
$1,660,000 for a 200 T/D Pulp Mill
$2,490,000 for a 300 T/D Pulp Mill

* Annual savings on fuel costs for wood fuel boiler versus standard boiler.

100 T/D Hardwood Mill:

Fuel Oil	10,292 gal/day @ $0.454 gal =	$ 4,675/Day
Bark	26.3 T/D byproduct of pulping	

Mixed Tropical Hardwood Mill w/Wood Fuel:

Fuel Oil	1969 gal/day @ $0.454/gal = $890/day	
Bark	30 T/D byproduct of pulping	$ 2,307/day
Fuel Wood	55.3 T/D @ $25.62/T = $1417/day	
	Savings Using Wood Fuel	$ 2,368/day $828,800/year

5. Impact on Optimization

The alternative courses of action are:

A. Invest the necessary capital to increase capacity of deficient processing areas as required to match the capacity of the rest of the mill.

B. Reduce production until limiting processing areas can keep up with mill production.

C. Determine the optimum combination of capital expenditure and production curtailment.

The optimum course of action is found at that point where profit is maximized.

An example is presented in table 5 to indicate the annual cost versus annual savings for various size mills. For example, in a 500 T/D mill in which a new wood fuel boiler is required and the total cost for conversion to wood fuel is $15,000,000 the incremental savings is $1,000,000 annually. This table may also be used to show the relative cost versus savings to install comparable equipment in mills of smaller size. This table shows that annual savings exceed annual costs (during an assumed 5 year amortization period) for mills over 225 T/D capacity.

(1) Change of furnace size. To keep steam production the same as that when firing oil, a grate larger in area than the furnace must be installed. This requires major modifications to the furnace including replacement of the bottom and front wall and enlargement of the side walls.

(2) Change in combustion air requirements. Complete new and larger combustion and overfire air systems must be designed in order to burn the wood. This would result in the installation of a new forced draft fan.

Converting from fuel oil to 80% wood for fuel increases the problem of particulate collection at the outlet of the boiler. Investigations must be made to determine the best types of systems to be used. These could consist of mechanical collectors, scrubbers, electrostatic precipators, or any combination of the three. The addition of this equipment will require the installation of a new induced draft fan.

In order to burn the additional wood as fuel, a larger wood handling system must be designed and furnished to convey the wood to the furnace to be burned. An expanded ash handling system must be designed and furnished to dispose of the collected bottom ash and particulate matter.

Conversion to 80% wood firing is a major project and would require a lengthy shutdown of the power boiler. This would require a temporary source of steam supply, such as a package boiler, during the progress of the work.

An alternate and far more costly course of action is the installation of a new unit sized for the changed conditions. Although modification to the existing power boiler will be expensive, the total cost may nevertheless be lower than that for a new installation.

4. Impact on Operating Costs

The major impact on operating costs would result from the substitution of fuel wood for fuel oil in the wood fuel power boiler.

The annual operating cost savings based on the costs of fuel wood and fuel oil established previously would be in the order of:

affected by this must be sized accordingly. The requirements in these areas would be dependent upon the actual raw materials in a specific location.

D. Centrifugal cleaning system is recommended. Mixed tropical hardwoods generally have a high resin content, and these resins are not easily saponified. Unbleached pulp cleaners can be used to aid in the removal of this pitch.

E. Power Boiler. If this unit is presently designed to use oil only as fuel, a new wood fuel boiler will be required. If this is a standard mixed fuel boiler, the lower combustion efficiency will reduce the heat input by up to 20%.

3. Impact on Capital Costs

It can be seen from item 2 above that a specific mill must be studied in order to determine limitations imposed on total mill production. After evaluating the capacity limitations of each major production system, the capital costs of overcoming the limitations can be considered.

A. Woodlands must be reviewed and a determination must be made concerning long term sustainable yield and costs of harvesting the additional wood required.

B. Wood processing capacity can generally be increased incrementally.

C. A mill with batch digesters can be increased in size by increments, however, a continuous cooking system will require a more careful study. Evaporator systems can usually be increased by increments. The liquor preparation system consists of many components. Capacity can often be increased by adding components and making design changes or by accepting lower efficiency. A brown stock centrifugal cleaning system may be added, however, additional thickening capacity may also be needed.

D. Recovery Boiler. After determination has been made of the increased liquor flow anticipated, this unit must be evaluated for maximum liquor incineration and steam generating capabilities. If the unit was conservatively designed for the original conditions, it may be possible to fire the additional liquor, generate more steam, and still meet the applicable codes. If the unit is operating at or near its rated capacity, it will not be possible to generate any more steam. The additional liquor, however, may be fired using the furnace as a smelter furnace. This will result in a discharge of increased particulate matter and will require the addition of a new electrostatic precipator operating in series with existing equipment, or a scrubber. In this case, a black liquor oxidation system would also be required.

E. Power Boiler. The combustion components of this unit will be dramatically affected by the substitution of wood for fuel oil. A larger traveling grate must be added to burn the additional wood. The addition of this grate could result in the following major changes:

SUMMARY AND CONCLUSIONS

The following general conclusions have been reached:

1. New 500 T/D Kraft Pulp Mill

It is technically possible to harvest run-of-the-woods tropical hardwoods, convert this material to chips, and manufacture market grades of bleached kraft pulp. It is also technically possible to substitute a substantial percentage of wood for the oil which is normally used as fuel for generation of process steam and power.

The financial viability of this pulp mill was examined on the basis of the before tax discounted cash flow return on equity and the debt service ratio which could be generated. The information developed from the financial analysis indicates that at an investment cost of $266,000,000 a direct manufacturing cost of $213.80/air dry metric ton, and current market prices for pulp, a negative return on equity would result. Variations in the assumptions on investment cost, manufacturing cost, and sales price demonstrate the sensitivity of return on equity to each of these factors. The sensitivity tests indicate that changes in selling price have almost twice the effect on the internal rate of return as do changes in investment or manufacturing costs. Accordingly, it was learned that at an f.o.b. mill price of $375/ton the before tax return on equity would be marginal, at $425/ton the before tax return on equity would be approximately 8%, and at $475/ton the before tax return on equity would be 12%.

Clearly under present conditions this would not appear to be a viable project if the pulp mill is considered exclusively on its own merits.

Considerations which may alter the major conclusions include the following:

Governmental Incentives. Most pulp mill projects in developing countries have been sponsored by or assisted by the national government of that country. The government may contribute a percentage of the total investment cost as a grant in order to provide an incentive for other investors. The government may pay for general development costs such as the woodlands and infrastructure, or provide low interest loans, tax incentives, or tariff protection. Any one or all of the above governmental incentives may be offered in order to improve the return on equity.

Specific Local Need. If the pulp is sold in local markets, the savings on shipping charges will favorably affect the return on equity.

Marketing. At present, there is an oversupply of hardwood kraft pulp on the world market. This has caused a reduction in the sales price. Indications are that, with the new hardwood kraft mills which are coming into production, the oversupply will continue in the immediate future. However, the 1990 consumption projections for Japan and Western Europe show a potential market opportunity for hardwood kraft pulp as an import. These marketing conditions must be followed closely.

Employment. This facility will provide direct employment for 1340 people. While the capability is being developed in a technical chemical process industry, there will be a need for 975 people who may be totally unskilled. In-house information from studies conducted in other developing countries has shown that a major industrial complex can support a population approximately 15 times the number of people directly employed. This employment multiplier effect arises from the need for goods and services to the facility and its employees.

Economy. This study is limited to financial analysis of the pulp mill as it would apply to private investors. By analyzing the social opportunity costs of labor, capital, and foreign exchange components, it would be possible to determine the potential benefits to the country as whole. An economic analysis is, therefore, recommended.

Size of Pulp Mill. Experience from other studies indicates that a 700 T/D pulp mill is closer to an optimum size. Revenues would be 40% greater, while the total investment would only rise by approximately 22%.

2. Impact on an Existing Pulp Mill

The use of mixed tropical hardwood for pulp wood and the substitution of wood for oil as fuel, in a steam generating boiler, requires no new technology. The financial justification for conversion of an existing kraft pulp mill, however, will vary for each specific mill and location.

The first requirement is to analyze the investment costs necessary to maintain production at the existing level. Characteristics of MTHW are such that more productive capacity will generally be required than for temperate zone hardwoods for the wood processing, pulp digesting, liquor evaporation, recovery boiler, and liquor preparation systems. A boiler designed for mixed fuel (hog fuel and oil) will be less efficient when using larger percentages of fuel wood. Each processing area must, therefore, be studied to determine the cost to obtain the original production when using the new pulp wood.

The potential savings should then be calculated based upon the cost differences for mixed tropical pulpwood versus present pulpwood and fuel wood versus fuel oil. The cost of each of these components will be highly dependent upon the specific location selected.

Since optimization of profits is one goal, the information developed can be used to determine the profit at which benefits from the use of MTHW for pulp and fuel are greatest. The most likely production limiting unit will be the power boiler. The example presented shows the cost savings resulting from the use of wood as fuel and, by comparing these savings to the capital cost of a new wood fuel boiler, indicates the attractiveness of this investment. Under present market conditions, it may be desirable to accept some reduction in production to obtain the savings from the use of fuel wood.

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