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PAPERS FOR CONFERENCE ON IMPROVED UTILIZATION OF TROPICAL FORESTS

MAY 21—26, 1978

MADISON, WISCONSIN USA

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Papers for

CONFERENCE ON IMPROVED UTILIZATION OF TROPICAL FORESTS

May 21-26, 1978
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This volume contains the papers submitted in advance of the Conference on Improved Utilization of Tropical Forests, May 21-26, 1978, at Madison, Wisconsin, USA.

A companion volume to contain the summations of the conference will be published as soon as possible after the session.

CONTENTS

Author	Paper Title	Page
Section I--Tropical Forest Resource*		1
S. L. PRINGLE, Forestry Department, Food and Agriculture Organization	Quantity and Quality of the Tropical Forests.....	3
ROBERT C. KOEPPEN, U.S. Forest Products Laboratory	Some Anatomical Characteristics of Tropical Woods.....	23
Section II--Environment and Silviculture*		38
DUNCAN POORE, Evenlode, Stonesfield, Oxon, UK	Values of Tropical Moist Forests.....	39
JOHN J. EWEL and LOUIS CONDE, University of Florida, Gainesville, Fla.	Environmental Implication of Any-Species Utilization in the Moist Tropics.....	63
CHARLES B. BRISCOE, Jari Florestal e Agropecuaria, Belem, Para, Brazil	Silviculture in Plantation Development.....	83
DEMOCRITO L. DAGONDON and FELIPE B. ABRAHAM, JR., Nasipit Lumber Co., Manila, Philippines	Practices and Experience of Nasipit Lumber Company, Inc., in Its Natural and Artificial Regeneration of Forests and Plantations.....	101
S. D. RICHARDSON, Asian Development Bank, Manila, Philippines	Forests and the Faustian Bargain.....	111
P. F. STAGER CARVAJAL, Manasa Da Amazonia S.A., Manaus, Amazonas, Brazil	Little Known Woods of the Brazilian Amazon.....	119
E. R. PALMER, Tropical Products Institute, London, England	Factors Affecting Pulpwood from Plantations and Natural Forests in the Tropics.....	141
Section III--Harvesting, Transport, and Storage		155
JACK R. SCHOENING, Weyerhaeuser Company, Longview, Wash.	Forest Industry Development in Southeast Asia.....	157
ULF SUNDBERG, Royal College of Forestry, Garpenberg, Sweden	Implications of Improved Utilization of Tropical Forests on Harvesting and Transport...	165
ALFEO MINATO and RAUL E. DIAZ, H. C. Mason and Associates, Portland, Oreg.	Implications of Logging Systems for More Complete Utilization (abstract only).....	175

Author	Paper Title	Page
Section IV--Wood Fiber and Reconstituted Products Research		177
F. H. PHILLIPS, A. F. LOGAN, and V. BALODIS, CSIRO, South Melbourne, Victoria, Australia	Suitability of Tropical Forests for Pulpwood: Mixed Hardwoods, Residues, and Reforestation Species.....	179
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.....	199
Section V--Wood Fiber and Reconstituted Products Research		216
JAMES F. LAUNDRIE, U.S. Forest Products Laboratory	Kraft and Neutral Sulfite Semi-chemical Pulping of Mixed Tropical Hardwoods.....	217
DONALD J. FAHEY and JAMES F. LAUNDRIE, U.S. Forest Products Laboratory	Market Pulp and White Papers from Mixed Tropical Hardwoods.....	241
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.	257
GARY C. MYERS, U.S. Forest Products Laboratory	Hardboards from Mixed Tropical Hardwoods.....	273
ROLAND O. GERTJEJANSEN, D. W. HAAVIK, H. F. CARINO, S.P.A. OKORO, and H. J. HALL, College of Forestry, University of Minnesota, St. Paul	Properties of Particleboards from Mixtures of Philippines Hardwoods.....	285
E. R. PALMER, Tropical Products Institute, London, England	Investigations at the Tropical Products Institute of Fibrous Materials for Use in Pulp and Paper.....	301
Section VI--Industrial Plans and Practice		315
GEORG PETROFF, Centre Technique Forestier Tropical, Nogent-sur-Marne, France	Tropical Hardwood Pulps.....	317
R. L. STAEPELAERE, Parsons and Wittemore, and P. L. GINSBURGER, Arbocel, Paris, France	Utilization of Bleached Sulfate Tropical Hardwood Pulp.....	343
PEDRO M. PICORNELL, Paper Industries Corporation of the Philippines, Makati, Rizal, Philippines	Some Points to Consider in Improving the Utilization of Tropical Forests.....	379

Author	Paper Title	Page
Section VII--Investment Considerations		387
HAYDN H. MURRAY, Indiana University, Bloomington, Ind.	Problems in Process Chemical Production in Developing Countries.....	389
J.E.M. ARNOLD, Forestry Department, Food and Agriculture Organization, Rome, Italy	Economic and Political Environment for Investment in Natural Tropical Forest Development....	399
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.....	415

CONFERENCE OBJECTIVES

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

All major issues will be discussed including:

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

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

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

SECTION I

TROPICAL FOREST RESOURCE

Authors: S. L. Pringle
R. C. Koeppen

QUANTITY AND QUALITY OF THE TROPICAL FORESTS

By

S. L. Pringle

Food and Agriculture Organization
of the United Nations
Rome, Italy

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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.

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.

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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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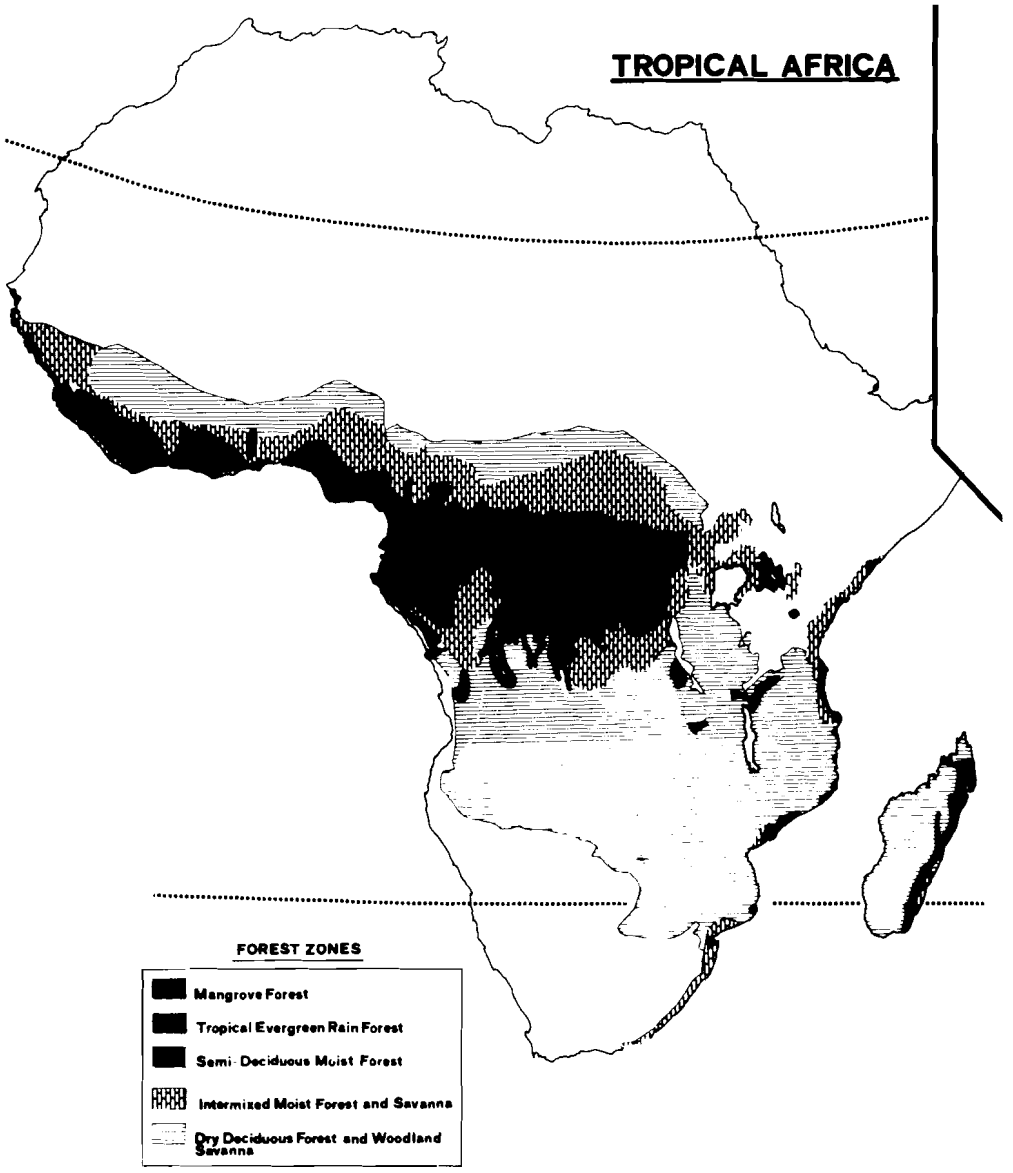
5/ These maps are based on a number of sources and an arbitrary grouping of forest type detail. They draw heavily from Schmithüsen, J., "Atlas Zur Biogeographie," Bibliographisches Institut, 1976, and Oxford University Press "Vegetation Map of Africa," published on behalf of the Association pour l'Etude 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.



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TROPICAL ASIA PACIFIFIC

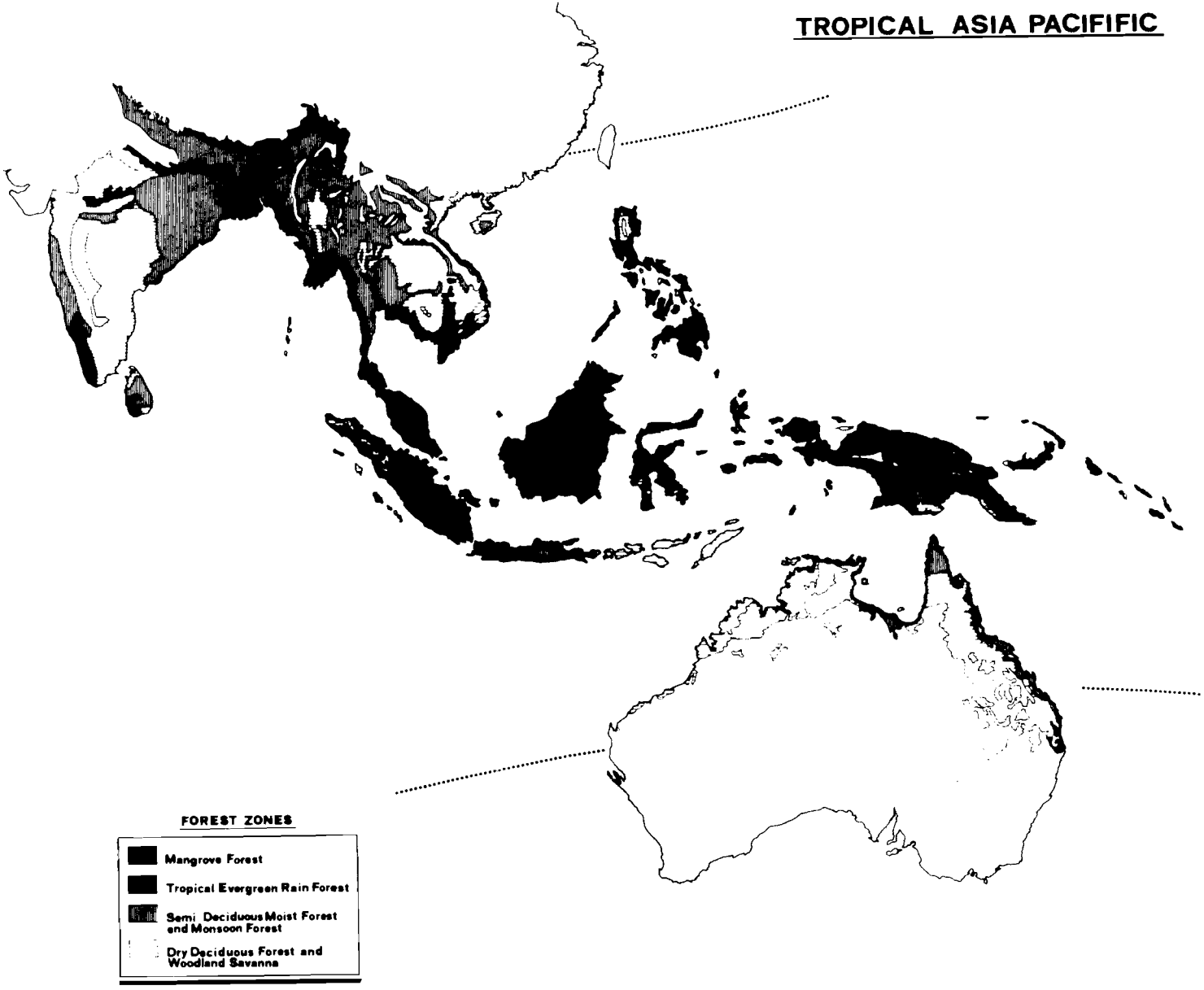

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Table 1.--Forest areas in tropical countries (in million ha)

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.

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, "Situação 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.

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

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.

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 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.

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.

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

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	Latin America	Major locations 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.

(Page 1 of 3)

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.

(Page 2 of 3)

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.
Dry Tropical				
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).

(Page 3 of 3)

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

Robert C. Koeppen

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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

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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 Length (mm.)	Fiber Wall thickness (μ)	Fiber Runkel ratio	SiO_2[2/] %	Normal canals
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 coloneura	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)

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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

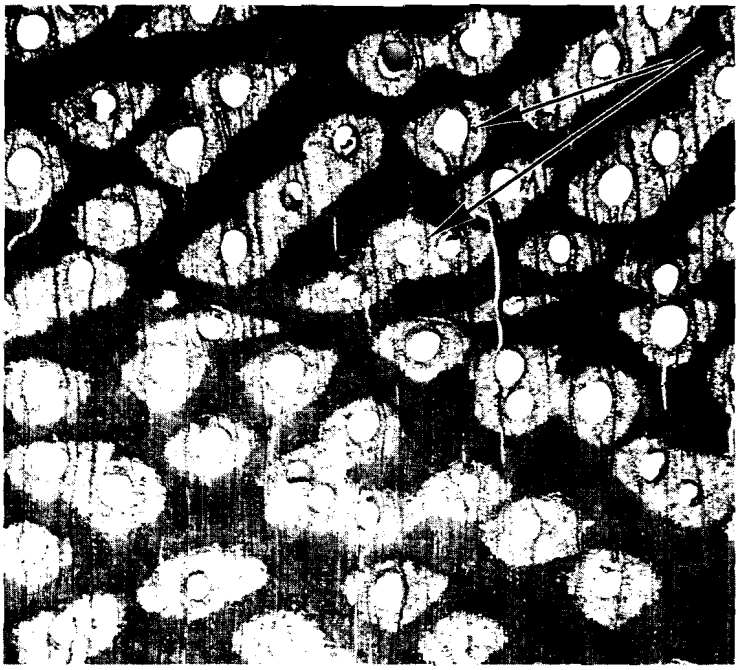

Figure 1.--Cross section (30X) of Enterolobium schomburgkii, from Colombia, with aliform to confluent axial parenchyma.

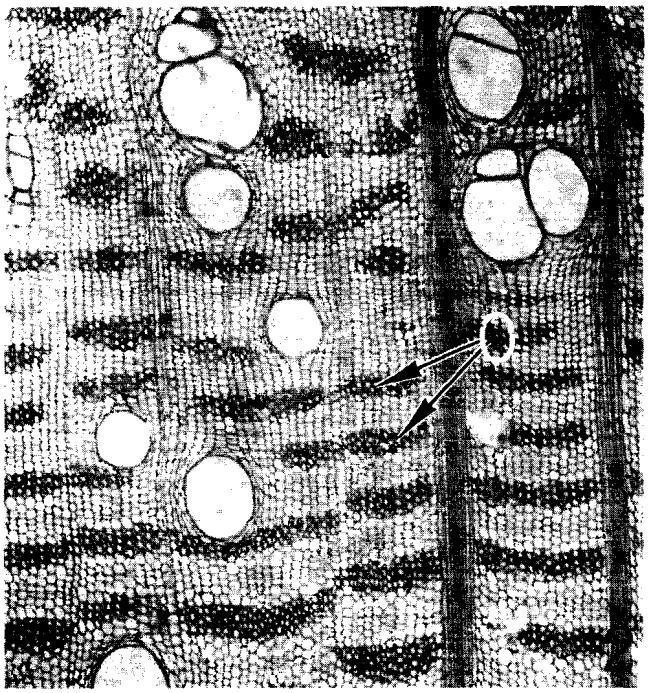

Figure 2.--Cross section (30X) of Erythrina subumbrans, from Philippines, with broad bands of axial parenchyma. Fibers (F) show as darker patches.

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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

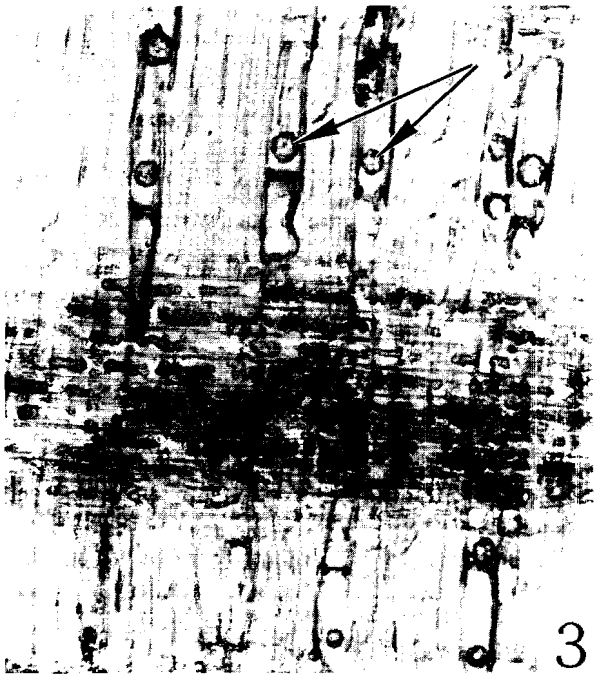

Figure 3.--Radial section (400X) of Dialium guianense, from Colombia, showing silica bodies in the axial parenchyma cells.

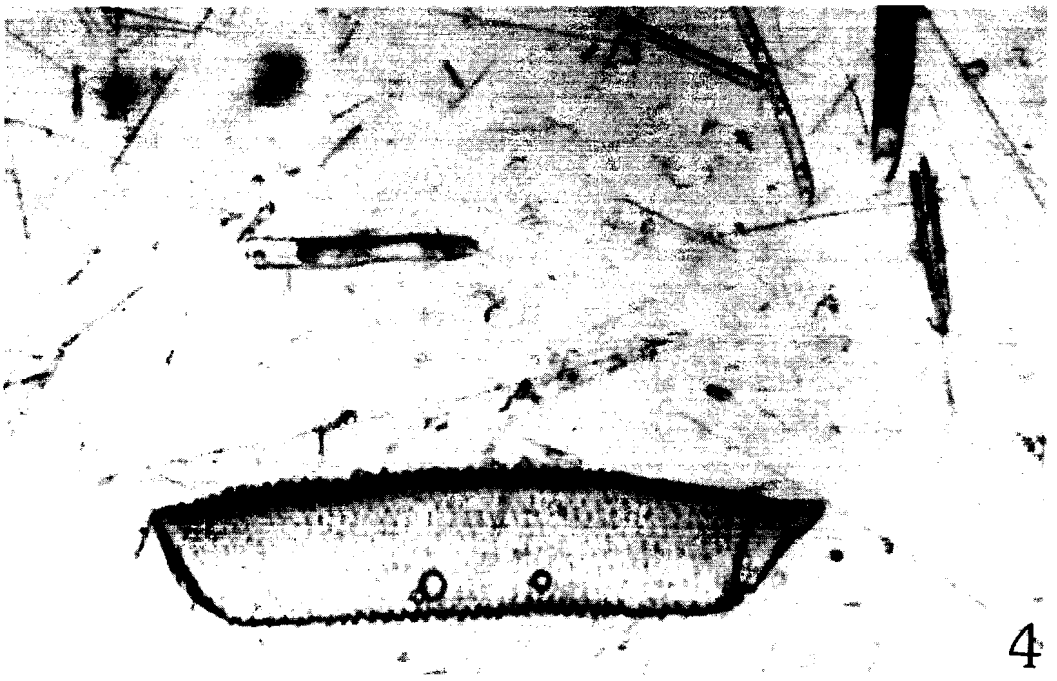

Figure 4.--Maceration (225X). Vitreous silica casts of cells in Maquira guianensis, from Surinam. All lignin and cellulose have been removed.

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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

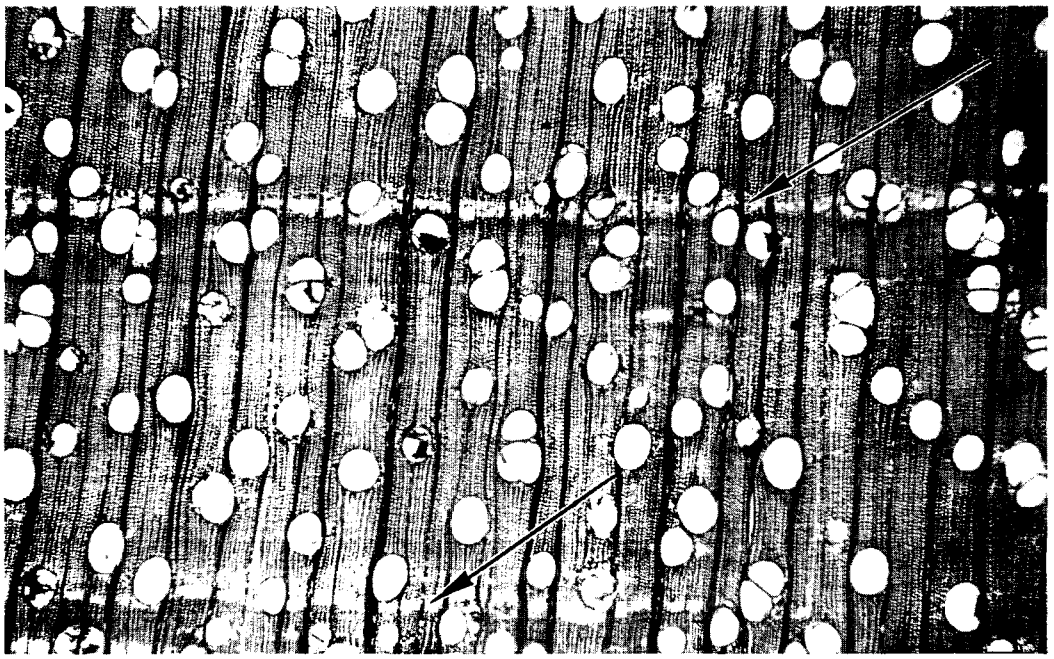

Figure 5.--Cross section (30X) of Shorea polysperma, from Philippines, showing axial canals arranged concentrically.

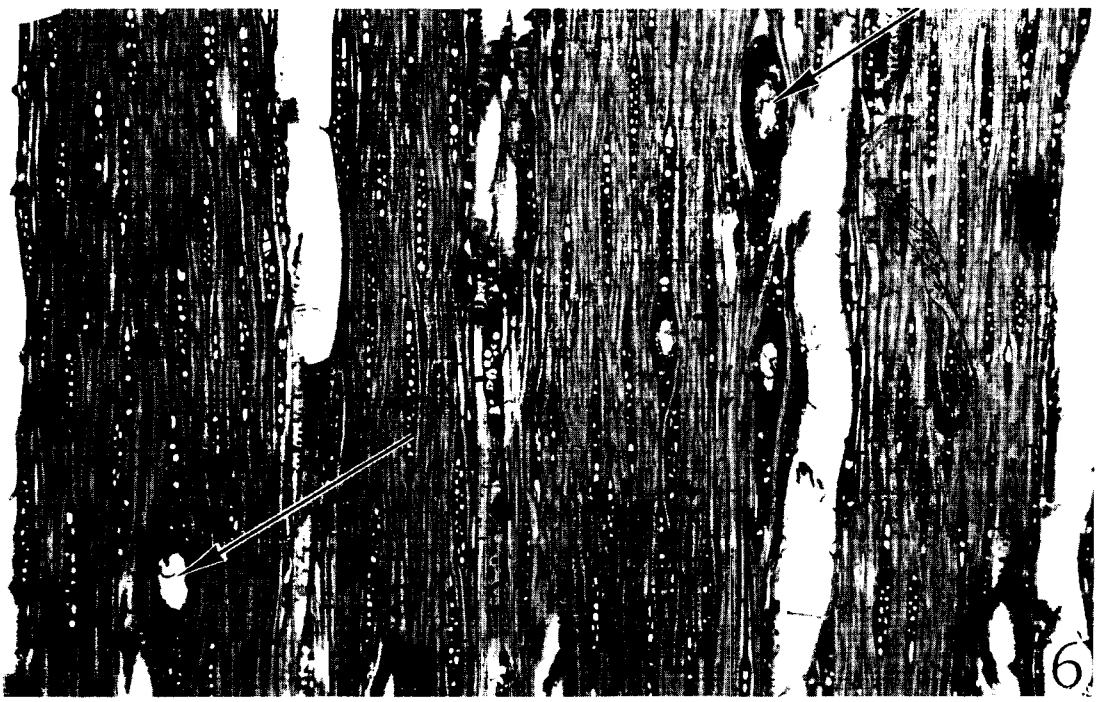

Figure 6.--Tangential section (30X) of a species of Tetragastris from French Guiana showing horizontal canals running through the wood rays.

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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.

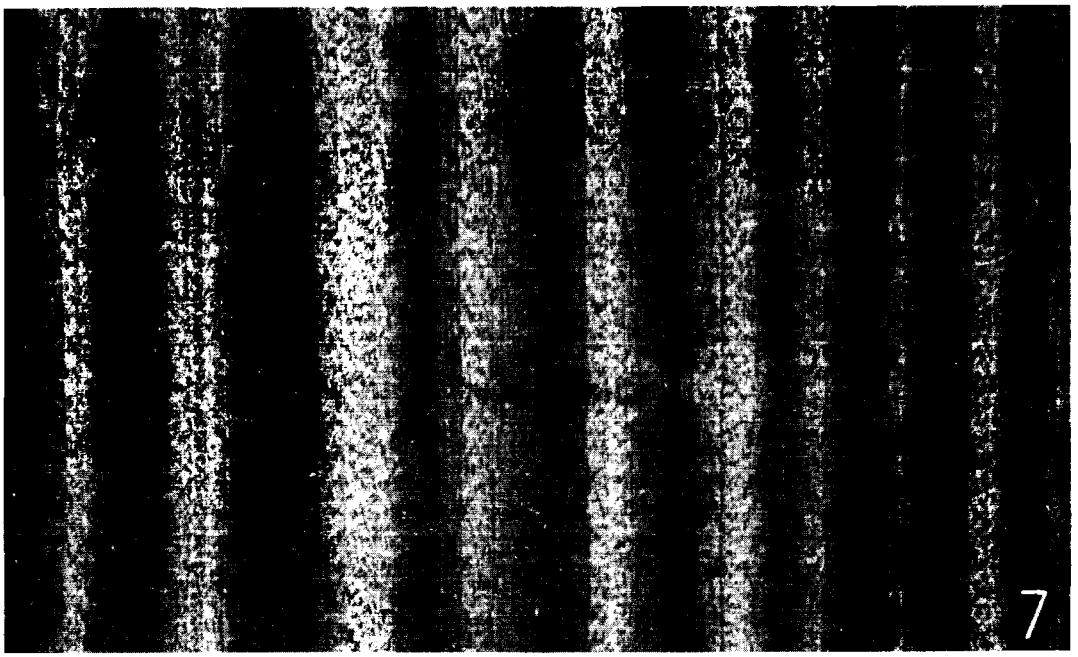

Figure 7.--Ribbon stripe in Entandrophragma cylindricum, from Ghana, produced by slicing interlocked grain radically. (Photo 1X)

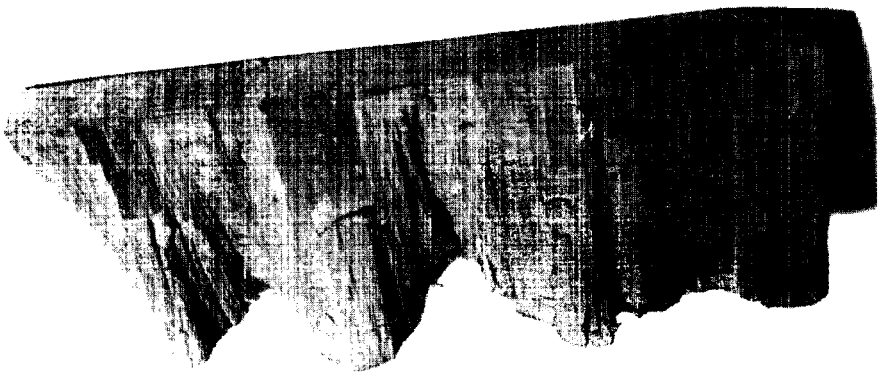

Figure 8.--Interlocked grain of radically split section of Hymenaea courbaril, from Puerto Rico, showing pattern of grain deviation. (Photo 1X)

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SECTION II

ENVIRONMENT AND SILVICULTURE

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VALUES OF TROPICAL MOIST FORESTS

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VALUES OF TROPICAL MOIST FORESTS

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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.

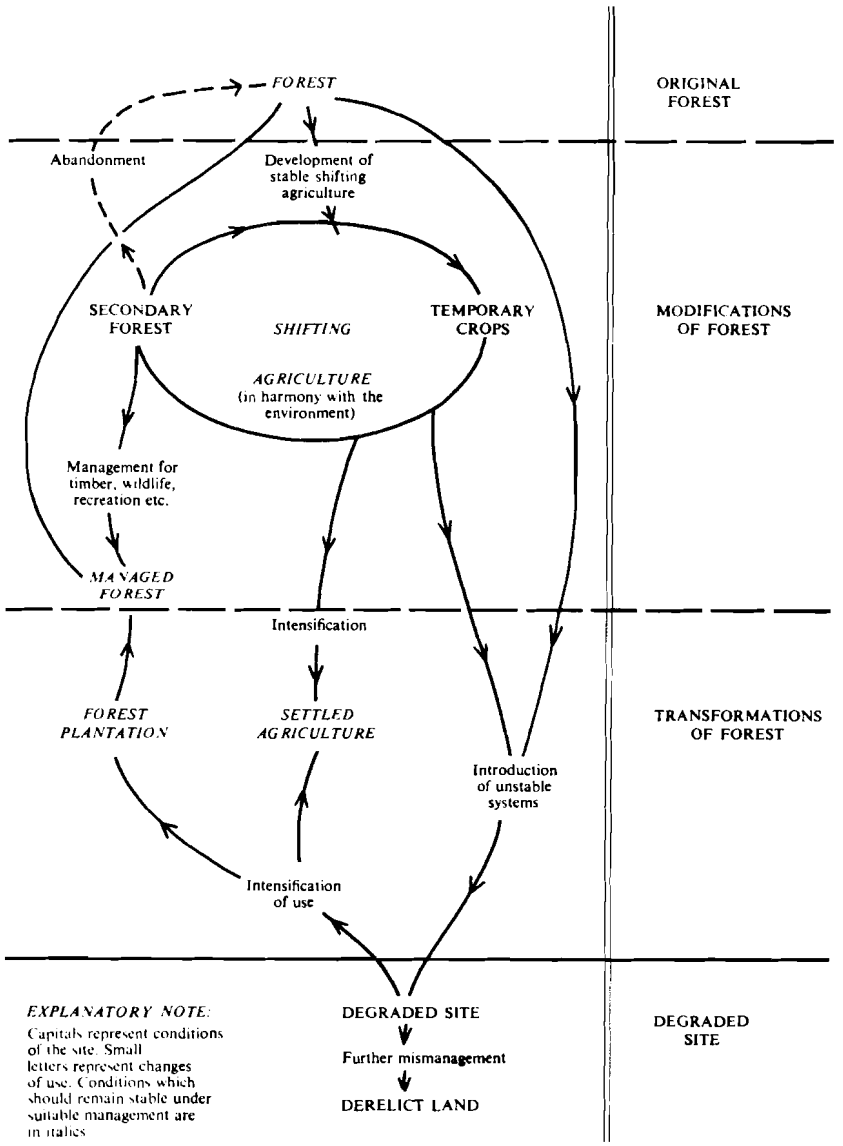

Fig. 1 : Interrelationships of shifting agriculture with other uses

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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.

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

(Page 1 of 2)

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

Extract from: Environmental Impact Assessment--SCOPE 5
Principles and Procedures

(Page 2 of 2)

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.

(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.

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.

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 m s that extraction should not begin until enough knowledge is available to sure 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 *in situ* 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 340×10^9 metric tons (Whittaker and Likens in Woodwell and Pekan, 1973), compared with 405×10^9 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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ENVIRONMENTAL IMPLICATION OF ANY-SPECIES UTILIZATION IN THE MOIST TROPICS

By

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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.

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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.

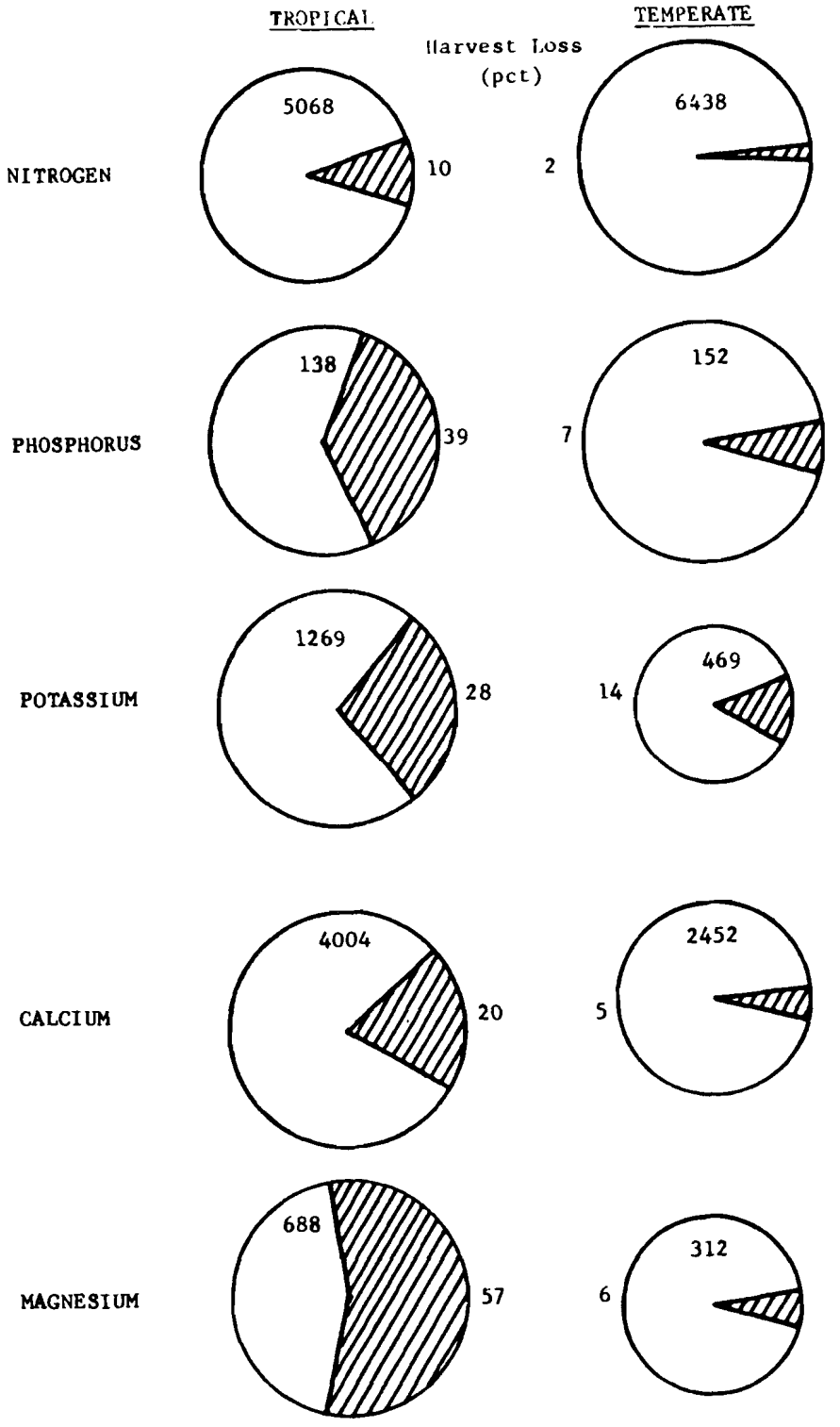

Figure 1. Total ecosystem nutrients (numbers in circle) and the fraction lost through harvest in sample temperate and tropical forests. Values are kilograms per hectare. Cross-hatching indicates the amount removed when trees are harvested (boles only), assuming that all roots, branches, and leaves remain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

(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 Para
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

(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

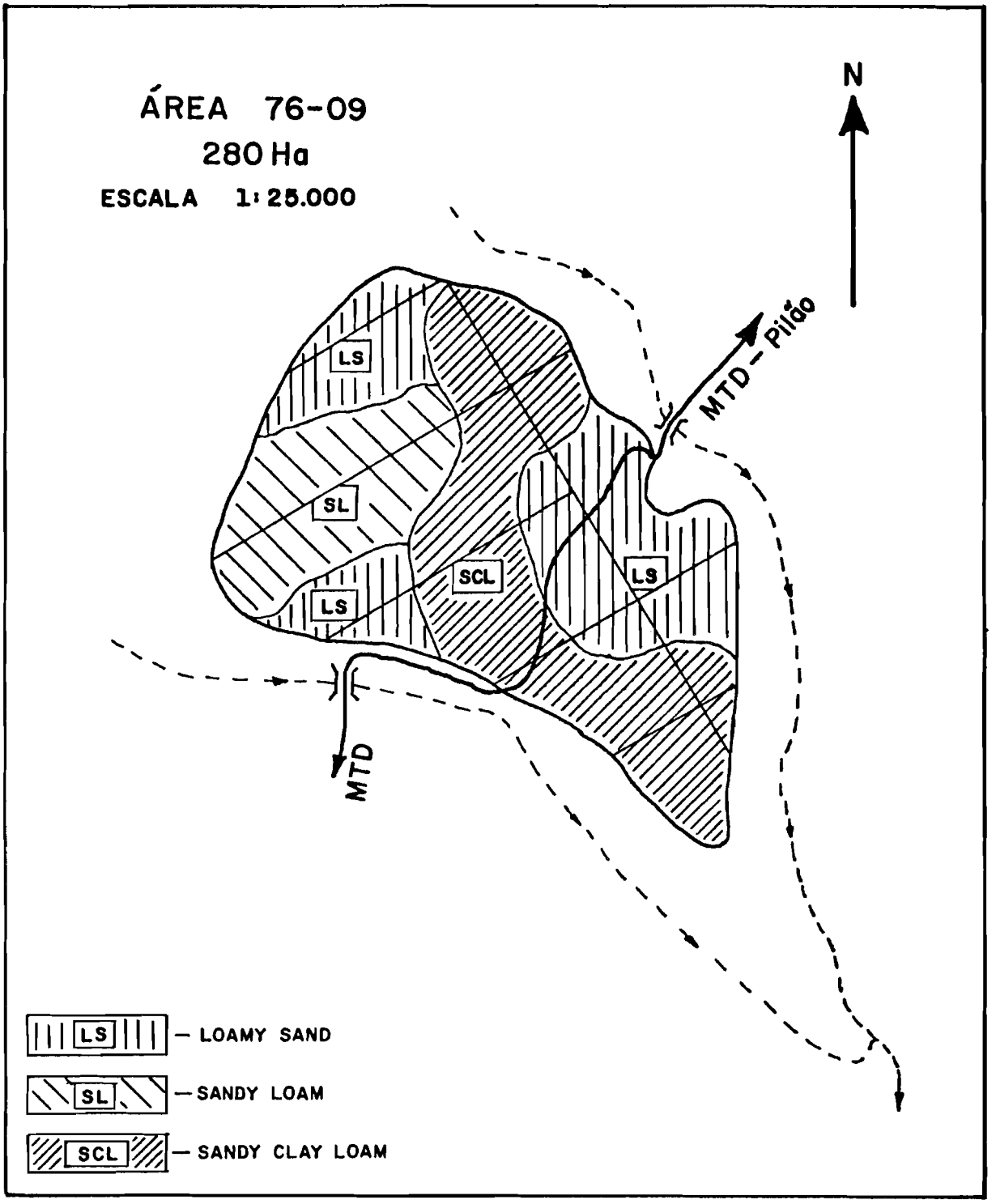

Figure 1.--Sample soils classification by topsoil texture, Jari.

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. oocarpa

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 ≥ 25 m, first thinning is when CAI ≤ MAI or when LCR (live crown ratio) ≤ 33%, whichever is earlier. The two subsequent thinnings are made when CAI ≤ PAI or when LCR ≤ 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 ≤ 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.

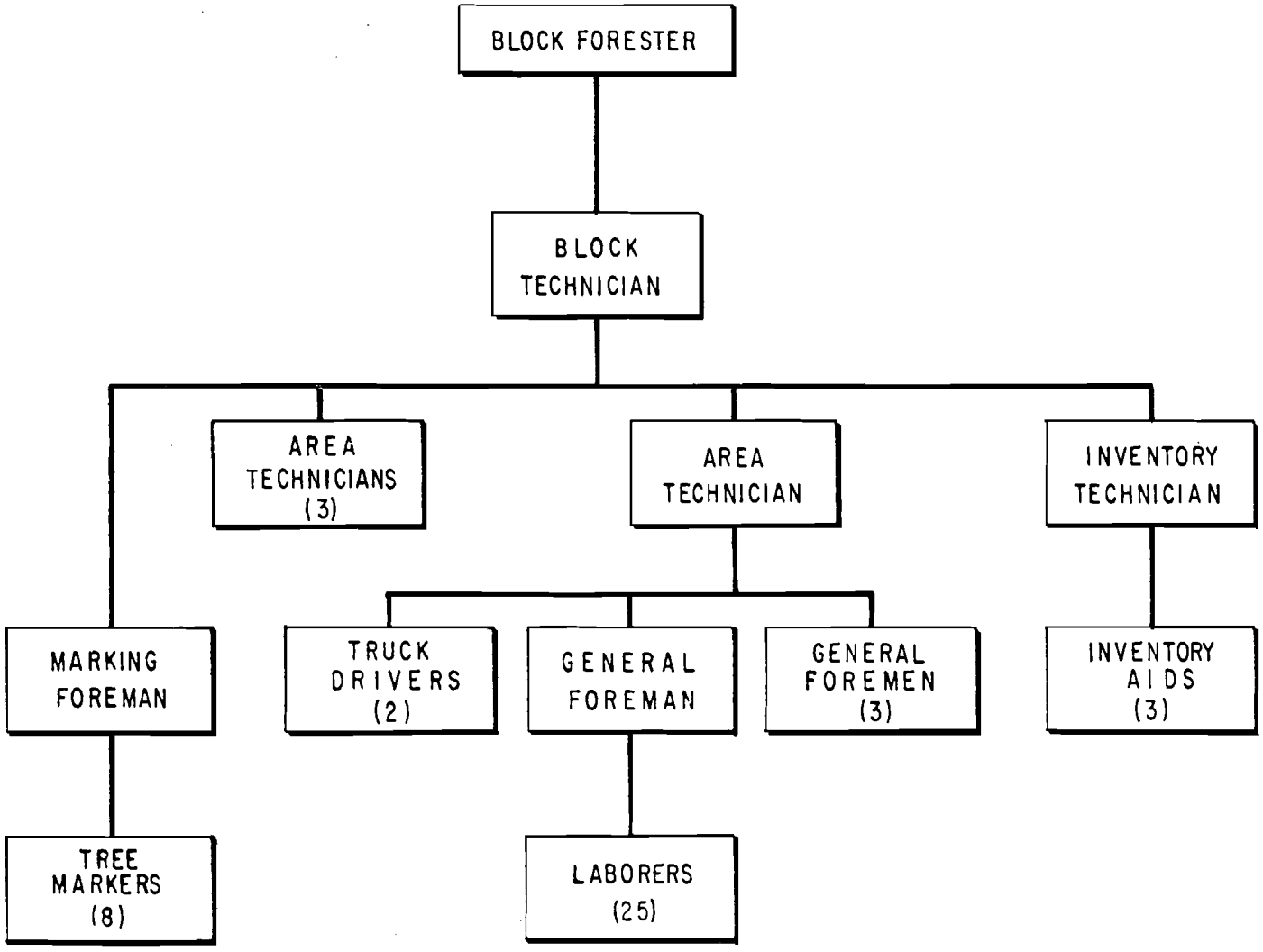

Figure 2.--Organization chart for 20,000 ha block, Jari.

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. IN ITS NATURAL AND ARTIFICIAL REGENERATION OF FORESTS AND PLANTATIONS

By

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Assistant Field Manager

and

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This is a report on the practices and experience of Nasipit Lumber Company, Inc. (NALCO) in its dipterocarp forest and industrial tree plantations inside an area covered by a timber license agreement granted by the Philippine Government.

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

NALCO also pioneered in the practice of "selective logging," the Philippine version of the selection system. In the NALCO concession today, there are 34,000 hectares of residual forest. Studies in a 19-year-old residual forest shows encouraging results--in regeneration and in growth.

As a complementary move to forest development and expanding wood utilization program, since 1961, NALCO has engaged in intensive tree plantation development. Today, its industrial plantations of *Albizia falcataria*, *Gmelina arborea*, *Tectona grandis*, *Pinus spp.*, *Dipterocarp spp.*, *Eucalyptus spp.*, *Ochroma pyramidale*, and other species are growing very well. The paper briefly discusses the applied silvicultural practices as related to nursery and plantation operations.

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

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INTRODUCTION

Nasipit Lumber Company, Inc. 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. It grew through the years and today NALCO and its affiliates have an integrated wood processing complex of sawmills, hardboard factories, veneer and plywood plants, wood variety shops, finishing plants, dry kilns, wood preservation, gang nail and sawdust briquetor plants.

The forest concession of NALCO and its affiliates, as of January 1, 1977, covers a forest reserve of 155,000 hectares consisting of 62,220 hectares of operable virgin forest, 39,866 of logged-over areas, 8,848 hectares of industrial tree plantations, and 44,125 hectares of other vegetative covers. The concession is located in the provinces of Agusan, Bukidnon, and Misamis Oriental in the Island of Mindanao, Philippines. The terrain is 10 percent gentle to moderate, 70 percent rough, and 20 percent very rough and precipitous; the soil is generally deep clay-loam with pH 5 to 6.8; and the average annual rainfall is 188 inches.

This paper is a progress report of NALCO's practices and experience in the silviculture of its indigenous forest and industrial tree plantations. The Company has preserved its cut-over area and since 1956 pioneered in the natural regeneration of its dipterocarp forest through selective logging, the Philippine version of the selection system. The establishment of industrial tree plantations started in 1961, although experimental plantings were done as early as 1958. These plantations have been growing so well that they have been attracting much attention.

The second-growth forests, residual forests, and plantations are very encouraging. The silvicultural practices are gradually improved through forest research. It will not be amiss to state that NALCO has been developing its forest and plantations entirely with its own resources, initiative and technical knowledge.

THE VIRGIN FOREST

The dipterocarps in the virgin forest comprise 73 percent of the total stand, namely: Shorea almon, Shorea polysperma, Shorea negrosensis, Shorea squamata, Shorea agsaboensis, Shorea gisok, Shorea guiso, Parashorea plicata, Pentacme contorta, Dipterocarpus gracilis, Dipterocarpus warburgii, and Dipterocarpus grandiflorus. They occupy the highest canopy of the forest. Other tree species associated with the dipterocarps and occupying the lower stories belong to the families of Meliaceae, Sapindaceae, Anacardiaceae, Euphorbiaceae, Burseraceae, Annonaceae, Myristicaceae, Lauraceae, etc. which comprise about 27 percent of the total stand. The forest is dominated by mature and overmature trees and the younger and smaller-sized trees have been under long periods of suppression and many of them have poorly developed crowns and trunks. The size class and volume distribution per hectare of dipterocarps are as follows:

DBH (cms.)	Trees/ hectare	Volume/Ha. (cu.m.)
Seedlings	2,613	--
Saplings	506	--
5-10 cm.	50	--
20 cm.	25	4.64
30 cm.	10	6.98
40 cm.	9	14.54
50 cm.	7	18.45
60 cm.	5	21.99
70 cm.	5	30.11
80 cm.	4	32.47
90 cm.	3	28.19
100 and larger	8	111.87
Total	75	269.44

Silvicultural Practices in the Virgin Forest

Diameter Limit Method

From 1946 to 1955, the cutting of the virgin timber was by diameter limit method wherein all commercial species 50 cm. in diameter DBH and larger were cut and utilized. There was no tree marking done at the time.

The logging systems used were tractor logging and power logging, the latter making use of steam donkeys, tractor-mounted double drum yarders, and sled-mounted torque converter yarders. The steam donkeys required tremendous volume of fuelwood and smaller-sized trees at the areas of operations. Free skidding by tractors and unregulated cable yarding also caused heavy damages to the remaining forest growth. These systems of logging rendered the area practically clear of forest growth except a few scattered big defective trees which later regenerated the area during

seed years. Properly protected from kaingin-making, the logged-over areas will, through succession, be regenerated by various species belonging to the families of Moraceae, Ulmaceae, Urticaceae, Fabaceae, Euphorbiaceae, and Dipterocarpaceae. In 1973, samplings were undertaken in the dense second-growth dipterocarp forest that naturally developed in the areas cut over in 1954, summary of which is as follows:

	Dipterocarps	Nondipterocarps	Total
Number of young second growth trees/ha. (10 cm. and larger)	264 trees	453 trees[1/]	717 trees
Stand DBH	18.0 cm.	19.0 cm.	18.5 cm.
Merch. height	12.0 m.	15.0 m.	13.5 m.
Total height	16.0 m.	17.0 m.	16.5 m.
Volume/ha.	83.33 M^3	146.14 M^3	229.47 M^3
Current annual increment/ha.	4.39 M^3	7.69 M^3	12.08 cu. m./ ha./yr.

The dipterocarp stand is almost even-aged. It is evident that under favorable condition clearcut areas with a number of dipterocarp seed trees (5 to 10 trees/hectare) can be naturally regenerated.

Timber Stand Improvement of Secondary Forests

Due to the very dense stocking and thick growth of brush and vines in the secondary forests, timber stand improvement operations have been going on since 1973. The initial operation involves cutting of big vines, climbing bamboos, saplings of unwanted species, and small-sized poor quality trees. After three months when the vines and climbers have dropped to the ground, the trees to be removed are marked and felling directions indicated on the base of the trunks. A modified low thinning is applied wherein the valuable tree species are favored with the removal of unhealthy, overtopped trees, diseased and poorly formed trees, weed species, big cull trees, and dominant matchwoods. Vigorous dipterocarps and other valuable hardwoods which have good stem and crown development are retained as crop trees. In the process, 50 percent of the stand is thinned.

To facilitate skidding and to minimize damages in the crop trees, pre-laying of farm tractor routes to the log landings at roadsides and directed felling with the use of small power chainsaws and improvised felling wedges are practiced. The products of the thinning operations are utilized as chipwood for the hardboard factories and as fuelwood for the boilers. To study the response and behaviour of the remaining stand, TSI plots are established in those areas. The results show higher values of growth, better bole and crown developments.

1/ Mostly Endospermum peltatum.

Selective Logging in the Virgin Forest

Selective logging has been started in the Company's primary logging operations since 1956. It is a system whereby all mature and overmature trees (80 cm. and larger, including defective trees of lower diameters) of dipterocarp species are cut and removed from the forest and at the same time leaving 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 numbers and bands on each tree to be retained as residual. Until 1972, the residual tree marking was to mark and leave 60 percent of the total number of healthy residual trees of the 20 cm. to 70 cm. diameter classes and to allow 40 percent logging clearances and damages. And in 1973, the Bureau of Forestry amended the tree marking rule increasing the number of residual trees. The regulation requires the marking of 70 percent of the total number of healthy residual trees belonging to the 20 cm. to 60 cm. diameter classes plus 40 percent of the trees in 70 cm. diameter group.

Studies on an area selectively logged in 1958 show the following results:

Per Hectare Basis	1959 DATA				1972 DATA			
	Dipterocarp		Nondipterocarp		Dipterocarp		Nondipterocarp	
No. of seedlings	39		313		117		202	
No. of seedlings	28		53		36		66	
Number of trees (10 cm. dbh. and larger)								
DBH (cm.)	T	Volume (cu.m.)	T	Volume (cu.m.)	T	Volume (cu.m.)	T	Volume (cu.m.)
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	19.25	--	--
70	2	11.91	--	--	4	28.01	1	5.48
80 and up	3	34.40	--	--	8	103.58	--	--
Total	79	133.45	178	49.66	166	244.62	298	96.37
Current annual increment (cu.m.)						7.01	--	3.59

The foregoing finding shows that selective logging system is possible and can be applied in the absence of any other better system.

Timber Stand Improvement

In the absence of suitable yarding equipment for TSI operations in moderate to rough terrains, the forest improvement is limited to cutting of vines interferring with reproduction and young residual trees and of small-sized defective trees and weed species.

SILVICULTURAL PRACTICES IN THE TREE PLANTATIONS

Since 1961, NASIPIT and its affiliates have already established about 8,848 hectares of tree plantations inside its forest concession, consisting of 5,930 hectares of Albizia falcataria; 473 hectares of Gmelina arborea; 150 hectares of Tectona grandis; 256 hectares of Pinus kesiya, P. mindorensis, and P. carribea; 309 hectares of Eucalyptus deglupta, E. robusta, E. saligna, and E. grandis; 78 hectares of Ochroma pyramidale; and 1,752 hectares of about 10 other species. These plantations are now 15 years old and younger. The plantation developments are aimed to produce timber, pulpwood, and firewood mainly for the integrated wood processing complex of the Company.

Nursery Practices

The seeds for germination are collected from selected mother trees in the older tree plantations, from other sources, and from abroad. Delicate and fine seeds are germinated in the greenhouse. Seedbeds are raised and made of concrete. The soil is sterilized by steam, 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 percent organic top soil and 50 percent 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.

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. After logging operations in a setting, planting of the desired species is immediately done in log landings, roadsides, wide cableways, and felling sites. Delayed planting of the set-up is discouraged because of the rapid growth of 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 are pushed to the side or just left on the area. Healthy dipterocarps and other valuable trees found therein are retained provided they will not cause so 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 Albizia falcataria, Gmelina arborea, Tectona grandis, Pinus and Eucalyptus species, and other species. The NALCO plantations generally comprise about 70 percent planted trees and 30 percent naturally growing forest trees.

Ringweeding

Ringweeding is done 3 or 4 months from planting and every 4 months thereafter. 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 2 years before they are fully established. Thereafter, only cutting of vines and cleaning are done.

Thinning

Thinning of plantations of fast-growing species such as *Albizia falcataria* and *Gmelina arborea* is done twice within the rotation period of 15 to 20 years. The first thinning is applied at age 3 years. The average DBH and total height for 3-year-old plantations of *Albizia falcataria* are 12 cm. and 15 meters, respectively; those of *Gmelina arborea* are 14 cm. and 14 meters, 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 percent to 20 percent of the total stand is removed. Marking of trees to be thinned is done well ahead of the cutting.

The *second thinning* is also a low thinning and is usually done at age 6 years or 3 years from the first thinning. At that age, the average DBH and total height of *Albizia falcataria* are 21 cm. and 22 meters respectively; those of *Gmelina arborea* are 16 cm. and 20 meters, 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 percent to 40 percent of the original stand are thinned and 30 percent to 40 percent 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 prelaying of farm tractor routes are done ahead of the felling operations. Directed felling with the use of small-power chainsaws and improvised felling wedges are employed to facilitate skidding and to minimize damages to the final stand. Felled trees are delimbed and cut into multiples of 6 meters before they are skidded or winched to the skid road. Thinned materials consist of sawlogs and pulpwood.

The first thinning of plantation of slow-growing species such as pines is done in the sixth or eighth year. About 20 percent of the stand is thinned consisting of suppressed trees, some poor intermediates, and co-dominants. The schedule of the second thinning operation will still 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 and boloes. On the other hand, pruning of 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.

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 percent *A. falcataria* and 30 percent dipterocarps and other species. The yield per hectare was 222 cubic meters of *A. falcataria* consisting of 21 percent export quality logs, 9 percent sawlog quality, and 70 percent pulpwood.

At the time of the harvest, the trees were fully laden with matured seed pods. The plantation floor was laid bare and scarified by the 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 sampling of the reproduction was done 5 months later and there were 87,000 seedlings, 10 cm. to over 1 meter 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 shows the following data:

Number of remaining trees/ha.	856 trees
Stand DBH	7.07 cm.
Stand total height	8.0 meters

Coppice method. In 1968, an experimental harvest by clearcutting was undertaken in an 8-year-old *Albizia falcataria* plantation to gather data on yield and data for volume table construction. Three months after cutting, numerous sprouts were noted 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 show the following data:

Number of trees/ha.	440 trees
Stand DBH	21.0 cm.
Merchantable height	18.0 meters
Volume/hectare	180.00 cu. m.

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 *Albizia falcataria* plantations (3 years old and younger) in some sites had canker. 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. Some of the infected trees were able to survive but showed retarded growth and 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. 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 of Sweitenia machrophylla are frequently attacked by tip borers and Anthocephallus cadamba are defoliated almost throughout the year by larvae of a moth. So far, there is no practical and economical control for both kinds of infestation.

RESUME

The NALCO experience, though still a very limited one, is a convincing proof that applications of suitable silvicultural practices in the natural forests and in tree plantations will produce good stands. With forest research being intensified, it is hoped that better and reliable data can be obtained and made the basis for improved 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, before 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).

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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 under-utilized 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 <u>some</u> 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 rain-forest 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 out-weighed 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

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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).

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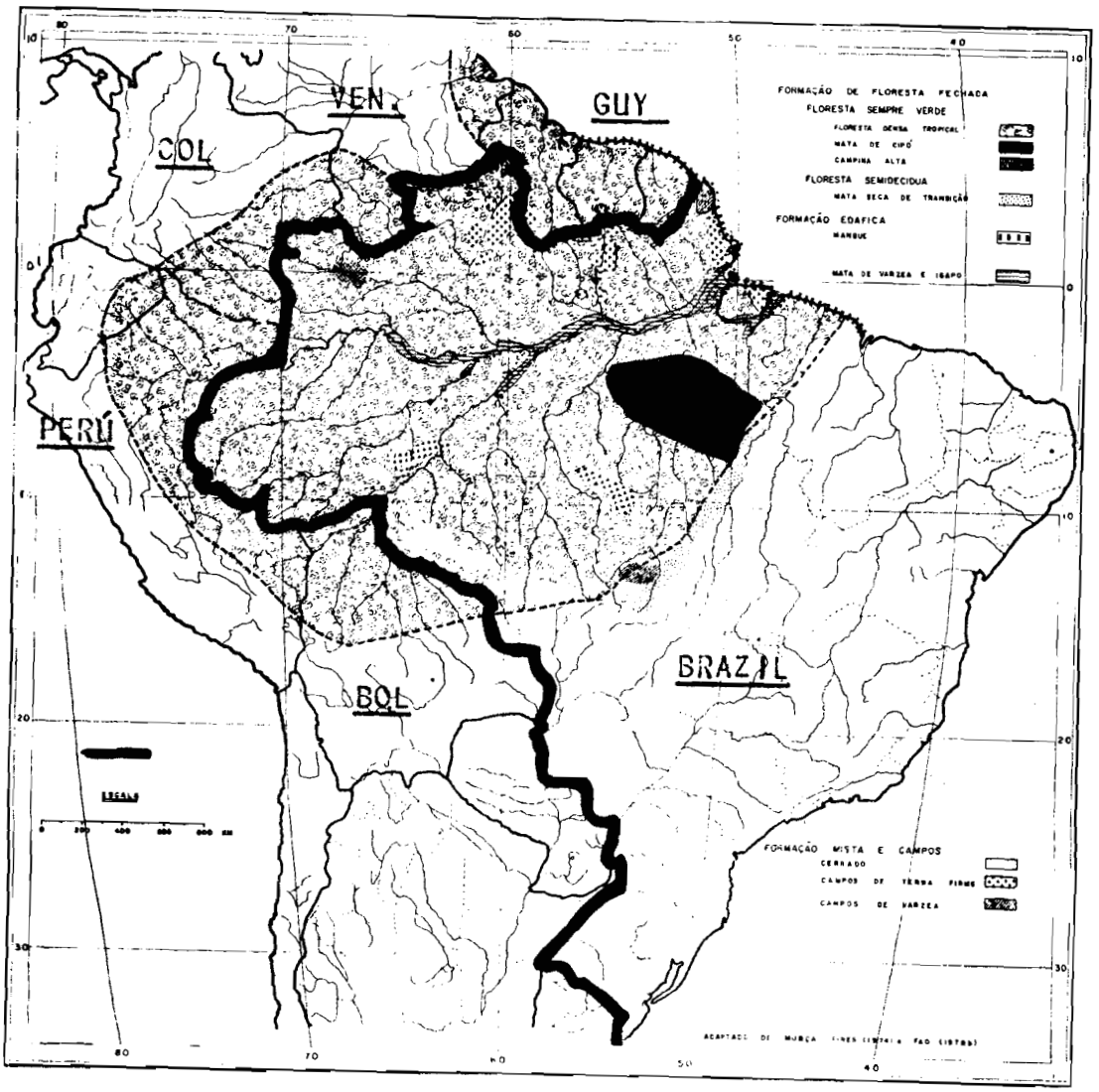
GRAPH Nº 1

THE AMAZONIC FLOREST



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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:

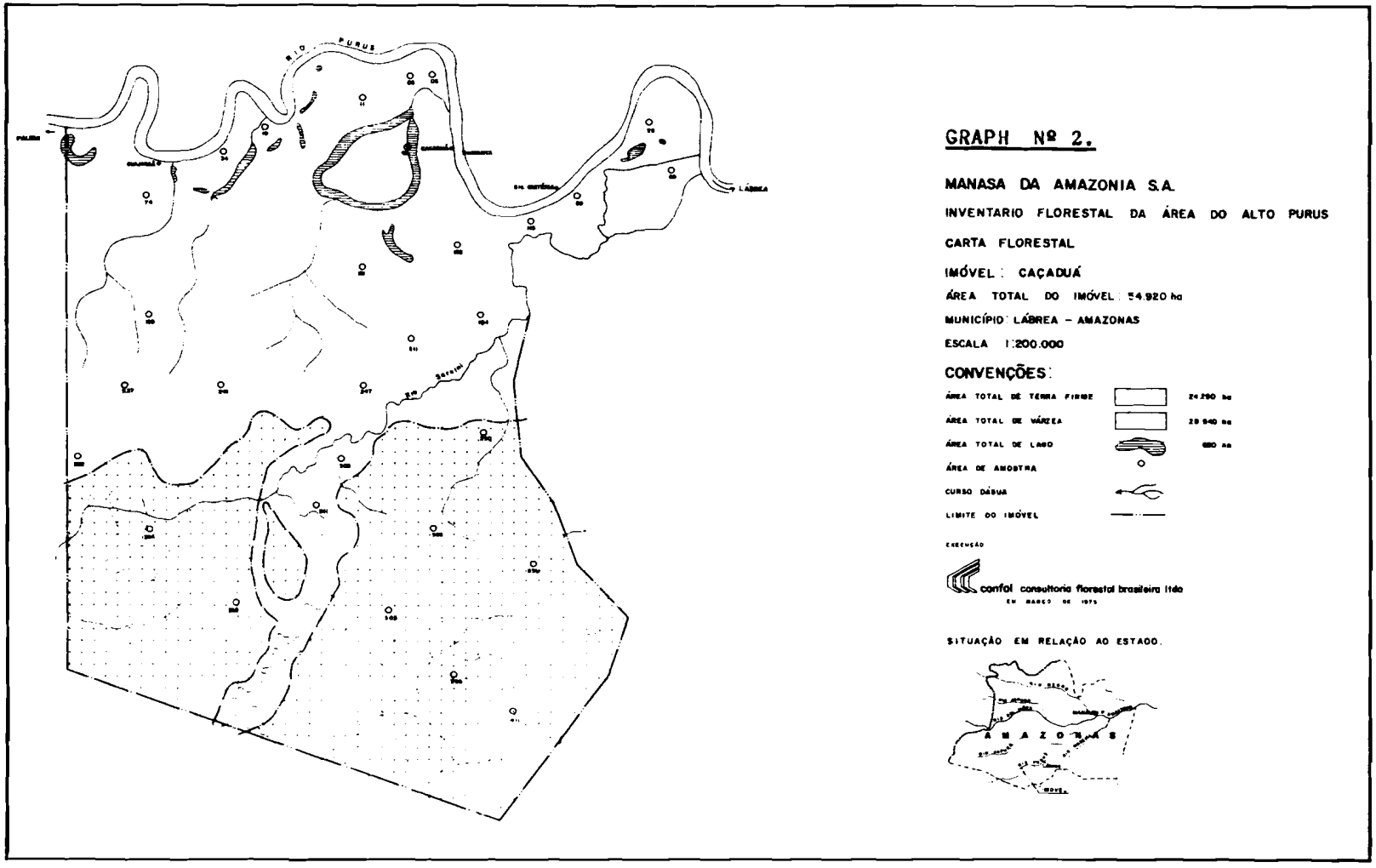

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Table 1.--Average density of wood of 63 species in m^3/ha

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 goeldiana	--	--	--	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 Manaba, 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	Guttiferae
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 prẽta	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, Altopurús, Amazônas--continued

Higher lands		
Faveira	Parkia multijuga	Leguminosae
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
Mamaõzinho	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 rajado	Pithecolobium racemosum	Leguminosae
Apuí	Clusia spp.	Guttiferae
Abiurana cutite	Lucuma riviqua	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 paraparará	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
Coração 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

(Page 4 of 6)

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	Lauraceae
Louro aritu	Acrodiclidium appelii	Lauraceae
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

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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

(Page 6 of 6)

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 guianensis)	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 (*Peltogyne 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									X
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 anamui	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 x 10^6 ha, but the area of plantations was 530 x 10^3 ha of softwoods and 746 x 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.

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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).

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 3×10^{10} m^3 with another 1×10^{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

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, $\frac{\text{Wt. of ovendry pulp}}{\text{Wt. of ovendry wood}}$	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

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 Pinus caribaea 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

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 hard-woods		Mixed USA hard-woods	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

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.

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

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FOREST INDUSTRY DEVELOPMENT IN SOUTHEAST ASIA

One Company's Experience and Observations

By

Jack R. Schoening

Woods Manager

Weyerhaeuser Company
Southwest Washington Region

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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

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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 by-passed 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

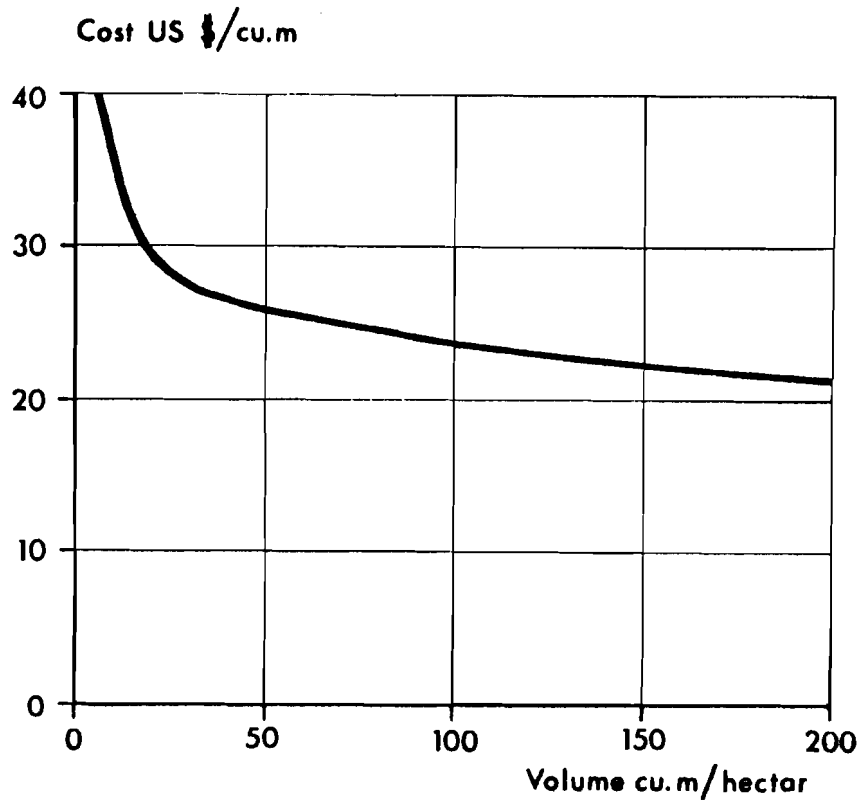
$$C_{Q_i} = a \cdot \left(\frac{1}{3} + \frac{2}{3\sqrt{Q_i}}\right)$$

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.

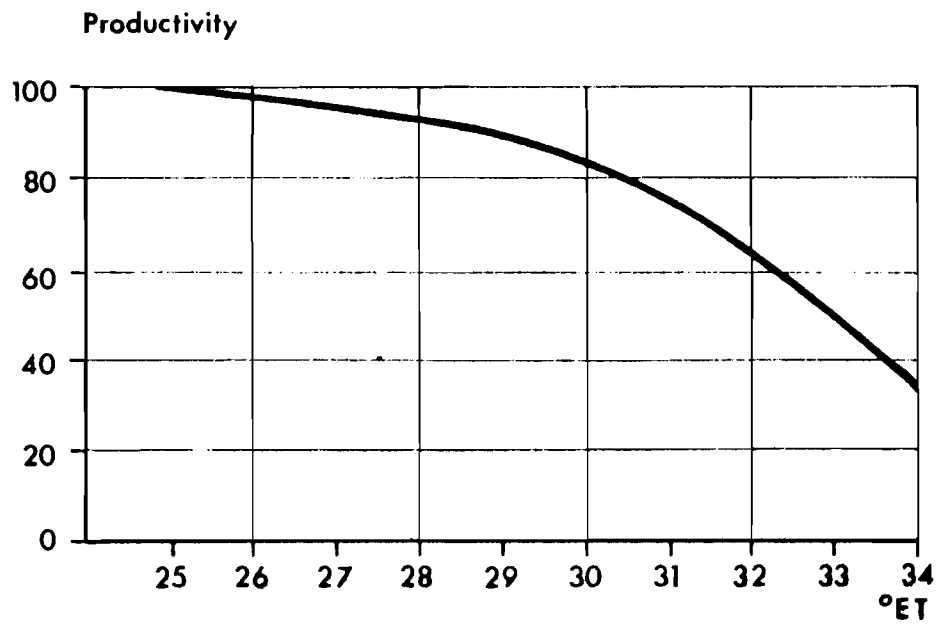
Species Mix

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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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. A good example is the Kuda-Kuda system which is prevalent in Indonesia and Malaysia. An example of a mechanized system in marshy lowlands is the barge-mounted yarder in Colombia, S. America. 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.

SECTION IV

WOOD FIBER AND RECONSTITUTED PRODUCTS RESEARCH

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SUITABILITY OF TROPICAL FORESTS FOR PULPWOOD:

MIXED HARDWOODS, RESIDUES, AND REFORESTATION SPECIES

By

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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

* 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)

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

ø Charge 1800 g(o.d.) chips cooked in 20 l rotary digester, 2 h at 170°C

Source of data Ref (3) (6) (7) (8) (9)

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

	Age (yr)	Screened yield+ (%)	Kappa number	At 250 Csf		
				Tear index (mN m^2/g)	Breaking length (km)	Crushø 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.

BLEACHED KRAFT PULP FROM MIXED HARDWOODS FROM IVORY COAST FORESTS

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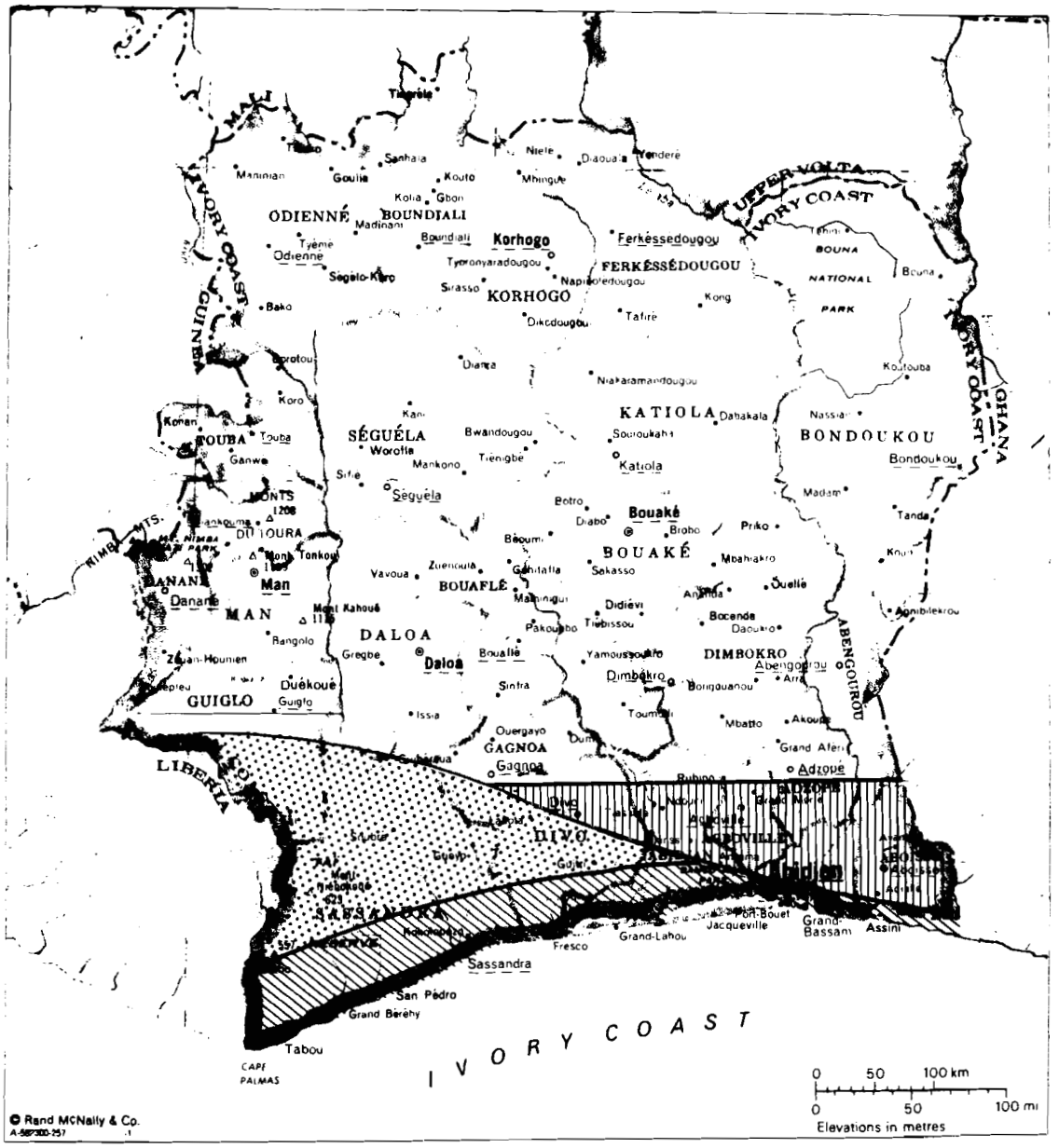
INTRODUCTION

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).



IVORY COAST

EQUATORIAL FOREST ZONE

CULTIVATED FOREST ZONE

COASTAL FRINGE

Figure 1.--Map of the Ivory Coast showing the location of the utilizable forest (1).

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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

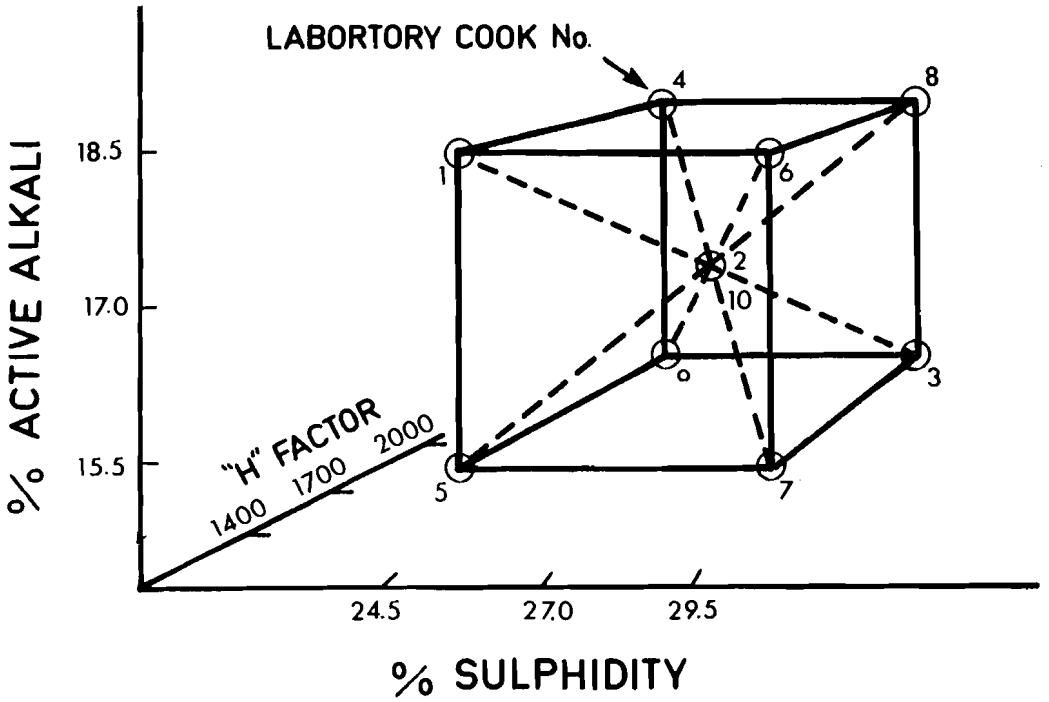

Figure 2.--Central composite design, stage 1. The numbers at each point show the order in which the cooks were done.

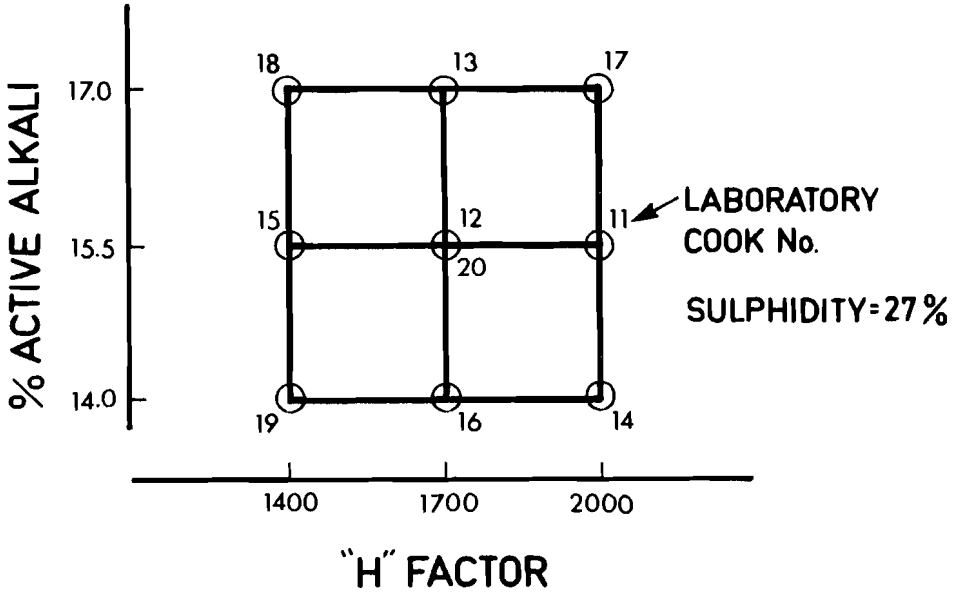

Figure 3.--Orthogonal composite design, stage 2. The numbers at each point show the order in which the cooks were done.

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.

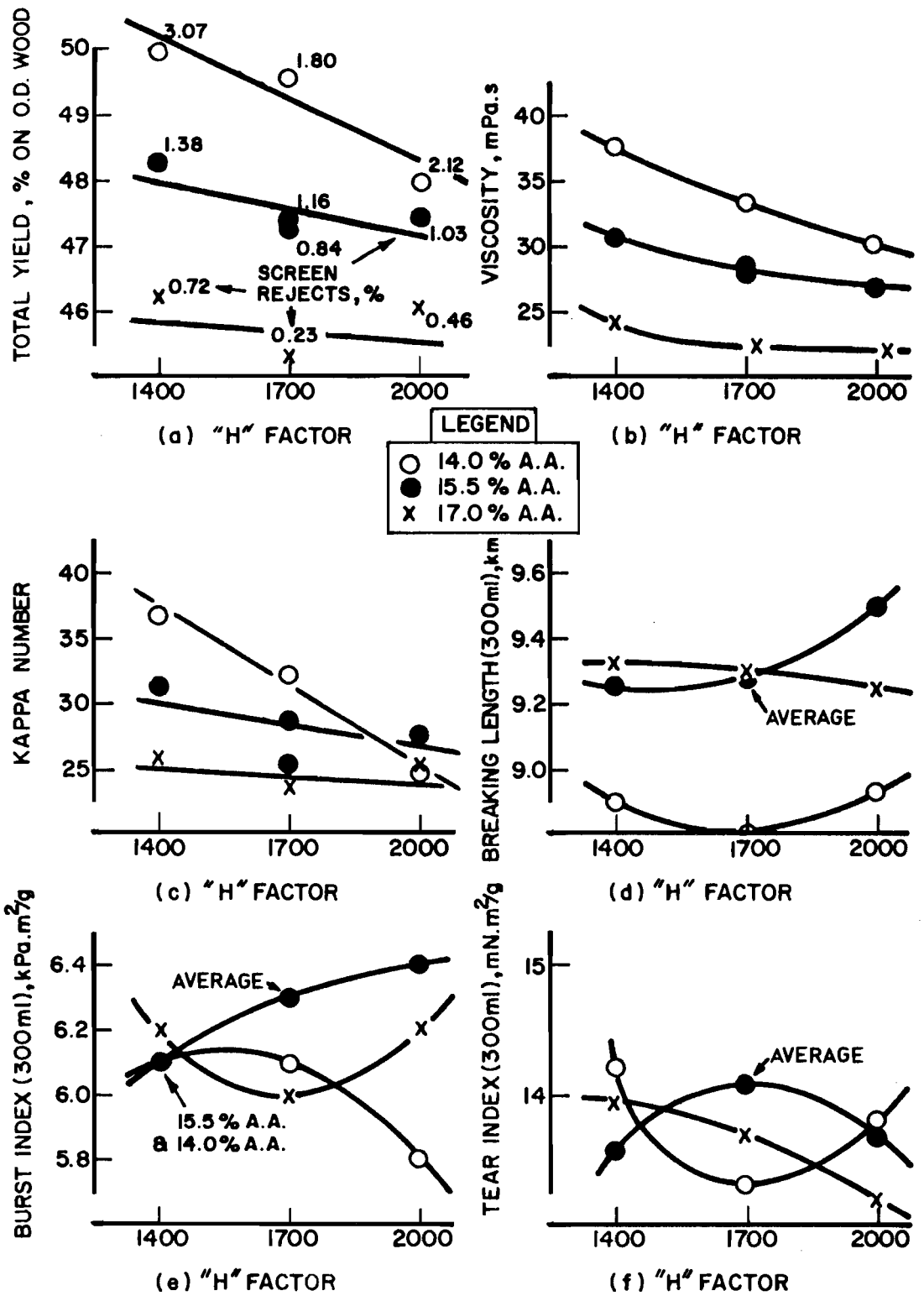

Figure 4.--Properties of pulps obtained in stage 2.

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 $mN \cdot m^2/g$.

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

We thank Mr. Emil Koller for his help in preparing and interpreting the statistical design and Mrs. Barbara van Lierop for assistance with the bleaching experiments.

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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, $mN \cdot m^2/g$	13.8	8.4	9.7	8.0	6.4	7.0	7.5
Burst index, $kPa \cdot m^2/g$	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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SECTION V

WOOD FIBER AND RECONSTITUTED PRODUCTS RESEARCH

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KRAFT AND NSSC PULPING OF MIXED TROPICAL HARDWOODS

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KRAFT AND NSSC PULPING

OF MIXED TROPICAL HARDWOODS

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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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1/ Holdridge, L. R., W. C. Grenke, W. H. Hatheway, et al. 1971. Forest environments in tropical life zones: A pilot study. Pergamon Press, New York.

2/ Chudnoff, Martin. 1976. Density of tropical timbers as influenced by climatic life zones. Commonw. For. Rev. 55, 3.

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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: Common name	Species: Botanical name	Specific gravity[1/]	Ash[2/]	Silica[2/]
				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

(Page 1 of 2)

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.

(Page 2 of 2)

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

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		Specific gravity[1/]	Ash[2/]	Silica[2/]
	Common name	Botanical name			
				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. Semi-chemical 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	Alcohol benzene	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/1	G/1	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

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/l	G/l	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

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

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 Concora 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	23.3	645	28.9	125.6	6.3	0.55
Lights		550	63.5	124.5	10.4	.64
		350	86.0	116.0	12.5	.72
A	24.9	675	21.0	128.6	4.6	.50
Heavies		550	57.0	136.0	9.1	.58
		350	71.5	130.0	11.0	.65
B	22.5	660	24.8	128.6	6.0	.54
Lights		550	52.0	126.0	9.4	.63
		350	75.0	120.0	11.4	.68
B	24.9	680	19.8	80.8	4.8	.48
Heavies		550	47.5	131.5	8.3	.58
		350	66.0	137.0	10.2	.64
			GHANA			
A	23.8	625	34.6	151.5	6.6	.57
Lights		550	60.0	140.0	8.8	.62
		350	85.5	118.0	12.8	.70
A	26.3	660	22.6	136.3	5.3	.51
Heavies		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

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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," another preprint for this Conference on Utilization of Tropical Forests, May 21-28, 1978, at Madison, Wis.

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

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 thermo-mechanical 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

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. Preprint for 1978 Conference on Utilization of Tropical Forests. (Tables 1 to 4.)

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/]				Liquor-to-wood ratio	Cooking temperature	Time to temperature	Time at temperature	Spent liquor				Kappa Nos.	Estimated yield[2/]	Paper machine run Nos.
		Na_2SO_3	Na_2CO_3	NaOH (Na_2O)	Na_2S (Na_2O)					Na_2SO_3	NaOH (Na_2O)	Na_2S (Na_2O)	pH			
		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 [6/]130	57 65	7168 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/]: Tropical hardwood unbleached kraft	Furnish[1/]: Softwood unbleached kraft[2/]	Furnish[1/]: Disk (D) or conical (C) refiner	Furnish[1/]: Freeness (Canadian Standard)	Furnish[1/]: Surface sized with starch	Properties: Weight: Square meters	Weight: 1,000 square feet	Thickness	Density	Bursting strength	Tearing resistance[3/]: MD	Tearing resistance[3/]: CD	Folding endurance[3/]: MD	Folding endurance[3/]: CD	Ring crush[3/]: MD	Ring crush[3/]: CD	Tension[3/]: Maximum stress: MD	Tension[3/]: Maximum stress: CD	Tension[3/]: Modulus of elasticity: MD	Tension[3/]: Modulus of elasticity: CD	Tension[3/]: Strain to failure: MD	Tension[3/]: Strain to failure: CD	Thickness[4/]
	Pct	Pct		Ml	Pct	G	Lb	Mils	G/cm^3	Pt	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 cm³)		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/cm³	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)		
					Single face side		Double back side				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	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/] 8 in. high				Top-to-bottom compression[4/] 3-1/4 in. high				Side-to-side compression[4/] (3-1/4 in. high)				End-to-end compression[4/] (3-1/4 in. high)				Impact resistance[5/]
		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	8.5	0.82	7.0	676	6.1	0.45	16.3	412	8.7	0.34	36.7	283	5.8	0.26	15.4	81
		483	29.1	.50	0.0													
									PHILIPPINE									
7143-7136-7143	0	687	2.7	.28	34.4	635	4.6	.53	20.0	336	5.2	.32	9.0	259	3.2	.33	11.4	98
		512	23.1	.50	0.0													
7144-7136-7144	2.2	835	7.0	.81	19.2	720	6.4	.54	7.4	[7/]423	7.5	.38	9.3	[7/]311	4.1	.36	19.3	94
		620	19.7	.50	0.0													
									COLOMBIAN									
7161-7160-7161	0	570	7.4	.57	4.1	478	4.6	.43	4.1	332	11.8	.40	29.3	218	6.4	.32	25.8	77
		502	11.1	.50	0.0													
7162-7160-7162	2.1	703	8.4	.68	16.7	560	6.0	.45	6.4	373	11.8	.36	21.9	252	10.7	.31	21.7	94
		540	17.1	.50	0.0													

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.

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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--			
			Modulus of rupture	Modulus of elasticity			90 pct RH		Water soak	
							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	--	--	--	--

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/]		Internal bond strength	Tensile strength	Dimensional movement from 50 pct RH to--			
			Modulus of rupture	Modulus of elasticity			90 pct RH		Water soak	
							Length	Thickness	Length	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

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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ABSTRACT

Laboratory particleboards were manufactured at panel densities of 42 and 48 pcf (673 and 769 kg/m^3) from furnishes of three hammermilled Philippine hardwood chip mixtures at urea formaldehyde resin levels of 5% and 8%. The three mixtures, A, B, and C, contained different proportions of 50 Philippine species, and the average specific gravities of the mixtures were 0.50, 0.70, and 0.52 respectively. Boards also were manufactured from a planer shavings mixture with a species composition identical to chip mixture C and from furnishes from steamed and unsteamed ring flaked chips of mixture A.

All strength properties increased with an increase in either resin content or board density. Linear expansion (LE) and thickness swelling (TS) were reduced by an increase in resin content but were not significantly affected by density. There were no differences between boards from ring flaked steamed and unsteamed chips, and these two boards were superior in MOR, MOE, and LE but not in IB and TS to the boards from furnishes of hammermilled chips and planer shavings. Boards from hammermilled chips of mixture B were overall of slightly lower quality than boards from the other two hammermilled chip mixtures. The properties of the planer shavings boards were intermediate to those from furnishes of hammermilled chips and ring flaked chips, except for TS where the planer shavings boards were superior.

The strength properties of all the urea bonded boards at 45 pcf (721 g/m^3) compared favorably with Commercial Standard CS 236-66 type 1B2 board, but the maximum allowable LE was, with one exception, met only by the boards from ring flaked furnishes. Exterior type boards made with phenol formaldehyde resin from a furnish of mixture A hammermilled chips met the minimum property requirements of Commercial Standard type 2B2 boards at 8% resin level but did not meet MOR and MOE minimums at the 5% resin level. Loss of MOR after accelerated aging was 50% or less for both resin contents.

Copies of the report describing particle preparation, testing, results, statistical analyses, etc. in greater detail are available from the authors.

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By

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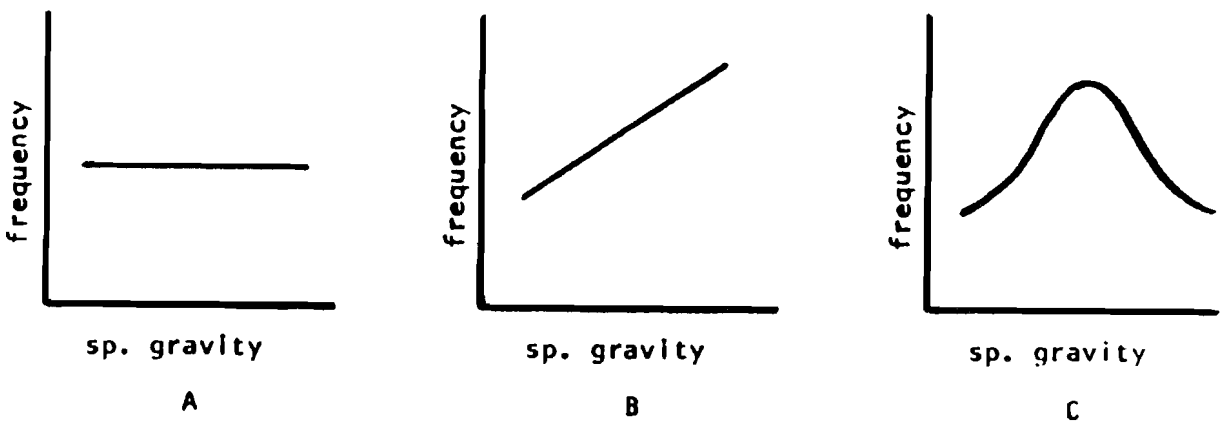
INTRODUCTION

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.



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.

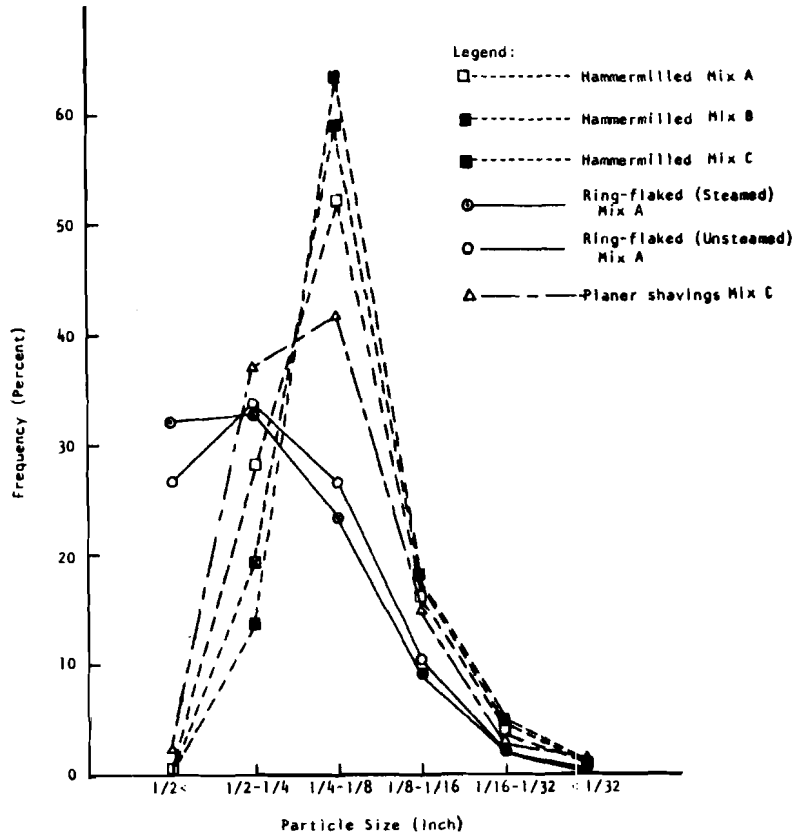


Figure 1.--Distribution of particle size for the various furnishes as determined by sieve analysis. The values on the χ axis are the diameters, in inches, of the circular holes in a William's chip screen.

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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.

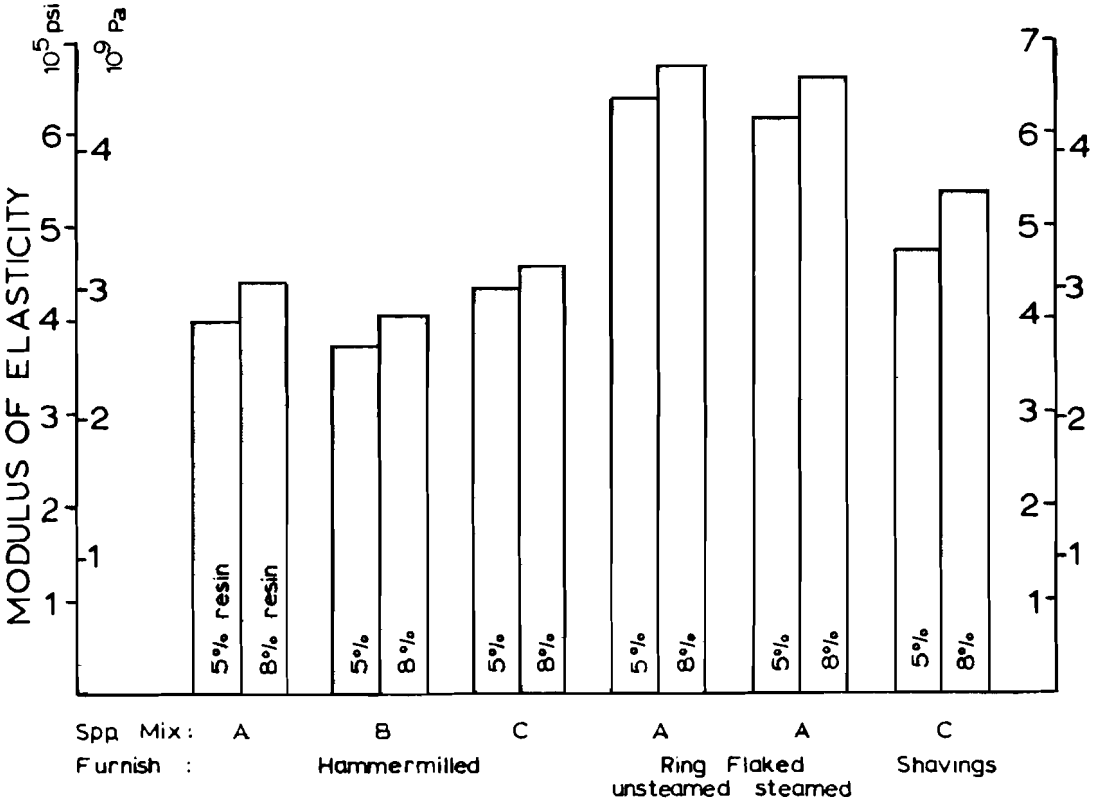

Figure 2.--Predicted mean values for modulus of elasticity of 45 pcf (721 kg/m^3) urea-bonded particleboards from Philippine species.

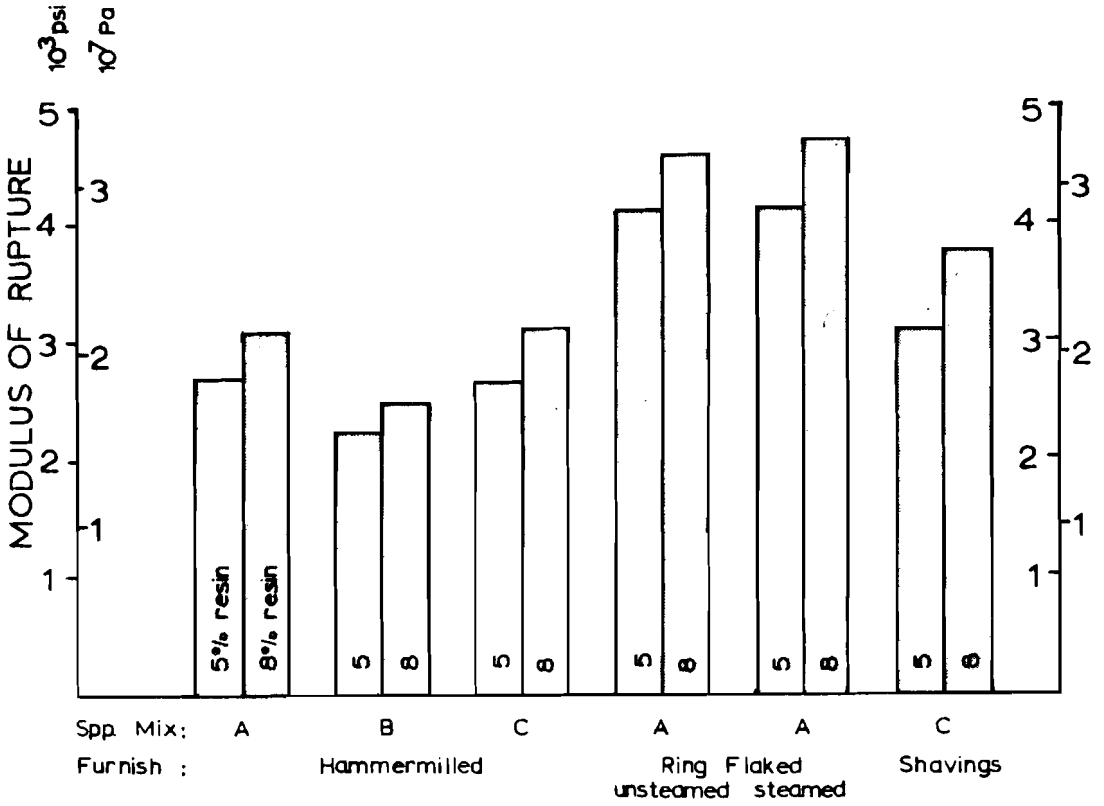

Figure 3.--Predicted mean values for modulus of rupture of 45 pcf (721 kg/m^3) urea-bonded particleboards from Philippine species.

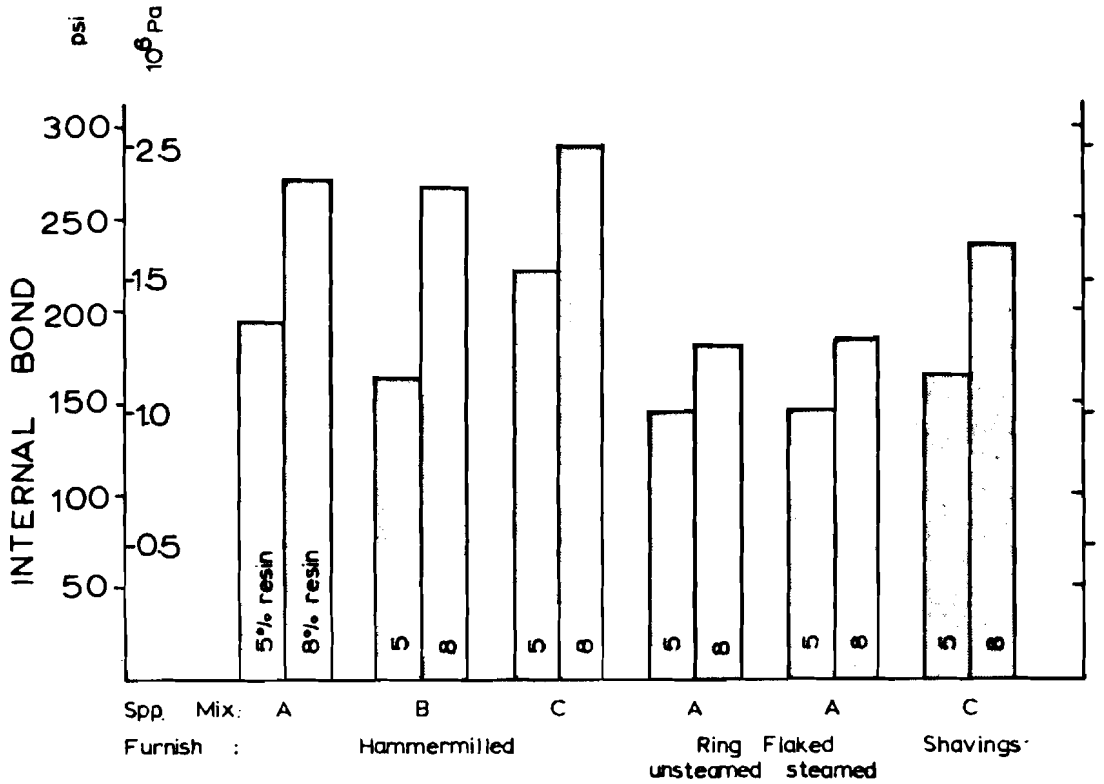

Figure 4.--Predicted mean values for internal bond strengths of 45 pcf (721 kg/m^3) urea-bonded particleboards from Philippine species.

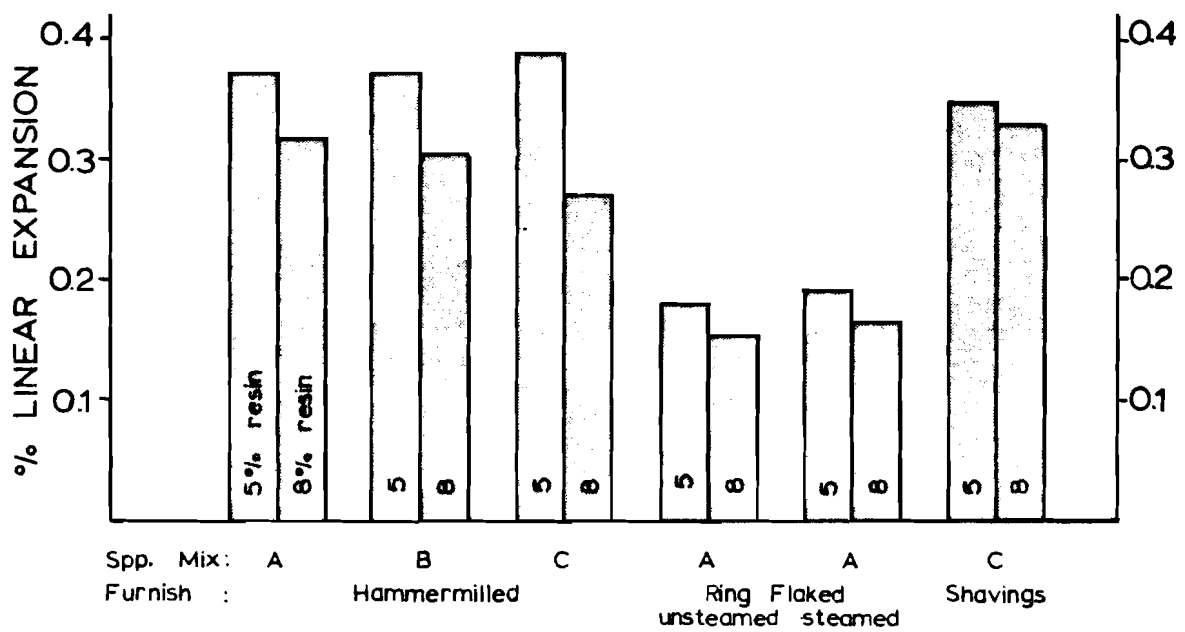

Figure 5.--Predicted mean values for linear expansion (50% to 90% to 50% RH) of 45 pcf (721 kg/m^3) urea-bonded particleboards from Philippine species.

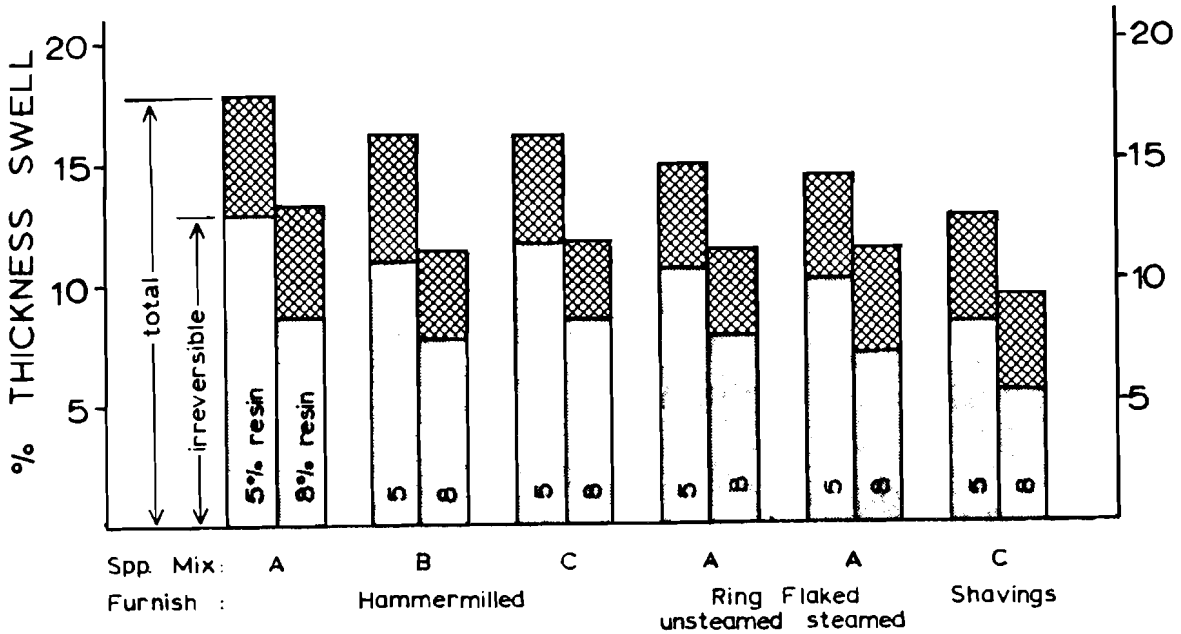

Figure 6.--Predicted mean values for total and irreversible thickness swellings (50% to 90% to 50% RH) of 45 pcf (721 kg/m^3 urea-bonded particleboards from Philippine species.

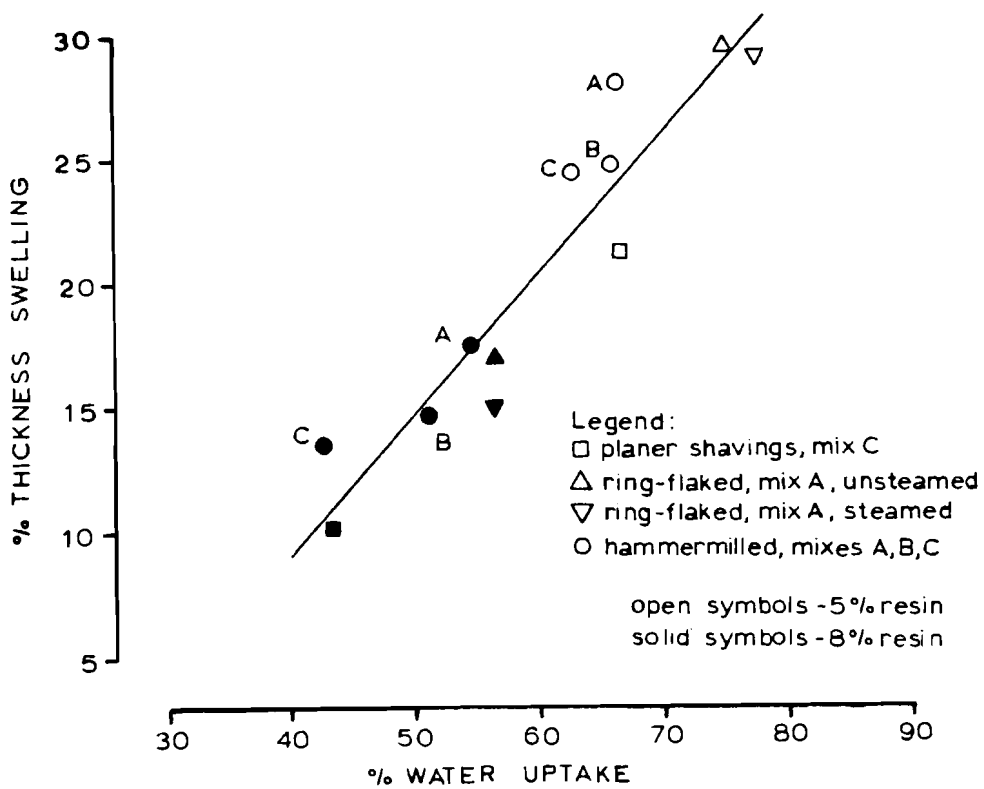

Figure 7.--Percent water uptake and thickness swelling from a 24-hour water soak at 22° C.

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)	(MPa)	Modulus of Rupture (psi)	(MPa)	Internal Bond (psi)	(MPa)	Linear Expansion[1/] (%)	Total Thickness Swelling[1/] (%)	Irreversible Thickness Swelling[1/] (%)	Water Uptake (%)[2/]	Thickness Swelling[2/] (%)
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 flaked[3/]	5	614	4230	4100	28.3	146	1.01	0.19	14.2	10.1	77.3	29.1
A	ring flaked[3/]	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

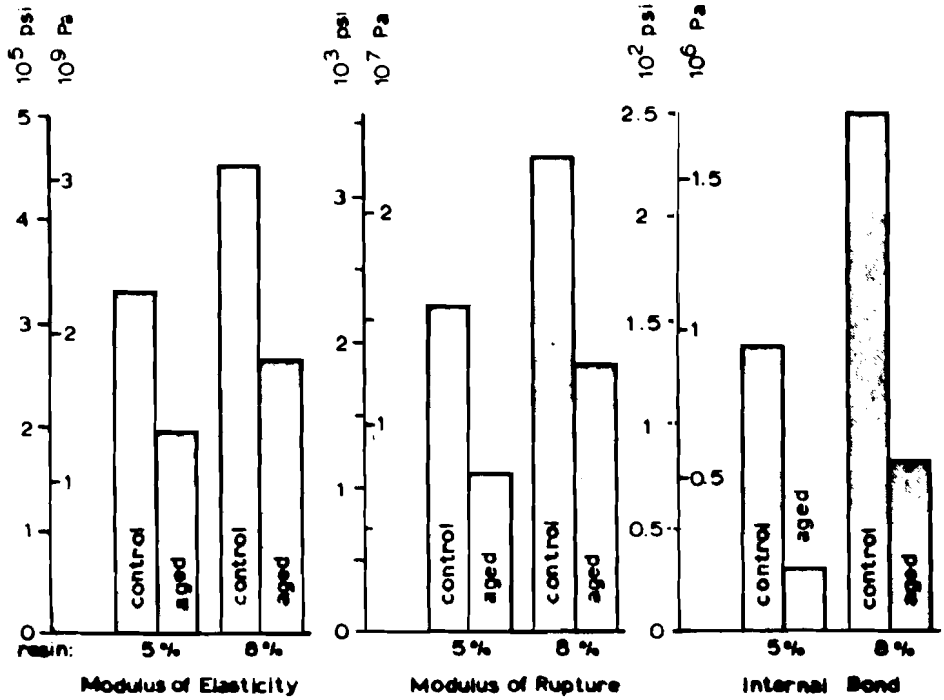

Figure 8.--Predicted mean values for modulus of elasticity, modulus of rupture, and internal bond of control and ASTM accelerated aged samples of 45 pcf (721 kg/m^3) phenolic-bonded particleboards from hammermilled chip mixture A Philippine species.

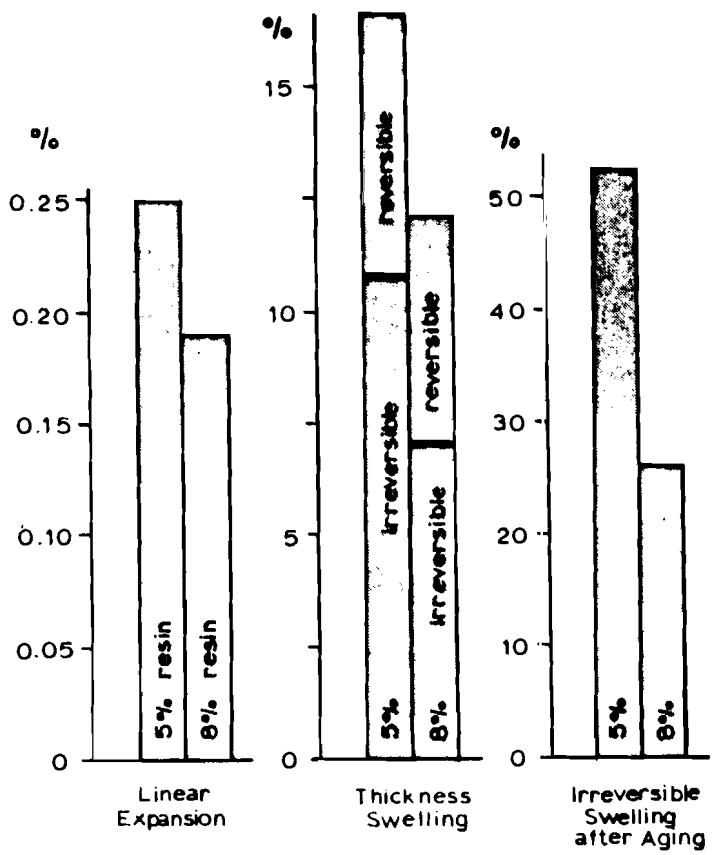

Figure 9.--Predicted mean values for linear expansion and total and irreversible thickness swellings (50% to 90% to 50% RH) and irreversible thickness and swelling after ASTM accelerated aging of 45 pcf (721 kg/m^3) phenolic-bonded particleboards from hammermilled chip mixture A Philippine species.

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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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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

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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.

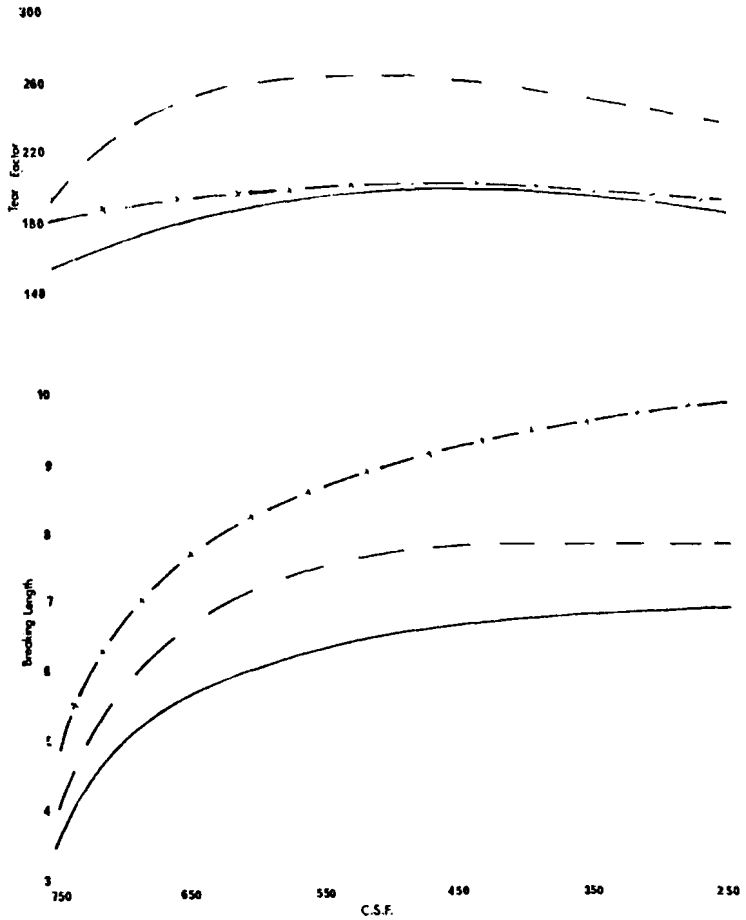
Even after examinations of 36 samples of *P. caribaea* from 11 countries, quality still cannot be predicted, and it is necessary to test all samples.

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

Mochaca British Honduras Natural Growth Age Unkown Kappa Number 29
Mango Creek British Honduras Natural Growth Age Unkown Kappa Number 29
Drasa Fiji Plantation Growth Age 10years Kappa Number 28



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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.

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	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

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.

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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	Year	No.
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SECTION VI

INDUSTRIAL PLANS AND PRACTICES

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TROPICAL HARDWOOD PULPS

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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.

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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.

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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

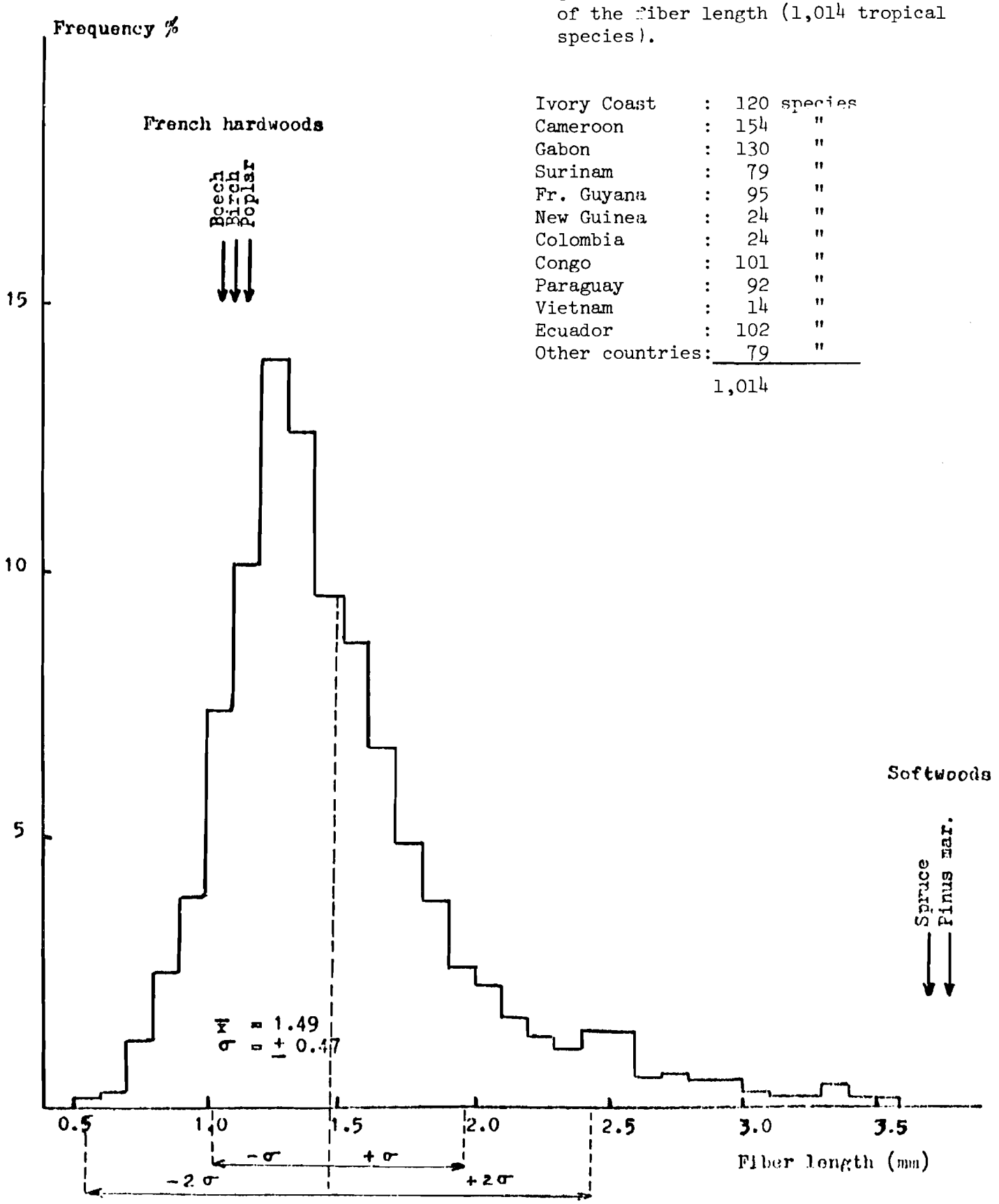
In certain forests the wood is of a higher density, which leads to a shortening of the breaking length and of the burst of papers and to an increase in the bulk and the porosity.

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 individuel 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

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Table No. 5 : 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

Table No. 6 : 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 σ %	
	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

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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

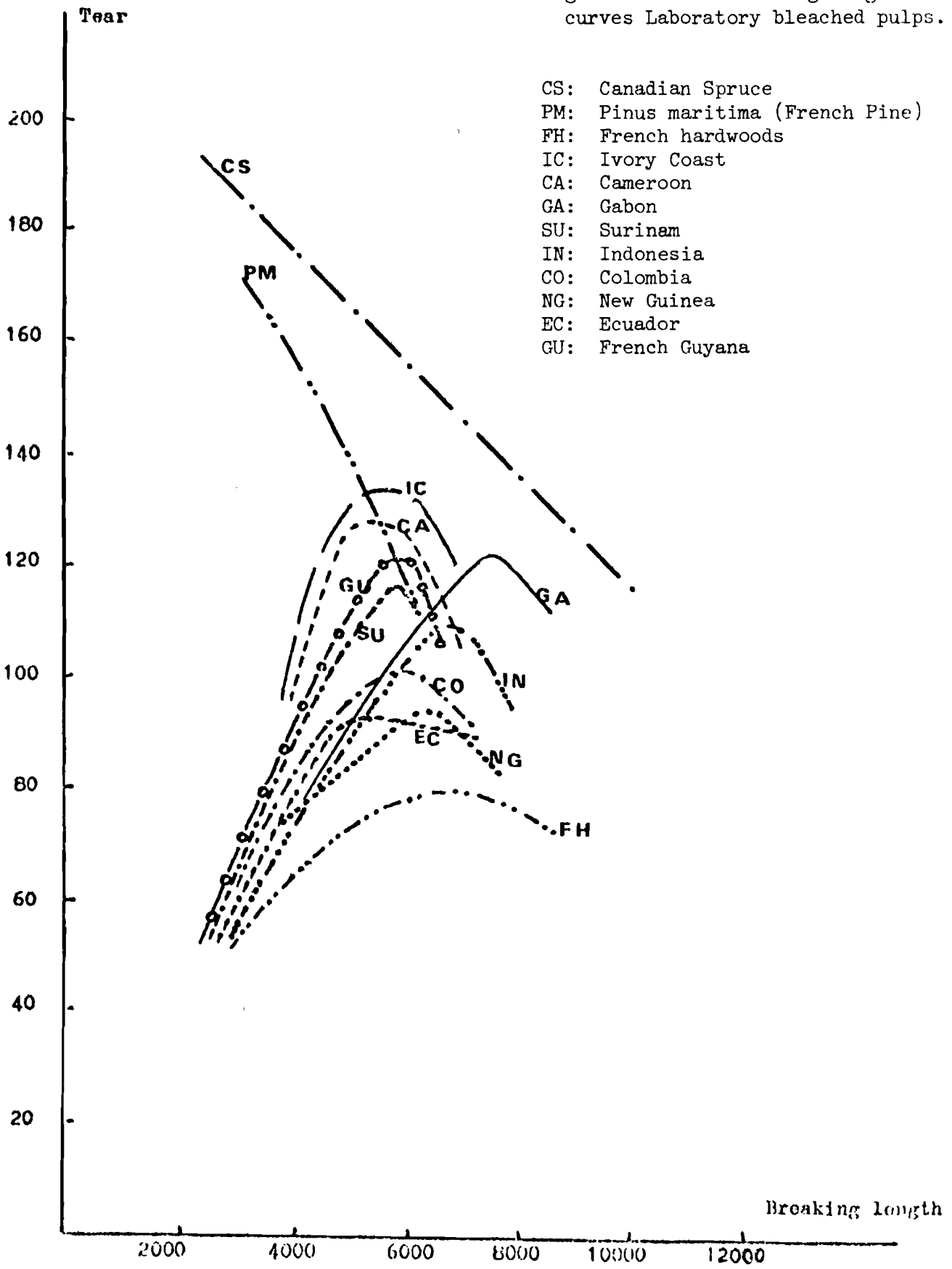
After some semi-industrial pilot tests we took part in some industrial trials using representative mixtures from a few tropical forests. Apart from the RICC experiment which lasted for 4 years, these are generally experimental manufactures of a few days' production from 1,000 to 5,000 tons of wood in 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 (ciment 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 Taïwan 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 monosulphite. 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.

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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

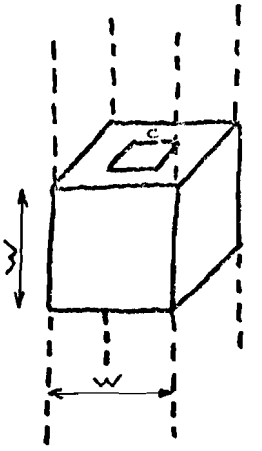
The research into the use of paper produced from tropical forests has considerably improved during the last few years. Transformation into chemical or semi-chemical pulp seems to be technically possible. The use of natural forest only represents the period of a few years in the mill's life because it 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 = $\frac{c}{w}$

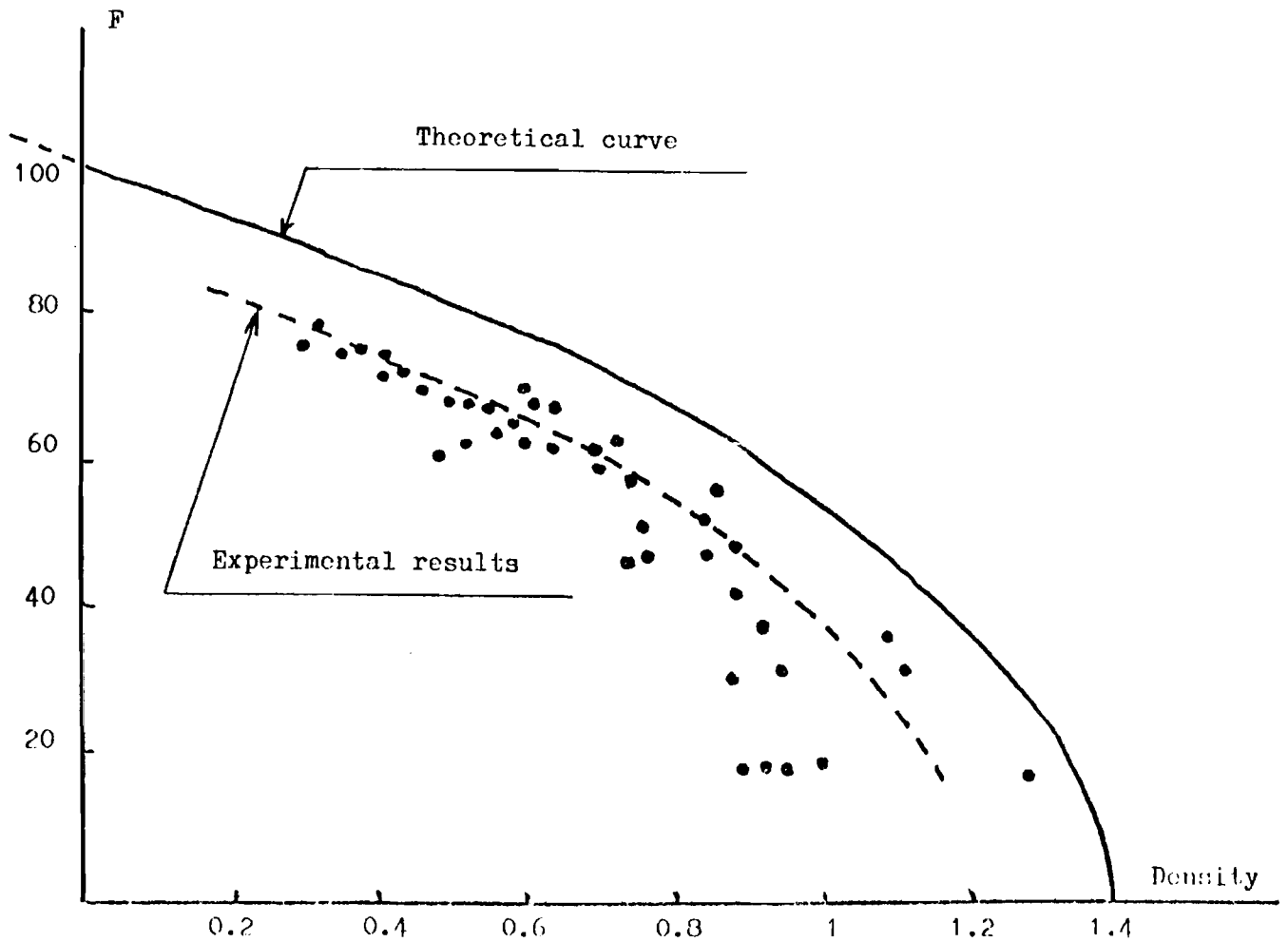
d = wood density
k = density inside the fibers

$$d = \frac{(w^3 - c^2 w)\,k}{w^3} = \frac{(w^3 - w^3 F^2 10^{-4})\,k}{w^3} = k - F^2 10^{-4} k$$

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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UTILISATION OF BLEACHED SULFATE TROPICAL HARDWOOD PULP

By

R. L. Staepelaere and P. L. Ginsburger

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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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
- $KMnO_4$ 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
- $KMnO_4$ 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.

AWW/100 kg	Pulps	°SR	Permea-bility	Tear	Break lenght	Stre-tch	Burst	bulk	Cont. opacity	R	S	K	Dennis son	Initial wet strength	Taber rigi-dity	Creep	Scott cohe-sion	CSF
0	SCANDINA-VIAN 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					488
0	GUYANA INDUSTRIAL TEST UN-BLEACHED 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 UN-BLEACHED K:26,5	14	227	44,1	1615	1,49	6,7	2,18	78,6	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	534
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		534
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	468	3,1	3	88	4,70	75		688
10		26	18	67	3600	2,60	19	1,56	81,6	89	430	3,1	8	-	4,30	44		488
20		40	6	68	4450	3,30	24,5	1,45	80,6	87,7	405	3,5	12	-	4,30	30		303

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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/IOOkg	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 O 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

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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
Composition					
Norland bleached LF ✱	23,5	24,5			
Eucalyptus	17,6	18,4			
White birch	5,9	6,1			
Cellulose d'Aquitaine SF ✱	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
Paper machine					
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/1cm	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 %	Amisol 6,5	Amisol 8	Amisol 16,5	Amisol 8	

✱ LF long fibers pulp
✱✱ 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/IOO 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°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.

TABLE N°8

AUSSEDAT-REY - CRAN-GEVRIER PAPER MILL

WOOD FREE OFFSET DRY FINISH PAPER. 140 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/100	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 O	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

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

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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 I2 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%

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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

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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

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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.

SECTION VII

INVESTMENT CONSIDERATIONS

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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 development 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.

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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.

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 volume[5/] 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.

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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]

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.

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

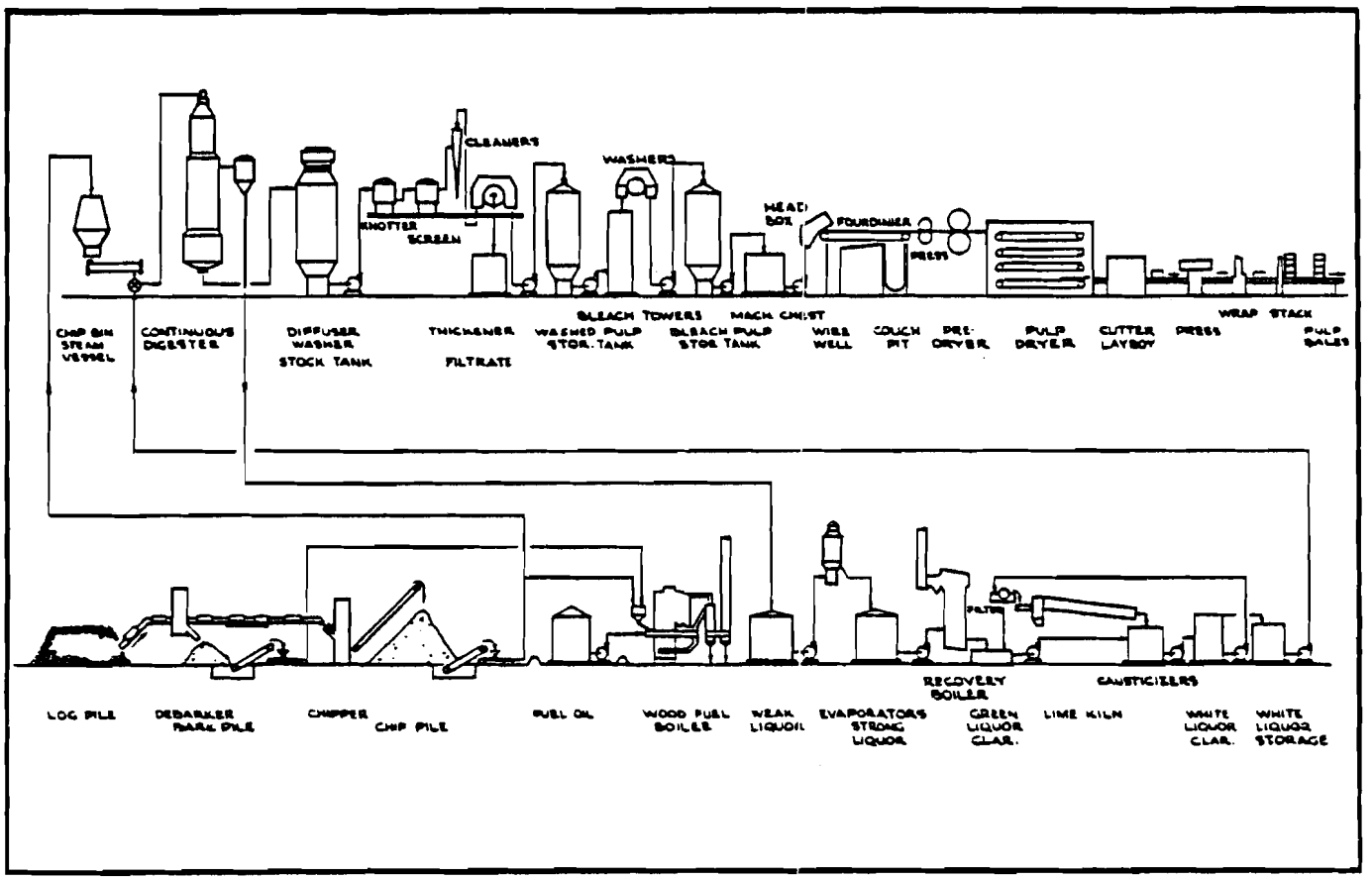

Figure 2.--Mixed tropical hardwood bleached kraft pulp mill process flow diagram.

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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.

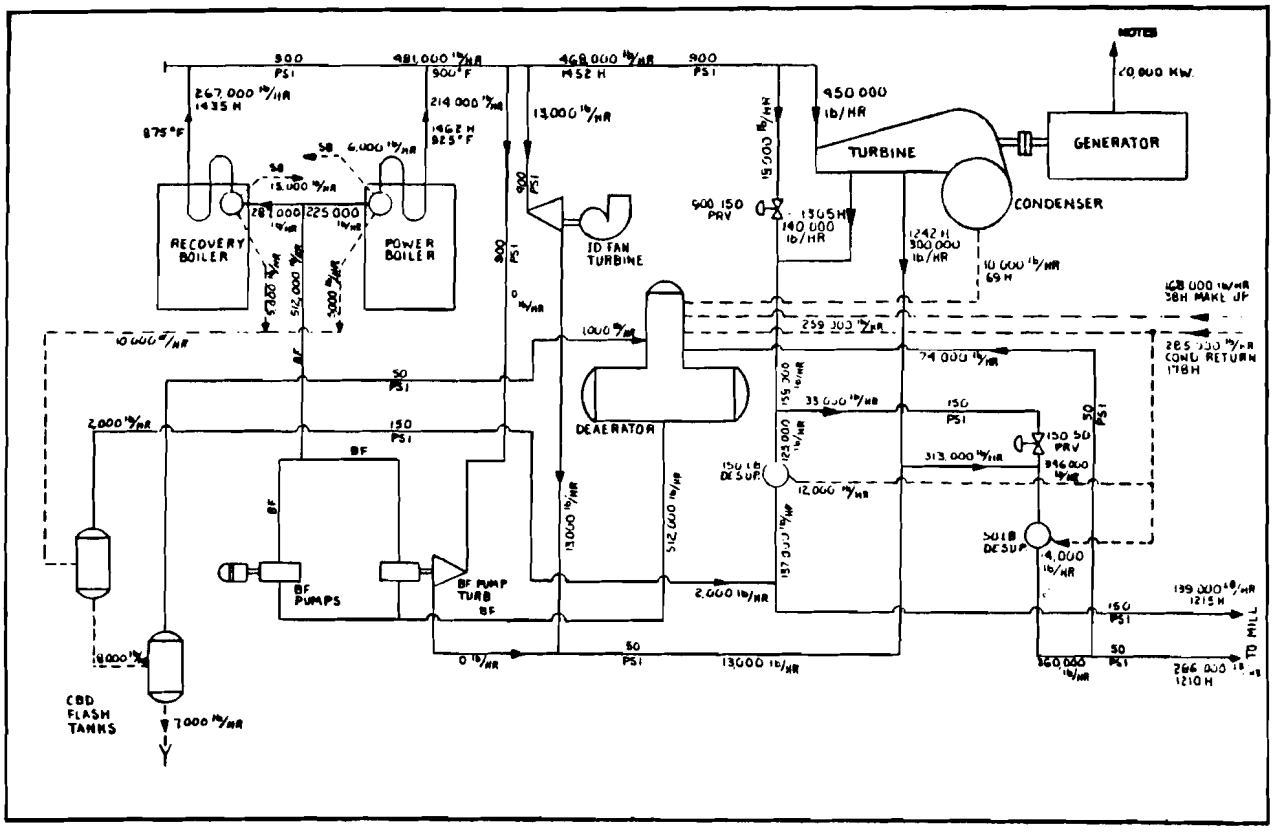

Figure 3.--Mixed tropical hardwood bleached kraft pulp mill heat balance.

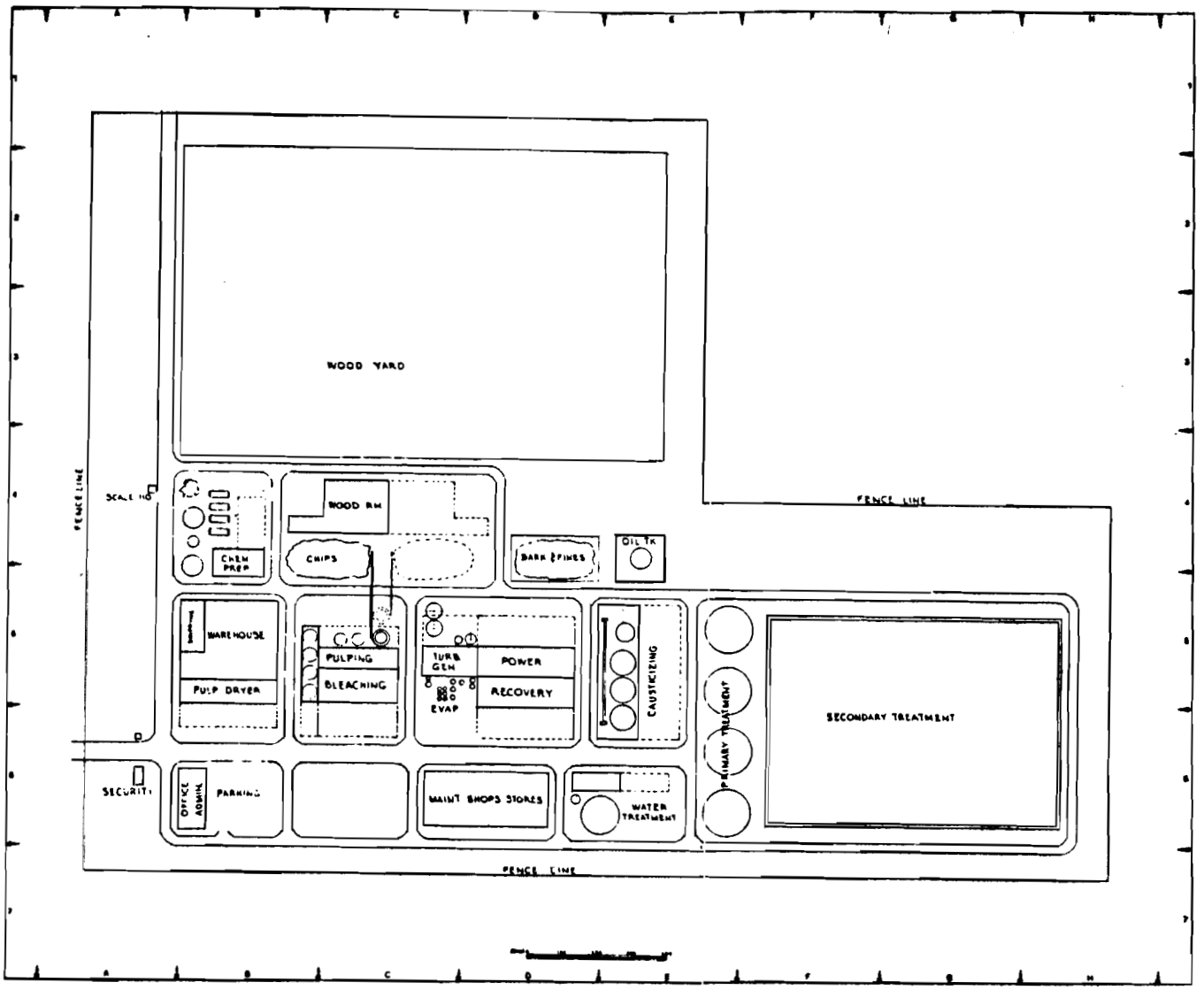

Figure 4.--Mixed tropical hardwood bleached kraft pulp mill plant arrangement.

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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	31416	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	39000	55375	44875	29850																				
Infrastructure	2200	2200	3300	2200	1100																				
Working Capital					11400																				
Test & Start-up		400	625	625	2350																				
Interest	-	-	4800	11760	19200	19200	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

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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.

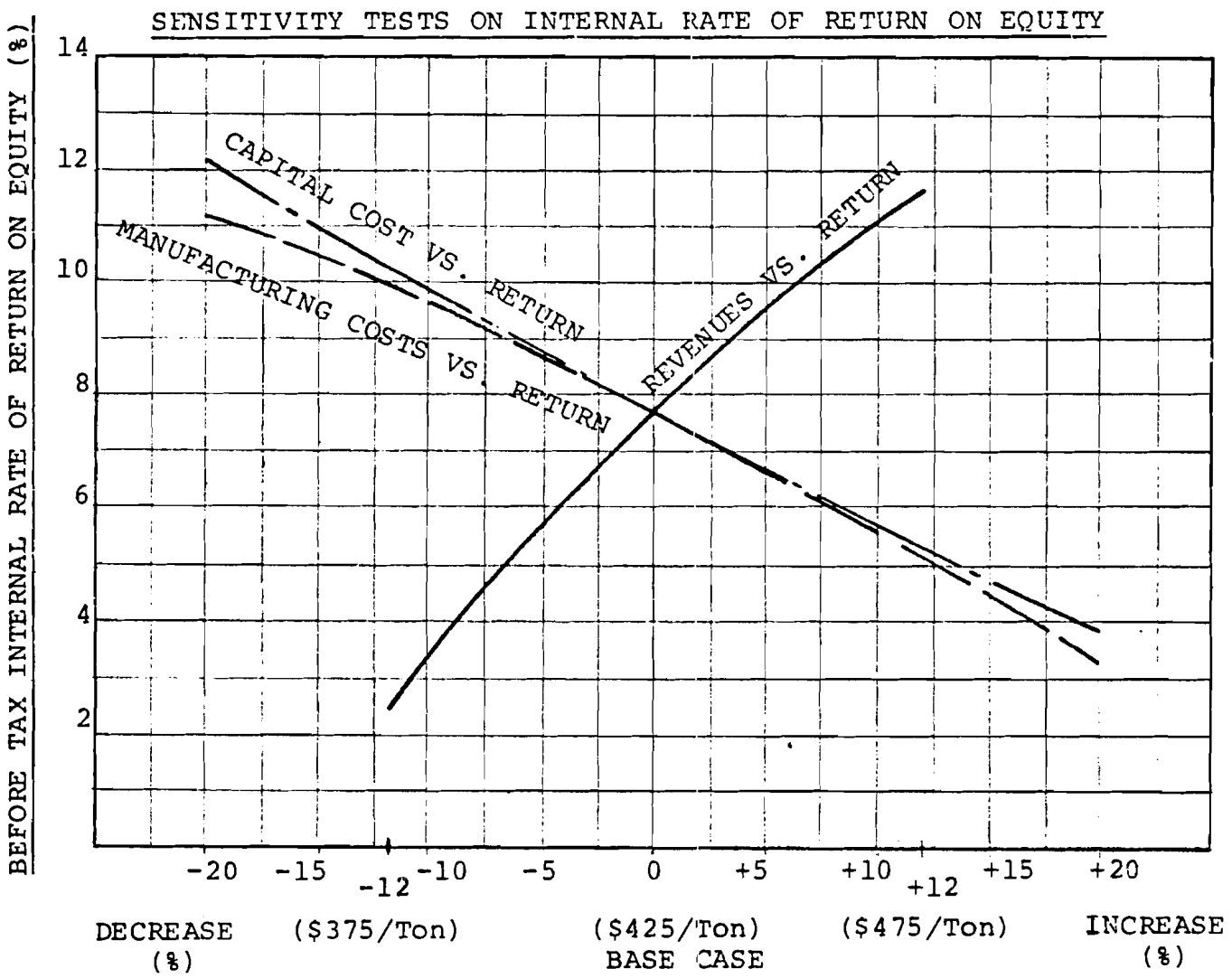
Assumptions for financial analysis:

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

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:

(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.

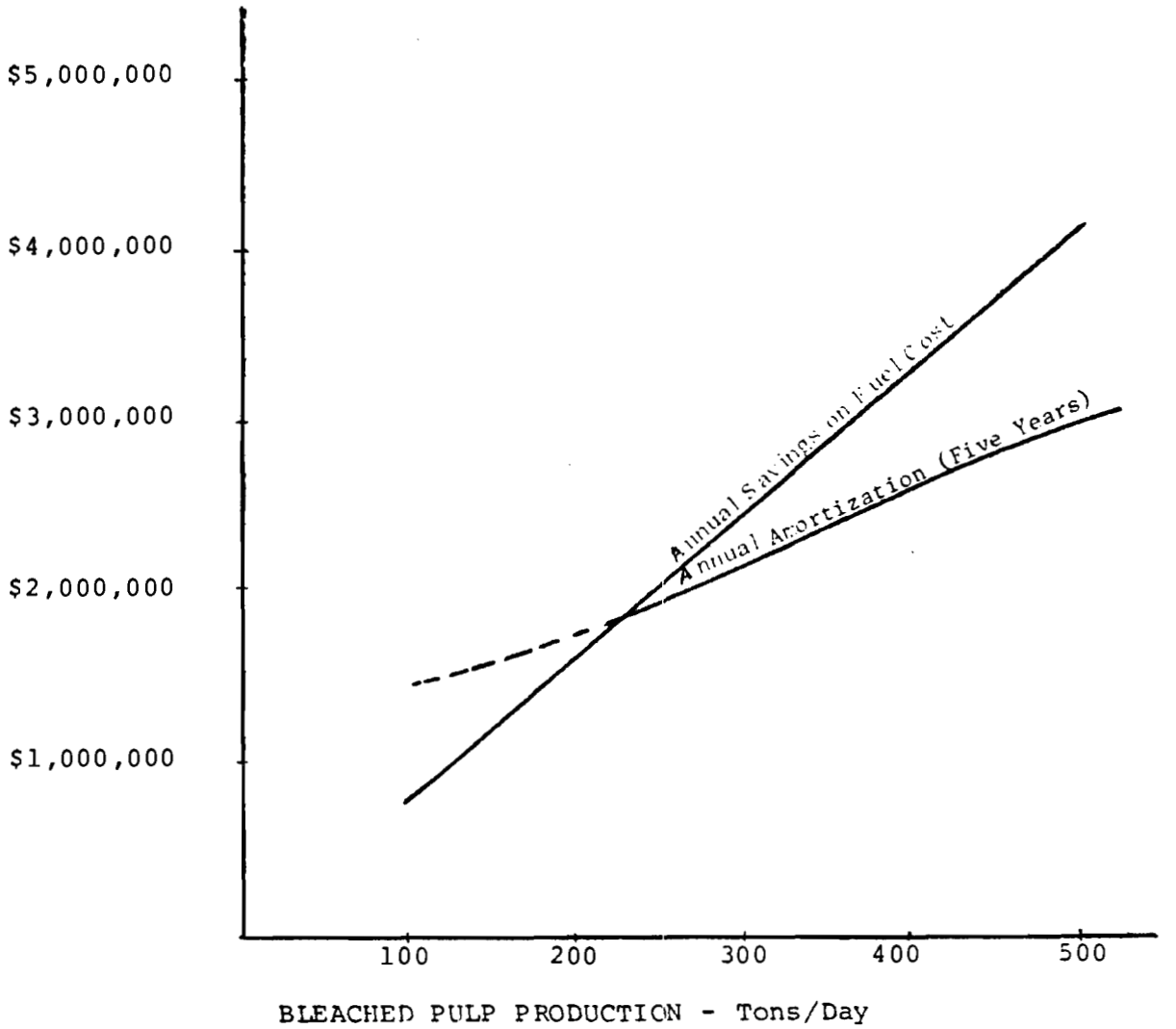
An alternate and far more costly course of action is the installation of a new unit sized for the changed conditions. Although modification to the existing power boiler will be expensive, the total cost may nevertheless be lower than that for a new installation.

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:

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.

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* $ 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.

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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