United States Department of Agriculture

Forest Service

Forest Products Laboratory

Research Note FPL-RN-0262

Sawing Hardwoods in Five Tropical Countries

Stephen P. Loehnertz
Iris Vazquez Cooz
Jorge Guerrero

Abstract

In this study, hardwood sawing technology was identified in five tropical countries: Ghana, Brazil, Venezuela, Indonesia, and Malaysia. The density of wood and presence of silica make it a challenge to saw many tropical hardwoods. The bandsaw is the most commonly used machine and is employed in many sizes and configurations. Sawblade parameters and operating procedures vary according to the nature of the species being sawn and are influenced as much by local custom as technical knowledge of the process. The most commonly reported problems include poor saw maintenance, lack of trained personnel, obsolete equipment, and inadequate sawtooth geometry and wear resistance. Some problems can be addressed by technology transfer, others must be addressed by research.

Keywords: Sawing, tropical, hardwood, sawtooth, abrasive, forest

September 1994

Loehnertz, Stephen P.; Cooz, Iris Vazquez; Guerrero, Jorge. 1994. Sawing hardwoods in five tropical countries. Res. Note FPL-RN-0262. Madison, WI: U.S. Department of Agriculture. Forest Service, Forest Products Laboratory. 11 p.

A limited number of free copies of this publication are available to the public from the Forest Products Laboratory, One Gifford Pinchot Drive, Madison, WI 53705-2398. Laboratory publications are sent to more than 1,000 libraries in the United States and elsewhere.

The Forest Products Laboratory is maintained in cooperation with the University of Wisconsin.

Sawing Hardwoods in Five Tropical Countries

Stephen P. Loehnertz, Research General Engineer
Forest Products Laboratory, Madison, Wisconsin

Iris Vazquez Cooz, Forestry Engineer
Instituto Forestal Latinoamericano, Merida, Venezuela

Jorge Guerrero, Forestry Engineer
Compania National de Reforestacion, Nirgua, Venezuela

Introduction

The purpose of this study was to identify hardwood sawing technology and the problems experienced by sawmills in tropical countries. We studied five countries-Ghana, Brazil, Venezuela, Indonesia, and Malaysia-for which we were able to obtain the most information. We believe these countries represent the range of conditions in Africa, Asia, and Latin America. Sources of information included available literature; visiting scientists at the USDA Forest Service, Forest Products Laboratory; other research institutions; sawblade manufacturers; Food and Agricultural Organization of the United Nations; International Union of Forestry Research Organization; and several universities.

It is incorrect to equate harvesting of tropical timber with deforestation. Deforestation is primarily caused by the spread of agriculture, which accounts for 60% of annual land clearing (Lyke and Fletcher 1992) and far exceeds the effect of cutting trees for wood and timber. Deforestation is driven by population growth and poverty and is likely to continue until the forest is economically developed to provide a livelihood for the local population. Table 1 shows the decrease in forest area from 1980 to 1990.

The value of the forest can be enhanced by knowing how to efficiently process the wood, especially for those species that are abundant but regarded as difficult to process as a result of silica, high density, or other characteristics. Applied research and technology transfer can help provide the required knowledge.

Table 1—Tropical forest (includes wet and dry) area data[a]

	Forest area ($\times 10^3$ km^2)		Average annual deforestation
Location	1980	1990	($\times 10^3$ km^2)
Latin America	9,230	8,399	83
Asia	3,108	2,749	36
Africa	6,503	6,001	50
Total	18,841	17,149	169

[a]World Resources Institute (1992).

Sawnwood Production and Exports

Production

The total hardwood sawnwood production for the five countries (Ghana, Brazil, Venezuela, Indonesia, Malaysia) is about 21% of the world's total. From 1980 to 1991, output increased in each country except Venezuela. Brazil's sawnwood output was more than 60% of the total for South America in 1991 and 7% of the world's total.

Exports

For the five countries, Malaysia exports the largest quantity of sawnwood, about 30% of total world exports and more than 50% of its production. Ghana exported about 40% of its sawnwood production in 1991, which was about 14% of the total for Africa and 1% of the world's total. Brazil's exports were less than 5% of its sawnwood production in 1991, but nearly 3% of the world's total (Table 2).

Table 2—Hardwood sawnwood production and exports[a]

	Production ($\times 10^3$ m^3)		Exports ($\times 10^3$ m^3)	
Location	1980	1991	1980	1991
Ghana	225	400	69[b]	161
Brazil	7,738	9,256[c]	662	429[c]
Venezuela	349[c]	235	—	—
Indonesia	4,800[b]	9,008[c]	1,203	756
Malaysia	6,284	8,860[b]	3,212	4,934[b]
Africa	5,621	6,112	1,104	869
Asia	43,357	53,316	6,628	7,064
World	115,790	130,825	13,190	14,931

[a]FAO (1993).
[b]Unofficial.
[c]FAO estimate.

Discussion

Ghana

Forest Resources

African forest resources are rich only in the southwest area where 70% of the surface is covered with forest, and half of this is dense forest (ITT0 1990). As a result of overlogging and deforestation, several areas will either be totally deforested in 10 years or all known stocks of commercial species will be exhausted. Eight-five percent of production is used as firewood; only a small part is used in the form of structural wood. Large areas of forest are cleared each year for agricultural use (IUFRO 1989).

Ghana has 0.08×10^6 km^2 of forest with 680 tree species, of which 66 have major economic value (76.3% of standing volume). Another 60 species are potentially marketable (18.3% of standing volume). However, only about 40 species are considered commercial for which there are both domestic and export markets. A second group of 20 species is considered marginally commercial. Two abundant species are wawa (*Triplochiton scleroxylon),* 15% of standing volume, and esa (*Celtis* spp.), 12% of standing volume (ITT0 1990).

Characteristics of some Ghanan species that can cause rapid dulling of cutting tools in machining include the following (basic specific gravity based on ovendry weight and green volume):

- High density, Kaku (*Lophira alata*) 0.90 basic specific gravity
- Silica, Bediwunua/Eyere (*Canarium schweinfurthii*) 0.40 basic specific gravity
- Calcium carbonate deposits, odoum (*Chlorophora excelsa* and *C. regia*) 0.55 basic specific gravity (Chudnoff 1984)

Sawmilling

In Ghana, harvesting and cutting of timber are highly mechanized with rules and regulations (Sagoe 1992). Every tree 60 to 62 cm in diameter or larger is numbered, and every felled tree is recorded. The largest logs are processed in mills closest to the forest, if possible, because transportation is inefficient. Sawing conversion ranges from 35% to 40%, but has improved in recent years.

The Timber Export Development Board of Ghana (Eshun 1993) states that from 1990 to 1992, average annual lumber production was 576,000 m^3/year. This is greater than reported in Table 2. Conversion efficiency is 53%. Lumber uses include joinery, mouldings, construction, paneling, profile boards, flooring, furniture, boxes/crates, cabinets, pallets, sleepers, windows, doors, window frames, and boat building. Plantation stock is used for poles. The average local market share of lumber is 340,000 m^3/year, and the average export share is 236,000 m^3/year. This volume is greater than reported in Table 2. The dimensions range from 25 to 100 mm in thickness, 150 mm or more in width, and 1.8 m or more in length. Lumber is occasionally planed upon request.

In Africa, more than 90% of the sawing machines are bandsaws (Sales 1992). Wheel diameter ranges from 1.10 to 1.80 m. Stellite is the basic tooth material; feed speed varies from approximately 5 m/min (small bandsaw) to 35 m/min for an average cutting depth of 0.40 m. Green lumber thicknesses are theoretically 21, 27, 34, 42, and 54 mm, but may vary 20% because of poor equipment maintenance. Lumber is not planed, and average yield is 40%, increasing to 50% in the best case (from log to boule, not square edged).

The current bandsaw parameters used in Ghana for cutting tropical hardwoods are reported in Table 3; shape S is usually used (Gyamel 1993). Common tooth profiles are given in Figure 1. The convex back reduces the clearance angle to a minimum and adds strength to the tooth. Mills that process hardwood logs containing silica normally use swaged and stellited saws. Typically, the saw is not used more than 3 h without checking for faults.

Reported Problems

Many reported problems are related to maintenance, such as the saw being used while dull, gullet burn while sharpening, incorrect and uneven tension, uneven crown, burrs left in gullet when sharpening, faulty wheel bearings, saw too thick for wheel diameters, and bandmill vibration. These problems result partially from a lack of skilled personnel in the shop and management (ITT0 1990). There has been no revolutionary development that would eliminate the need for highly skilled technicians and operators to obtain optimum results. In the future, the increasing inaccessibility of raw material sources may force decentralized processing to be integrated with logging, that is, mobile processing and power equipment.

Table 3—Common types of sawblade geometry

	Wheel diameter (m)	Profile	Type	Saw (mm) Thickness	Width	Pitch	Gullet depth	Side clearance	Angle (°) Hook	Clearance	Sharp-ness
Ghana	1.8	Shape S	Stellite	1.47;1.65	254	55	22	0.61	25-30	12-16	44
Brazil											
Sample A	1.25	Gum	Swaged, alternate teeth	1.25	120	45	11	0.8	10	20	60
Sample B	1.25	Gum	Swaged, alternate teeth	1.25	114	45	15	0.8	17	23	50
Venezuela[a]											
High density	1.4	Gum	Stellite	1.30	150	45	13	0.6	22	12	56
Malaysia											
Headrig	1.5	Gum	Stellite, alternate teeth	1.47;1.65	206	45	12.7	0.6	25	16-18	47-49
Small resaw	0.9-1.1	Gum	Stellite	1.06;1.24	102	32	11	0.5	25	16-20	45-49

[a]Munoz (1994).

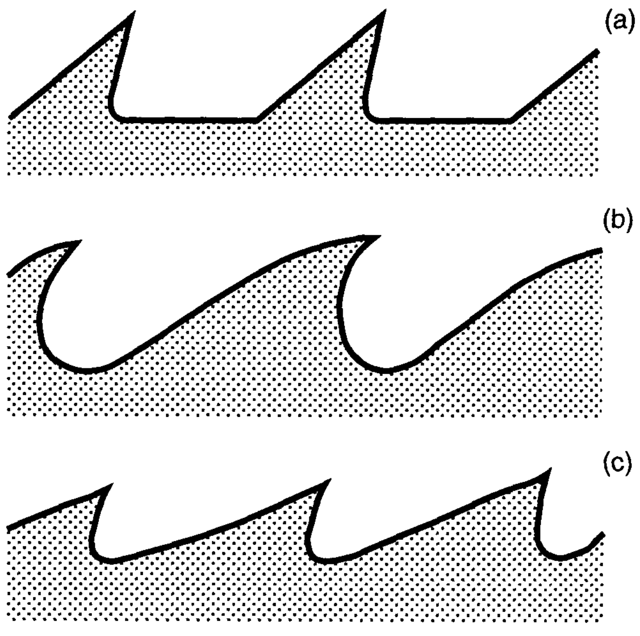

Figure I-Tooth profiles: (a) flat-bottom gullet or "gum" shape, (b) shape S, preferred for wide bandsaw blades, (c) shape N or tooth of the "wolf."

Brazil

Forest Resources

Brazil has 8.5×10^6 km^2 of forest resources. Of this, approximately 3.47×10^6 km^2 are tropical forest, which is about 30% of the world's total. Brazil's forests contain 15% to 20% of all species known (Figueroa and others 1987). The forest-based industries in the Amazon region, primarily located on river banks, contribute approximately 4% to Brazil's Gross National Product (GNP) (Setsuo 1992). About 60% to 70% of all woods in the Amazon region have a specific gravity greater than 0.70 g/cm^3.

Principal problems of the wood processing industry in Brazil include the following:

- Highly selective nature of forest exploitation
- Scarcity of qualified personnel at all levels
- Obsolete equipment and inadequate maintenance infrastructure

Too much emphasis is placed on a few species and too many trees are cut to get out the well-known, high-valued species (Lara 1992). As the supply of traditional species gradually diminishes, new species enter the market that require greater processing care (de Freitas 1985) as a result of high silica content, high density, or inordinate growth stress. Some examples follow:

- Ipe (*Tabebuia* spp.): high density, an abundant species, difficult to cut, 0.85 to 0.97 basic specific gravity (Mainieri and Peres 1989)
- Tauari (*Couratari guianensis, C. oblongifolia, C. pulchra*): silica, 0.50 basic specific gravity, up to 0.8% silica content in some species
- Itauba (*Mezilaurus itauba*): high density and silica content, 0.96 basic specific gravity, (Mainieri and Peres 1989); Parajuba (*Dialium guianense*): high density and silica content, 0.81 to 0.93 basic specific gravity (Chudnoff 1984)

Sawmilling

From 1980 to 1991, Brazil's sawnwood production ranged from 7.7 to 9.3×10^6 m^3 (Table 2). Sawnwood production is primarily used for civil construction, furniture, building, joinery, and packaging.

Para State—Para produces 30% of all timber in Brazil and 78% of all timber in the Amazonia. Information from Armco Do Brasil (Ambrosevicius 1993), a manufacturer of sawblades, indicates that exports from Para comprise 50% or more of all timber exports from Brazil in recent years. Of the 4,000 mills in Para, Professor Lara (1992) visited 400. One mill, Sawmill Betzel LTD, produces 35,000 m^3 of lumber per year. Lara observed logs being moved by bulldozers, not skidders, and estimated that 50% of the log is left in the forest. The company cuts only what the market demands. Lara divided the 400 mills he visited into three categories:

Small:	1 bandsaw producing 10 to 40 m^3 lumber per day
Medium:	2 bandsaws producing 60 to 70 m^3 lumber per day
Large:	3 to 5 bandsaws producing 90 m^3 or more per day

Maranhao State—The volume of lumber produced for three Cikel Sawmills in Maranhao combined is 50,000 m^3/year (de Freitas 1993); recovery is about 55%; lumber dimensions are 25 and 60 mm thick, with various widths. Only part of the mill production is planed, They use a bandsaw for breakdown with a depth of cut ranging from 150 to 800 mm and a circular saw for edging and cross cutting. The depth of cut ranges from 150 to 800 mm. The sawblade geometry from samples sent to us from their mill at Maranhao is given in Table 3. The saws are sharpened every 4 h, and blades are tensioned by rolling.

Reported Problems

In Lara's (1992) opinion, the species of Para are different than in other areas of Brazil; the wood is very green and hard, and the sawblade is the main limitation. As a result of difficulties, he often witnessed the saw being stopped in the cut. There are numerous blade losses, and blades are changed three or four times a day. The recovery can be very low with perhaps 80% of the fiber lost, 60% in the forest and 20% in the mill, giving only 20% recovery on a log basis. Further, Lara noticed maintenance and safety problems, which the mill operators often denied.

In the opinion of Cikel Sawmill managers (de Freitas 1993), the main problem with Brazilian sawmills is low utilization of saw capacity (low feed speed) because of under-powered equipment, inadequate tooth geometry, too much gap in saw guides, narrow blades, and poor tensioning.

Venezuela

Forest Resources

In Venezuela, the natural forest covers about 0.5×10^6 km^2, and 50% of the forest area is productive, mainly in the Guayana region. In addition, Venezuela has 0.005×10^6 km^2 of plantation Caribbean pine (SEFORVEN 1992).

The timber industry in Venezuela is centered around a few species with commercial value that are easy to saw without technical improvement in the mills. Many less-used species are not processed because of the nonexistent marketing system and the availability of established commercial species. About half the production (379,743 m^3) comes from traditional annual permits and the remaining (368,857 m^3) as a result of forest management plans (Rodriquez 1993). The minimum diameter (at breast height) required by law for a tree to be cut is 30 cm.

Common uses of sawnwood are construction, joinery, particleboard, plywood, pulp, paper, corrugated, and recycled fiber. The contribution of the forest sector to the GNP is less than than 1% (Luna and Cooz 1991). Thirteen main species, basic specific gravity ranging from 0.4 to 0.91, have commercial interest.

Another species gaining importance because of its abundance is Chupon rosado (*Franchetella anibifolia*), 0.70 basic specific gravity, which is difficult to machine because of its high silica content.

Sawmilling

Data for lumber production are given in Table 2. The usual recovery from a sawlog in Venezuela is 60% to 70% in sawnwood of commercial dimension. In the pine plantation (*Pinus caribaea*), the recovery may be close to 70% (Ninin 1993).

Venezuela has 291 sawmills; almost all use bandsaws (Ninin 1986). The most common type of mills produce 20 to 25 m^3 of sawnwood per shift. Common tooth styles are wolf and gum. Most blades are spring set, commonly by hand. Table 3 gives the sawblade parameters recommended for high density wood (Munoz 1993). Saws are changed every 4 h when cutting soft wood, but hard wood may require changing saws every 2 h or less (both cases without stellite).

Reported Problems

In general, deficiencies exist in the maintenance of sawmills (Ninin 1993). The sharpener (sawfiler) has little training, learning only the empirical methods from the previous sharpener. Only a few species with silica are processed because only a few filers know about stellite and other techniques. The sawyer usually has no training. These deficiencies makes it difficult to introduce new species. The primary problem is that the species have a high density and are abrasive.

Indonesia

Forest Resources

Estimates of natural forest area in Indonesia vary between 1.15 and 1.43×10^6 km^2 (Krutilla 1988). The Bornean province of Kalimantan possesses the largest remaining forest area (34%), followed by Sumatra (32%) and Inan Jaya (26%). Predominant species in the Kalimantan forests include meranti (*Shorea* spp), ramin, damar, and ulin; the Sumatrean forests are dominated by meranti, pine, mangroves, and ulin species. Eighty-three percent of Indonesian sawtimber production is from the combined regions of Kalimantan and Sumatrean. The composition of the forest resource in Irian Jaya is more heterogeneous than in the western Indonesia states, with nondipterocarp mixed hardwoods occurring prominently in the species mix.

Two abundant species that are difficult to process are Palapi (*Heritiera* spp.), 0.52 to 0.59 basic specific gravity, which contains silica, and Balau (*Shorea* spp), because of its density (0.70) and interlocked grain (Chudnoff 1984).

The Indonesian forest industry sector places much emphasis on exports, second in importance after petroleum and gas. Forest products exports account for 16% of the country's total export earnings (Kir 1989). However, continued domestic industrial wood demand could conflict with export levels.

In 1987, an estimated 76% of wood production was used as fuelwood; about half was from home gardens. The waste in logging may exceed the log volume extracted, perhaps more than 1.5 to 2 times, when considering the residual damage to the stand and the full range of log diameters (Mordeno 1990). Seventy percent of sawnwood is consumed domestically. The domestic market helps absorb products that are nonexportable.

Sawmilling

Sawmilling is the oldest and largest primary forest industry in Indonesia, with about 2,700 sawmills operating. The major centers of production are found in Kalimantan and Sumatra, where about 83% of the Indonesian sawntimber production is realized; 63% of log consumption goes to sawmilling. The usable wood waste from sawmilling is about 8×10^6 m^3. Increased efficiency in wood usage could have a significant effect on the wood supply (Kir 1989).

The main use of the sawntimber is building material and furniture manufacturing. Sawntimber production is export oriented, but domestic sawntimber consumption has increased each year, mainly because the quality and grade of the output often fall short of export requirements.

Reported Problems

Problems that have contributed to the low performance of the industry include inefficient production techniques and machinery, leading to low wood recovery ratios (less than 50%), lack of skilled labor, and poor managerial skills (Krutilla 1988).

Malaysia

Forest Resources

Malaysia is a leading producer and exporter of tropical hardwoods. The total forest area of Malaysia is about 0.2×10^6 km^2, 62% of total land area. In Sarawak, the forest cover is 77%, and in Sabah 60%. In Peninsular Malaysia where the conversion of forest into agriculture crops takes place at a high pace, 48% of the land area remains forest (Ghazali, 1990).

Nearly all logs produced in Peninsular Malaysia are consumed locally (mainly for sawntimber and plywood), and 80% and 90% of logs produced in Sabah and Sarawak, respectively, are exported. In 1988, sawlogs, sawntimber, and wood products were 12.9% of total gross export. The value-added contribution of the sector is small, that is, only 5.1% of the GNP.

The following hardwoods exported from Peninsular Malaysia (Maskayu 1992) are difficult to process:

- Balau (*Shorea* spp.), abundant, dense, 0.70 basic specific gravity, difficult to cut
- Merbau (*Intsia bijuga*, *I. palembancia*), abundant, 0.68 basic specific gravity, gummy
- Rengas (*Gluta* spp., *Melanorrhoea* spp.), silica, severe dulling (Chudnoff 1984)

Sawmilling

Malaysia has 916 sawmills of which 667 are in Peninsular Malaysia, 143 in Sabah, and 106 in Sarawak. Malaysia almost exclusively uses bandsaws for producing sawnwood. About 79% of the sawmills are in active operation. Waste is at a high level throughout the industry, considering that the average mill recovery rate is only 54.5% (Ghazali 1990). The major timber products in Malaysia are sawntimber, plywood (includes blockboard), veneer, moulding (includes dowels), woodchips, chipboard, wooden furniture, builders carpentry, and joinery.

The single, most important production unit of the Malaysian sawmill industry is a small bandsaw with wheel diameters ranging from 0.91 to 1.1 m, often used for both log breakdown and resawing.

The most common machinery of a Malaysian sawmill is a vertical log bandsaw, usually 1.83 or 1.52 m with a semiautomatic log carriage combined with generally six small resaws of the previously mentioned type. In general, the breakdown unit uses 203- to 254-mm-wide blades that run at approximately 1,829 m/min, which is about the minimum saw speed necessary to cut tropical hardwood. Attempts of a decade ago to modernize and automate sawmills were not successful because of the variety of species and the log diameters to be processed, along with variable target sizes.

A typical 1.52-m band headrig used for log breakdown of different species has the characteristics given in Table 3. Teeth are stellite tipped, mostly alternately. The clearance angle is apparently kept high to reduce feed force and prolong the life of the tooth and blade.

The specifications of the small bandsaws usually used for resawing in the majority of the sawmills are also given in Table 3. All teeth are generally stellite tipped. Most saw-sharpening machines are not equipped with cams for changing tooth profiles, which might partially explain the predominant use of the flat-bottom shape (Fig. 1). Many experts argue that this shape is not the ideal tooth profile for cutting medium to high density species, but it has proved in many countries to be capable of meeting all basic requirements. Unless the sawmill industry is prepared to sort logs according to density groups and/or abrasiveness of species, there appears no need to introduce another tooth shape (Schrewe 1986).

Reported Problems

The moulding, joinery, and furniture industries are facing difficulties in obtaining accurate dimensions of sawn material from sawmills (ATTC 1991). Although almost all sawmills have facilities for bandsaw maintenance, the typical sawfiler does not know the profile, tooth height, angles, swage, or other parameters about the saw.

Conclusions

Hardwood sawing technology and the related problems were identified in five tropical countries: Ghana, Brazil, Venezuela, Indonesia, and Malaysia. The density of wood and occurrence of silica make it a challenge to saw many tropical hardwoods. The bandsaw is the most commonly used machine and is employed in many sizes and configurations. Sawblade parameters and operating procedures vary according to the nature of the species being sawn and are influenced as much by local custom as technical knowledge of the process. The most commonly reported sawmilling problems include poor maintenance, lack of trained personnel, obsolete equipment, and inadequate sawtooth geometry and wear resistance. Some of these can be addressed by technology transfer, others by research.

The main opportunities for our research appear to be in the areas of sawtooth geometry and wear characteristics. Information from Brazil referenced the blade and tooth geometry as problems. The high density and abrasive nature of species from Venezuela was given as a limitation to processing. From Malaysia came the suggestion to review test results on “difficult” species and develop knowledge of factors influencing machining quality. If research can result in developments that reduce the need for highly skilled sawfilers, it would be a further benefit.

References

Ambrosevicius, Jesus Tadeu. 1993. Personal communication, December. Sao Paulo, Brazil: Armco Do Brasil S.A.

ATTC. 1991. Annual report. Jalan Ampang, 50450 Kuala Lumpur, Malaysia: ASEAN Timber Technology Center. 42 p.

Chudnoff, M. 1984. Tropical timbers of the world. Agric. Handb. 607. Washington, DC: U.S. Department of Agriculture. 464 p.

de Freitas, Amantino Ramos. 1985. Properties and utilization of tropical woods. IUFRO meeting project group P5.01; 1984 November 19–23; Manaus. Research Priorities in South America for Tropical Wood.

de Freitas, Amantino Ramos. 1993. Personal communication, November 23. Sao Paulo, Brazil: Division of Forest Products and Textiles, Coordinator, Instituto de Pesquisas Tecnologicas, R.E. 0026.5.

Eshun, A.A. 1993. Personal communication, November 19. Takoradi, Ghana: Timber Export Development Board of Ghana.

FAO. 1993. Forest products 1980–1991. FAO Forestry Series 26, FAO Statistics Series 110. Rome, Italy: Food and Agriculture Organization of the United Nations.

Figueroa Colon, Julio C.; Wadsworth, Frank H.; Branham, Susan, eds. 1987. Management of the forests of tropical America: prospects and technologies. In: Proceedings of a conference; 1986 September 22–27; San Juan, Puerto Rico. New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station.

Ghazali, Dato' Baharuddin Hj. 1990. The promotion of further processing and exports of timber products: Malaysian experience. In: Proceedings of an ITTO seminar. The promotion of further processing of tropical hardwood of the Africa region, Accra, Ghana. 31 p.

Gyamel, J.O.K. 1993. Personal communication, August 12. Kumasi, Ghana, West Africa: Principal, School of Sawdoctoring, Timber Export Development Board of Ghana.

ITTO. 1990. Further processing of tropical timber in Africa. In: Proceedings, Promotion of further processing of tropical hardwood timber; 1990 February 13–16; Accra, Ghana. Timber Export Development Board of Ghana.

IUFRO. 1989. Seminar, project group, for properties and utilization of tropical woods. In: Proceedings of research needs in wood technology: results of the African survey (1988); 1989 Nov. 19–25; Abidjan, Cote de Ivorie (Ivory Coast).

Kir, Adnan. 1989. Wood products: domestic consumption and marketing, Indonesia. In: UTF/INS/065/INS Forestry Studies. Field document V-1/Directorate General of Forest Utilization, Ministry of Forestry, Government of Indonesia; 1989 October. Jakarta: Food and Agriculture Organization of the United Nations. 122 p.

Krutilla, Kerry. 1988. A guide to investment and trade in the forest products sectors of Southeast Asia: Indonesia, Malaysia, and the Philippines. In: FPEI Working paper series 32; 1988 January; Research Triangle Park, NC: Southeastern Center for Forest Economics Research.

Lara, Flavio. 1992. Personal communication, July. Para, Brazil: Professor of Forestry, Federal University of Para, Belem,

Luna, A.; Cooz, Iris Vazquez. 1991. Analisis de los datos estadisticos relacionados con el comportamiento del sector forestal venezolano en el periodo 1984–1988. Merida, Venezuela: Instituto Forestal Latinoamericano (IFLA). Revista Forestal Latinoamericana N. 6: 39–51.

Lyke, Julie; with Fletcher, Susan. 1992. Deforestation: an overview of global programs and agreements. Report for Congress. Congressional Research Service, The Library of Congress.

Mainieri, C.; Peres, J. 1989. Fichas de Caracteristicas das Madeiras Brasileiras. Sao Paulo, Brasil: Instituto de Pesquisas Tecnologicas.

Maskayu. 1992. Export of timber—November. Kuals Lumpar, Malaysia: MalaysianTimber Industry Board (MTIB). 12: 1–16.

Mordeno, Angelo G. 1990. Harvesting and transportation in Indonesia. In: UTF/INS/065/ INS Forestry Studies, Field document I–4/Directorate General of Forest Utilization, Ministry of Forestry, Government of Indonesia; 1990 October. Jakarta: Food and Agriculture Organization of the United Nations.

Munoz, Alfonso. 1993. Personal communication, November 23. Bolivar, Venezuela: Forestry Engineer, Universidad Experimental de Guayana. Upata, Edo.

Munoz, Alfonso. 1994. Personal communication, May 16. Bolivar, Venezuela: Forestry Engineer, Universidad Experimental de Guayana. Upata, Edo.

Ninin, L. 1986. Personal communication. Merida, Venezuela: Professor Emeritus of Wood Technology. Manual de aserrado y afilado. Universidad de Los Andes, Facultad de Ciencias Forestales.

Ninin, Luc. 1993. Personal communication, July 17. Merida, Venezuela: Professor Emeritus of Wood Technology, Laboratorio de Productos Forestales (LABONAC).

Rodriguez, A. 1993. El Manejo Forestal en Venezuela. Revista Del Servico Autonomo Forestal Venezolano (SEFORVEN). 8: 26–27.

Sagoe, John. 1992. Personal communication. Takoradi, Ghana: Timber Industry Analyst, Ghana Timber Export Development Board.

Sales, Christian. 1992. Personal communication, August 18. Paris, France: Directeur Scientifique, Centre Technique Du Bois et de L' Ameublement.

Schrewe, Horst. 1986. Sawmilling research and industry. In: Forest Industries Development Group, Asia Pacific Region. RAS/78/010 Working Paper 44; September. Kuala Lumpur, Malaysia: Forest Industries Expert, APFIDG: 1–18.

SEFORVEN. 1992. Mapa de Areas Bajo Regimen Especial. Ministerio del Ambiente y de los Recursos Naturales Renovables. Caracas, Venezuela: Servicio Autonomo Forestal Venezolano.

Setsuo, Iwakin. 1992. Developing a model of integrated wood processing complex for sustainable forestry in the Amazon region. Nagoya, Japan: United Nations Center for Regional Development, UNCRD/EPMU Working Paper Series 92–1, June. 55 p.

World Resources Institute. 1992. World resources 1992–1993: survey of 87 tropical countries, based on satellite images, government reports, and on-the-ground spot checks by FAO workers or consultants. New York: Oxford University Press. 119 p.

☆U.S. GOVERNMENT PRINTING OFFICE: 1994 - 546 - 037 / 00005