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Forest Products From Latin America

An Almanac of the State of the Knowledge and the State of the Art

Abstract

In 1985, the U.S. Congress mandated a program commonly called the Caribbean Initiative. To fulfill their portion of this Initiative, the USDA Forest Service developed a "Program for Tropical Forestry in Latin America and the Caribbean." This document is part of the Forest Service program, and it was funded by the legislation for the Caribbean Initiative.

This document is based on an extensive survey (nearly 3,000 documents) of the world literature pertaining to Latin American woods and their use. It contains a discussion of the resource, the literature, the state of the knowledge, and the state of the art in actual practice, by primary and secondary processing and by product areas within the processing options. A discussion about new initiatives and programs that are needed in research, technology transfer, and training is included. In addition, lists of references, the bibliography, and limited lists of the tree species are discussed in the literature.

Keywords: Tropical timber, Latin America, forest products, research, manufacture

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

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Forest Products From Latin America

An Almanac of the State of the Knowledge and the State of the Art

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Preface

Although we recognize that a considerable contribution to employment and income in Latin America is generated by nonwood products and services from the forests, these are beyond the scope of this almanac. Excluded are nonwood products such as rattan, leaf products, bamboo, cork, honey, fruits, mushrooms, nuts, and wildlife. Also excluded are services from the forests such as watershed protection, recreation, and tourism. This almanac is primarily concerned with the products made directly from the wood of trees. For example, the state of the knowledge and the state of the art in the manufacture of wood pulp for use in making paper are included, but not the state of the knowledge and the state of the art in the manufacture of paper.

The literature cited and the accompanying bibliography were largely derived from electronic searches of the world forestry and forest products literature from about 1968 to present. Additional searches of the literature were made manually for the earlier periods, and a complete literature search of all USDA Forest Service, Forest Products Laboratory, research on tropical woods and products was made. Requests for publications from all Latin American institutions involved in forest products research were also solicited. The literature reviews were augmented by visits to eight Latin American countries (Brazil, Chile, Costa Rica, Ecuador, Guatemala, Honduras, Mexico, Venezuela), with scientists in the forests products area, and with personnel in government and industry. Reviews of this document by key scientists in several of the Latin American countries have added greatly to the veracity of its content. More than just a report of the existing literature, this almanac is a synthesis of this information presented in a usable and valuable form.

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To make this document a working tool, we have endeavored to have all aspects to be as true to actual situations and needs as possible. The only valid way to accomplish this was to have it thoroughly reviewed by several people. We sent nearly 60 copies of the original draft to people who reviewed it and made comments. Without the substantial help of these reviewers, the document would be much less effective. Special recognition is given to Frances Devlieger, Universidad Austral de Chile, Valdivia, Chile, for extensive contribution to this document.

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Executive Summary

Prompted by a critical reduction in the tropical forests of the world and the global implications of such reductions, the U.S. Congress in 1985 mandated a program commonly called the Caribbean Initiative. Subsequently, the USDA Forest Service, to fulfill their portion of this Initiative, developed a "Program for Tropical Forestry in Latin America and the Caribbean." This document is part of that Forest Service progam, and it was funded by the legislation for the Caribbean Initiative.

The USDA Forest Service, Forest Products Laboratory, sees this program as an opportunity to effect changes in the utilization of the forests of Latin America that will help to slow the diminution of the resource. It may seem that using a resource is hardly the way to conserve it, but history has shown that wise use and placing a value on a renewable resource can result in its continuation. Such, we feel, is the case with the forests of Latin America.

Although this document has been prepared by the USDA Forest Service, the execution of our suggestions will only be possible with the cooperation of many nations and organizations. We hope that the suggestions will be fitted with the suggestions made by International Union of Forestry Research Organization (IUFRO) in their document "Improved Utilizations of Timber Resources in South America: A Programme for Action" and with other international plans to sustain the forests of Latin America.

This document is based on an extensive survey (nearly 3,000 documents) of the world literature pertaining to Latin American woods and their use. The literature has been reviewed and synthesized to provide recommendations in the areas of research, technology transfer, and training.

The following recommendations are in no way exhaustive, but rather suggestive of areas for potential work. Each individual country or region will develop its own needs. The following abbreviated recommendations for research, technology transfer, and training are deemed by the authors and reviewers to be of the greatest importance.

Research Recommendations

Anatomical and Physical Properties

1. Wood anatomists and technologists should keep in touch with government and private forest surveys or botanical expeditions to obtain samples of new or unevaluated species for testing.
2. For preferred species of a wide geographical range, anatomical and physical property data, on a regional basis, should be assembled for possible use in genetic control of properties in planting stock.

Mechanical Properties

1. A network of laboratories needs to be developed to evaluate species for mechanical properties using standard testing methods. The methods should be jointly established by the Latin American community to best serve the local needs for use of the timbers in question, as well as the broader world markets (see Part II, Veneer and Plywood Manufacture).
2. A coordinating group of representatives from forest products research laboratories throughout Latin America should initiate a program to formulate internationally recognized test and design standards aimed at more efficient use of native species.
3. Mentor laboratories need to be designated to coordinate research and train researchers (see Part IV, Training).
4. Those involved with evaluation of mechanical properties of native species should attempt to identify statistical distributions and interactions of various physical and mechanical properties.
5. An international effort should be made to develop a method for nondestructively evaluating and grading lumber for structural applications.

Chemical Properties

Laboratories throughout Latin America should continue determining conventional chemical properties of new woods and examine in more detail the chemical properties of known woods.

Pulping

Vigorous effort should be made to find organisms that will permit efficient biological pulping of the indigenous woods of Latin America. Based on the current degradation of the major waterways and oceanic waters of Latin America, it is suggested that the World Bank be approached for funding of this endeavor through their environmental concerns branch.

Sawing

1. An international team should study the problem of growth stress and find ways to circumvent or prevent them.
2. An international effort should be made to develop and test new saw blade materials and cutting methods for the sawing of high-density and siliceous woods.

Drying

1. Drying schedules should be developed for mixed species to provide adequate volumes for economical and quality kiln drying.
2. Research related to solar drying systems needs to be intensified, in particular the development of low-capacity driers for small enterprises.
3. Research should be conducted on all species for which there is no drying information and that have commercial possibility, to establish the drying potential by the three-step screening method.

Veneer and Plywood

1. Latin American standards should be developed for structural plywood using input from the standardized mechanical properties testing that was previously noted. A similar networking system should be used to accomplish the work.
2. Continuing research should be conducted on new species, as they become available, to determine peeling and slicing properties, drying features, and their ability to be glued.
3. Species mixes of lesser-known species with similar characteristics and properties should be tested for plywood manufacture.

Wood Preservation

1. A concerted effort should be made to evaluate the lesser known, small diameter, and high-density species for natural durability and use in preservative treatment applications.
2. Extractives from naturally durable woods should be evaluated for prevention of fungal and insect attack, synthesis, and fixation in nondurable woods to replace currently used toxic chemicals.

Reconstituted Board

1. Research should be conducted at numerous laboratories on the manufacture of structural composite boards from indigenous woods for each specific area. Research should be done on design and manufacturing technology.
2. Standards for Latin America need to be developed for structural composite board products, using the previously discussed networking system.

Engineered Uses of Wood

1. Researchers should exploit currently available nondestructive evaluation methods and develop new methods of stress rating structural wood products such as poles, lumber, and fabricated structual components.
2. Research should continue to develop safe, durable, low cost, wood housing for the homeless.
3. Researchers need to focus on improved design of wood connections. This includes chemical as well as mechanical connections and should involve the development of more accurate design models and innovative connection methods.

Technology Transfer Recommendations

General Needs

1. An effort by United Nations Development Program/Food and Agriculture Organization (UNDP/FAO) should be made to assist in the development of a charter forest products extension service in a selected country. This extension service should be an exemplary group that would serve as a training source for other countries in developing their own forest products extension services.
2. The assistance of the countries of the world that now have functioning and successful extension services should be obtained to help in the development of the exemplary extension service in the selected country mentioned in No. 1.

Pulping

The state of the art in the pulping industry in Latin America is at a very high level and the known technology transfer needs are just to keep up with new developments as they become available.

Sawmilling

1. A program needs to be developed to provide intercountry assistance to upgrade of sawmills throughout Latin America by means of a sawmill improvement team.
2. Regional sawdoctoring clinics should be established for the training of millwrights and sawfilers where national programs are not available.

Drying

Regional schools, industrial associations, individual industries, governmental agencies, and universities should develop and conduct kiln drying short courses, in a manner similar to the saw doctoring short courses.

Veneering and Plywood

Structural plywood technology should be transferred to the industry in Latin America. However, because of needs for markets prior to manufacture, this transfer would have to be coordinated with development of wooden housing and light construction.

Preservation

1. Wood preservation experts in Latin American countries need to conduct seminars on preservative treatment problems related to preservative chemicals, processes, and environmental concerns. These seminars should be held periodically in key locations.
2. The wood preservation industry and scientists working in the preservation discipline should conduct sessions for key governmental persons to transfer information on the benefits of treated wood and the hazards of uncontrolled use of dangerous and toxic chemicals.
3. Research institutions with experience in treating the diverse and little used species should conduct informational sessions for the wood preservation industry to advance the use of high density and little used species.
4. More preservative treatments and field testing should be conducted in all countries. This effort should be coordinated so as to reduce any unnecessary duplications.
5. The wood preservation industries in the individual countries need to develop product standards and appropriate identification of approved products. Further, it is recommended that the industry promote the standards concept to the public in the form of informational brochures and advertising.
6. In each country, wood treaters need to form Wood Preservers Associations to promote and control the industry, with participation of representatives from government, research institutions, and users.

Wood Engineering

1. A networking system of institutions and individuals involved in wood engineering and structural design should be formed to exchange ideas and technology in Latin America.
2. Demonstration wood structures should be built for exhibitions such as trade expositions, craft fairs, museums, and resort attractions. Such buildings should incorporate engineered components such as glulam, wood I beams, box beams, laminated veneer lumber and/or metal plate wood trusses designed and built using native species as a means of showing the versatility of wood.

Other Wood Technology

Regional seminars on basic wood technology should be established to inform those involved in wood products manufacture about the performance of wood and how to use it most efficiently and effectively in both domestic and export markets.

Training Recommendations

Wood Anatomy

Identification experts from Latin America, who do not have experience with computer-assisted identification, need to seek training in Germany, Japan, or the United States to develop expertise in the use of these systems.

Sawmilling

In each country, instructors need to be trained to conduct the necessary technology transfer sessions in sawing and saw maintenance.

Drying

In each country, instructors need to be trained to conduct drying short courses for kiln operators and mill managers.

Wood Preservation

Key individuals in the governments of Latin America need to receive training in the area of environmental effects of chemicals, especially those used in the wood preservation industry. And, that this training be received in one of the countries that at this time has an advanced level of expertise.

Engineered Wood Use

The wood research community should place special emphasis on publishing articles dealing with the positive aspects of wood structures in regard to fire, decay, and insect attack. Such articles should be aimed at the general public as well as government and business officials in charge of lending and insurance policies.

Introduction

The tropical forests of the world and their disappearance are growing concerns throughout the world for many reasons. In 1985, the U.S. Congress, in its concern for the tropical forests of the Americas, mandated and funded research in a program commonly called "The Caribbean Initiative." As a result, the Forest Service initiated a "Program for Tropical Forestry in Latin America and the Caribbean" that included Forest Service participation by the Southern Region (R-8), the Southern Forest Experiment Station (SO), the Southeastern Forest Experiment Station (SE), the Forest Products Laboratory (FPL), and the International Forestry (IF) staff.

For their part in this program, the FPL established a team to accomplish the following goals.

1. To develop a broad base almanac on the situation in forest products research and development in Latin America
2. To develop key contacts in South and Central America for cooperative research, training, and transfer of forest products technology
3. To start development of a Latin American-U.S. networking system in forest products research, in cooperation with the International Union of Forestry Research Organization (IUFRO) (Freitas and others 1986), U.S. Agency for International Development (USAID), the USDA Forest Service, U.S. Department of Agriculture, and selected universities
4. To develop a program of continuing research and the appropriate funding to support the program.

Within these goals, we believe, is an opportunity to effect changes in the utilization of the tropical forests of Latin America that will help to slow the diminution of the resource. It may seem that using a resource is hardly the way to conserve it, but history has shown that wise use and value applied to a renewable resource can result in its continuation. Such is the case with the forests of Latin America.

A large portion of the destruction of the forests is due to factors such as settlement and land alteration to agricultural use, (Lanly and Clement 1979; Gradwohl and Greenberg 1988). In many cases, the timber resource is simply burned to clear the land. In other cases, selected species are taken out and the remainder is burned. By utilizing the forest as fully as possible, even if the land is to be cleared, other forest areas may be spared from cutting. For some products and processes, the best method of use may be to clear the land of the diversified native forest and then establish plantations of trees most suited to the desired product. This approach also reduces the need to use other areas of native forest, thus preserving them or at least conserving them.

To many landholders, the forest is an obstacle of little or no value that should be removed and replaced with something of value. If the value of the forest and its renewability can be demonstrated, the forest will be looked on as a resource to be maintained and used and not to be regarded as an obstacle.

Although foresters, wood technologists, and other scientists can find technological ways to use wood better and more efficiently, other obstacles still stand in the way. These obstacles include governmental, societal, and traditional barriers. This document will not attempt to solve these problems of better wood use and prevention of forest depletion, but they cannot be disregarded as major barriers in the arena of wise use.

Governmental barriers are often viewed as major obstacles to the promotion of wood in use. Examples include government banks refusing to loan money for houses constructed of wood, insurance restrictions, and bureaucratic delays in planting forests for a sustained resource and in shipping commodities of wood. All of these deter the development of a viable wood industry and consideration of the forest as a valuable resource.

Societal barriers are perhaps the easiest to deal with. These are the shifting barriers developed in commodity products from time to time-the shift from wood furniture to metal, for example. These are barriers that must be handled by industry in marketing endeavors.

Traditional barriers (entrenched ideas of people about the use of wood) are probably the most difficult to overcome. A more complete discussion of these barriers appears later in the text.

In the world literature, there are myriad research documents on the forests and forest products of Latin

America. Yet, needs are obvious in the forest products industry of the region. These questions then arise, Are the needs just for technology transfer, or are there still research needs that should be filled? The way to answer to these questions is to carefully examine the literature, visit key technical people in the countries involved, and observe the state of the art in utilization of the forest resource. This document is the result of such a program of investigation. It is aimed at seeking answers to these questions.

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Part I

Raw Materials

Forest Resources

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Natural Forests

About 97 percent of all the natural forests from northern Mexico to southern Argentina is mixed tropical hardwood (Fig. 1). Most of these forests lie between the tropics of Cancer and Capricorn. These forests range from sea level at the Pacific and Atlantic oceans to around 1,240 m (4,000 ft) elevation in the mountains. At least 2,500 species of trees grow in these forests (Britannica 1974). Some of the species are well known for use in furniture manufacture, paneling, musical instruments, knife handles, and other specialty products. Others are known by local Indians but unknown to industry, and some are totally unknown.

The mix of species of commercial importance varies by site. Swamp and marsh sites carry such commercial species as Virola *(Dialyanthera spp.);* Jacareuba *(Calophyllum brasiliense);* Alerce *(Fitzroya cupressoides);* Ipe or Lapacho *(Tabebuia spp.);* Sajo or orey *(Camp*nosperma *panarnensis)* (Chudnoff 1984).

Areas that are periodically flooded are characterized with additions of other species, such as Degame *(Calycophyllum candidissimum);* Crabwood *(Carapa guianensis);* Baromalli *(Catostemma spp.);* Honduras rosewood *(Dalbergia stevensonii);* Jarana *(Holopyxidium jarana);* and Mora *(Mora excelsa).*

The well-drained and high forests of the tropics carry such species as Araracanga *(Aspidosperma spp.);* Goncalo Alves *(Astronium graveolens);* Haiari *(Alexa imperatricis);* and Imbuia *(Phoebe porosa),* which grow to elevations of about 1,240 m. Most of the woods of the high forest species are of moderate to high density, ranging from about 40 to 60 lb/ft^3 (640 to 960 kg/m^3). The variety of species from the well-drained, high forests are well known for uses ranging from manufacture of furniture to uses for ship construction and durable structural timbers.

Approximately half of Latin America's tropical hardwood forests lie in the Amazonian basin. From above, these natural forests appear remarkably uniform, although typically there are 100 or more tree species per hectare, with the mix of species varying from one region to another (Fig. 2).

The forest canopy is formed from tall, often shallow rooted, and extensively buttressed trees. From beneath the forest canopy, the jungle of plant life tends to obscure the variety of species (Britannica 1974) (Fig. 3).

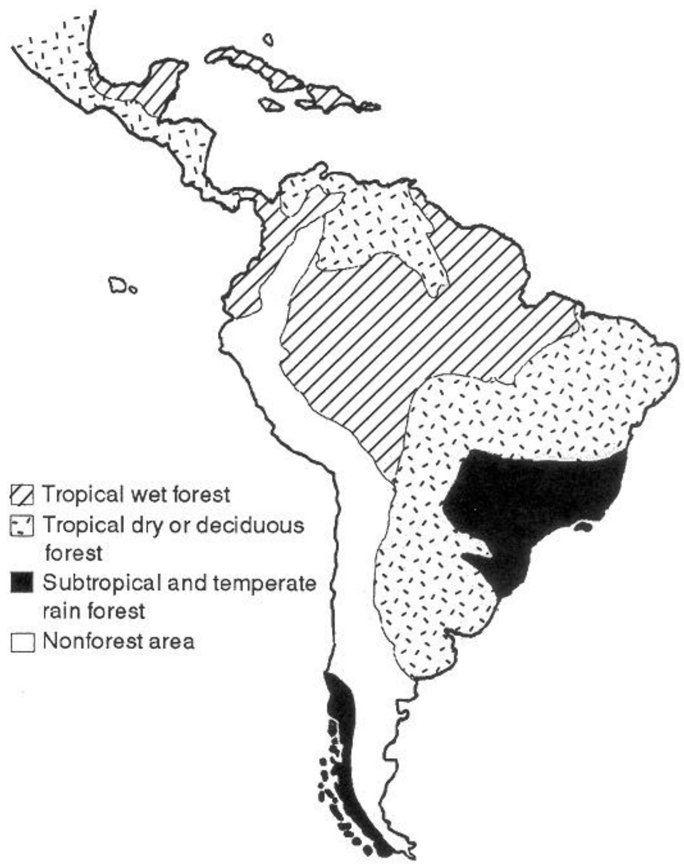

Figure 1-Latin American forest areas. (ML90 5464)

Wood densities range from 8 to 80 lb/ft^3 (128 to 1,280 kg/m^3), namely balsa and lignumvitae (Chudnoff 1984). Characteristics of wood color, chemistry, and mechanical properties vary dramatically. Efforts to describe Latin America's natural forest are often as varied as the forest, depending on the interest for reporting.

Tropical deciduous forests exist where the climate is characterized by prolonged dry seasons, as in areas of Venezuela, Colombia, and the Brazilian Plateau. These forests are covered with widely dispersed trees

Figure 2-Typical tropical moist forest. (M90 0174)

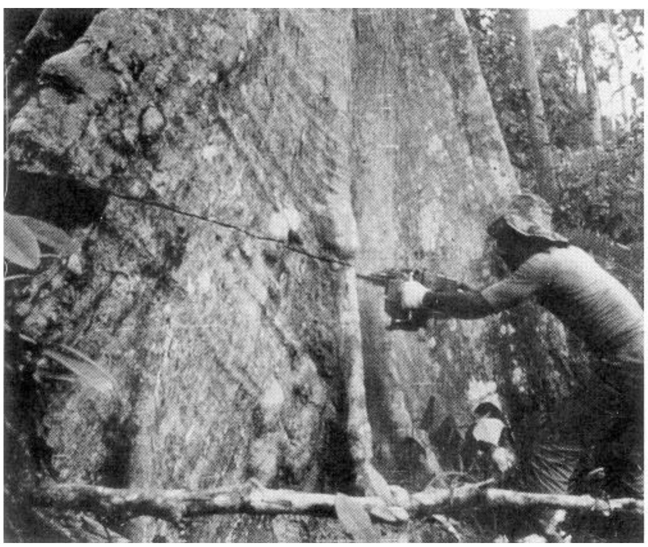

Figure 3-Buttressed tropical tree. (M90 0150)

of moderate height. Most notable, although not deciduous, are the Parana pine forests *(Araucaria angustifolia)* that cover vast areas between the Rio Parana and the Atlantic Ocean, stretching from Curitiba, Brazil, to northern Argentina. These trees dominate dense forests containing many species, including hardwoods (e.g., amburana *(Amburana cearensis);* curupay *(Anadenanthera macrocarpa);* Brazil-nut tree *(Bertholletia excelsa);* pochote *(Bombacopsis quinata);* verawood *(Bulnesia arborea);* Spanish cedar or cedro *(Cedrela spp.);* and lignumvitae *(Guaiacum spp.)* (Chudnoff 1984). Lignumvitae is perhaps the

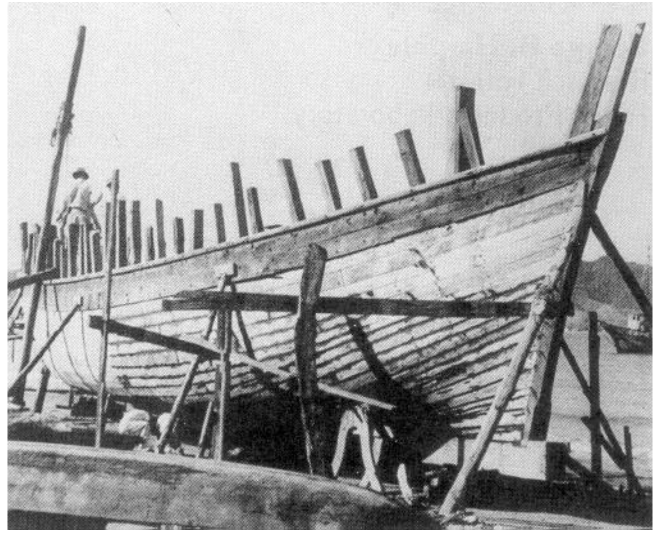

Figure 4-Shipbuilding in 1940s Eucuador using tropical woods. (M90 0126)

most dense of the tropical hardwoods 80 lb/ft^3 (1,280 kg/m^3) and is often used for propeller shaft bearings of ships because of self-lubrication and hardness.

Commercial use of Latin America's tropical forests date from the early 1500s when Spain first established seaports in the Caribbean. Timber was sought for ship repair, general construction, and fuel. With their great variety, Latin America's tropical forests provided ideal inventories for 16th century ship repair and construction (Teesdale 1945a,b) (Fig. 4). Among the hardwood species, some were naturally resistant to marine borers and rot, and some with bent stem forms were ideal for use as ship keels or ribs. Other trees were straight and suitably tough to make deck planking and other "whip-sawn" lumber products. The Spanish introduced the ax, adze, and saw for production of these products. In many areas of Latin America, the craft and tools of the 16th century Spanish shipwright are still in evidence.

As wooden merchant ships gave way to steel cargo ships, Latin America's natural forest became less important as a materials resource for ship construction. In the early 1900s, little was known about the variety of Latin America's forest resources (Gerry 1918). However, with investigations, the mahoganies of Latin America were found to be a preferred material for construction of airplane propellers (Horn 1918; Maudlin 1917), and demands increased for the varieties of appearance grades of hardwoods found to be available from Latin America's tropical forests. These woods complemented hardwood furniture and millwork manufactured in the United States (Colgan 1919; Heck 1920; Koehler 1927).

During 1929, Dr. L.J. Markwardt of the Forest Products Laboratory wrote as follows:

> The American countries south of the United States have an aggregate area of 8,500,000 square miles

and a population of 95,000,000. They take one-sixth of our total exports, representing a value of nearly US$800,000,000 in 1921; and almost one-third of our exports of manufactured products, valued at nearly US$600,000,000 in 1921. Having, for the most part, a large surplus of territory for their existing population, and manufacturing industries insufficient to supply their own requirements, they must furnish us in exchange chiefly raw materials-food, fibers, hides and skins, minerals, fertilizers, rubber and gums, dyeing and tanning materials, and timber. (Markwardt 1929)

During the 1940s and 1950s, Latin America's natural forests became increasingly important as a source of supply for the increasing demands of the United States for specialty products (Koehler 1947). With increased demand, efforts were made to better describe the tropical forests of Latin America (Bell 1952; Gerry and Flick 1951). Also, abundant but previously ignored species were evaluated for suitable uses in U.S. manufacturing (Davis 1949; Dohr 1953; Dohr and Drow 1948; Pillow 1951).

During the 1960s and 19708, selective exploitation of Latin America's forests increased with world demands for specialty products from the kaleidoscope of species found in the natural tropical forests. At the same time, demands were increasing for paper, structural lumber, and wood panel products. In response to the wasteful practices of selective harvesting, "any-tree harvest" and improved utilization practices began to emerge (Chudnoff 1976; Youngs and Laundrie 1979).

Today, removals from Latin America's natural forests for commercial use are estimated to represent only 0.4 percent of the total growing stock. However, with growing populations, more than 80 percent of these removals are estimated to be for local fuelwood, and less than 20 percent for industrial use. The industrial harvests from natural forests are still primarily for production of high-valued lumber and veneer products (McGaughey and Gregersen 1983). Some volumes of removals from natural forests are for pulp production, but primarily they are an economic way to establish plantation forests to supply pulpwood and to supply sawlogs for production of commodity lumber (Table 1).

Table l-Forests of Latin America 1980[a]

Subregion	Forest area (ha)	Percentage of land	Area (× 10^3 ha) Annual deforestation	Forest plantations	Annual planting
Mexico	46,250	23.5	530	159.0	7.8
Central America	18,679	36.7	382	25.4	3.9
Caribbean	44,511	78.9	21	48.8	8.1
Brazil	357,480	42.0	1,360	3,855.0	158.0
Andean	206,210	46.2	1,535	372.4	26.8
Southern cone	46,605	11.3	155	1,453.0	93.2
Total	719,735	35.7	3,983	5,913.6	297.8

[a]McGaughey and Gregerson 1983;
Source: FAO, Jaakko Poyry estimates.

Secondary Forests

Many areas of Latin America's natural forests have been permanently lost to creation of sugarcane plantations, grazing pastures, hydroelectric water reservoirs, roadways, and other permanent uses. However, areas cleared by logging, fire, or for agricultural purposes, if left alone, will begin a natural biotic succession. Once started, initial weed and shrub domination yields to tree species and establishment of a secondary forest.

Secondary forests typically consist of trees that are quick growing and light-demanding, as opposed to the slower growing and shade-tolerant species of the climax forest. On reaching maturity, unmanaged secondary forests tend to shade out their regeneration, thus facilitating succession to shade-tolerant species representative of the climax tropical forest.

Secondary forests include trees such as balsa *(Ochroma spp.)* (Fig. 5); Copaia *(Jacaranda copaia);* Sangre *(Pterocarpus spp.);* Long John or Mierenhout *(Triplaris spp.);* Yemeri or Quaruba *(Vochysia spp.);* and many other commercially desirable species suitable for carpentry lumber, furniture, plywood, and some specialty uses such as are known for balsa (Chudnoff 1984). These successional species are often favored for sustained yield forest management programs (Eisenhauer 1975; Prevosto 1976).

Plantations

Latin America's forest industries are becoming increasingly dependent upon plantation forests (Fig. 6). Approximately 38 percent of total harvests currently come from plantation forests. New plantations are being created and as those already established become more mature, plantation harvest is expected to increase almost tenfold by the year 2030 (Table 2). Aesthetic, recreational, and wildlife benefits are not intended outputs of plantation forests, but their creation allows opportunities for protection of such nonwood benefits provided by natural forests (Caldevilla 1978; Grayson 1978; Spears 1984).

Plantation forests are created to provide roundwood supplies that are more economical to harvest and process than supplies from natural and secondary forests. The plantation forests of Latin America represent advanced silvicultural and utilization concepts (Booth 1974; Burley 1985; Chirinos 1970; Couto and Nautiyal 1984; Slooten 1977; Wormald 1975). Except for the naturally occuring *Pinus caribaea*, *P. oocarpa*, and *P. patula*, most of the short-rotation species are exotics

Figure 5-One-year old balsa plantation in Ecuador. (M90 0153)

Figure 6-Fifteen-year-old pine at Jaari. Brazil. (M90 0129)

to Latin America's forest. Among the exotics, varieties of *Eucalyptus* species and *Pinus radiata*, *P. elliottii*, and *P. taeda* are grown for production of both pulpwood and sawtimber (Asenjo 1975; Booth, 1975; Guerra 1973; Zeeuw and others 1980). Eucalypts are often grown specifically for production of charcoal (Booth 1974; Guerra 1973).

The single largest plantation forest in Latin America is an agro-forestry venture, known as the Jari project, located in northern Brazil. In 1967, this 1.6×10^6 ha agro-forestry plantation was initiated on the banks of the Rio Jari tributary of the Amazon. The plantation is primarily intended to produce wood fiber for pulp production. A number of fast growing exotic tree species were planted, including *Gmelina arborea*, *Eucalyptus deglupta*, *E. urophylla*, and *Anthocephalus chinensis.* About 100 native species are also utilized, such as *Jacaranda copaia*. The plantation includes approximately 3,500 ha of continuously cropped rice land and several thousand head of cattle and water buffalo (Strohl 1983).

Components for the pulp mill were constructed in Japan and brought on barges to the Jari site (Haage 1983; Hornick and others 1984). Now, more than 10 years later, the Jari project appears to have overcome many startup problems and may become a viable venture. Ludwig sold the operation to a consortium of Brazilians, who now manage the operation.

Extensive plantations of eucalyptus are to be found in other parts of Latin America, too. For example, in Argentina there are 210,000 ha of *Eucalyptus grandis*, *E. viminalis*, *E. globulus*, and *E. camaldulensis*, which in 1984 produced 1.5×10^6 m^3 of roundwood. In Chile, 59,400 ha have been planted to several species of eucalyptus (INFOR-CORFO 1987).

About 160 km east of the Jari project, another plantation was started in 1971 by the AMCEL Corporation. In 1986, AMCEL had approximately 50,000 ha planted with plans to have 80,000 ha planted by 1988. Species planted are about 85 percent *Pinus caribaea* var. *hondurensis*, plus a mixture of *P.* oocarpa and *P. caribaea var. caribaea.* According to McDonald and Fernandes (1984), this is the world's largest pine plantation. However, in 1988, the Corporation Venezolana de Guayana had about 250,000 ha of *Pinus caribaea var. hondurensis* planted in the state of Monagas, and they ultimately expect to increase their plantings to 500,000 ha (Fig. 7). Some of these plantations are now being harvested.

In Chile, radiata pine has been planted at the rate of 60,000 ha per year for 8 to 10 years (Chilean Forestry News 1988). Several private companies each own more than 100,000 ha of pine plantations; specifically, Compania Manufacturera de Papeles y Cartones S.A. owns about 250,000 ha, and Forestal Arauco Ltda., a subsidiary of Celulosa Arauco y Constitution S.A., owns about 300,000 ha of pine (Han-R. 1988).

Chile and Brazil are most noticeable for their export marketing of lumber and pulp products from plantation forests. In 1977, the Forestal Arauco reported the first export of plantation grown radiata pine logs from Chile, 19,000 m^3 of logs were shipped

Table 2–Roundwood production potentials of Latin American forests[a]

	Production[b] (× 10^6 m^3/year)			
	1985	1990	2000	2030
Mexico				
Natural forest				
Logs	5.65	6.60	8.95	33.50
Cordwood	3.60	9.90	7.00	24.50
Subtotal	9.25	11.50	15.95	58.00
Plantations				
Logs	0.05	0.10	0.35	15.00
Cordwood	0.35	0.60	1.20	10.00
Subtotal	0.40	0.70	1.55	25.00
Total	9.65	12.20	17.50	83.00
Central America				
Natural forest				
Logs	4.50	5.10	6.50	11.00
Cordwood	0.70	2.20	3.00	9.00
Subtotal	6.20	7.30	9.50	20.00
Plantations				
Logs	–	0.10	0.15	14.00
Cordwood	0.20	0.45	0.80	12.50
Subtotal	0.20	0.55	1.00	26.50
Total	6.40	7.85	10.50	46.50
Caribbean				
Natural forest				
Logs	0.90	1.05	1.80	12.60
Cordwood	0.50	0.60	0.80	6.60
Subtotal	1.40	1.56	2.60	19.20
Plantations				
Logs	0.10	0.15	0.40	6.00
Cordwood	0.15	0.25	0.50	8.60
Subtotal	0.25	0.40	0.90	14.60
Total	1.65	2.05	3.50	33.80
Brazil				
Natural forest				
Logs	22.50	22.50	27.50	157.50
Cordwood	10.00	11.50	13.50	76.00
Subtotal	32.50	34.00	41.00	233.50
Plantations				
Logs	5.00	10.00	18.00	100.00
Cordwood	16.00	18.00	30.00	80.00
Subtotal	21.00	28.00	48.00	180.00
Total	53.50	62.00	89.00	413.50

	Production[b] (× 10^6 m^3/year)			
	1985	1990	2000	2030
Andean				
Natural forest				
Logs	6.40	7.45	8.65	25.00
Cordwood	3.00	3.00	4.00	12.05
Subtotal	9.40	10.45	12.65	37.05
Plantations				
Logs	0.90	1.40	2.50	24.00
Cordwood	1.60	4.00	8.00	29.00
Subtotal	2.50	5.40	10.50	53.00
Total	11.90	15.85	23.15	90.05
Southern cone				
Natural forest				
Logs	2.40	2.20	1.60	2.50
Cordwood	0.55	0.60	0.60	2.00
Subtotal	2.95	2.80	2.20	4.50
Plantations				
Logs	5.40	7.00	11.85	21.00
Cordwood	6.34	8.85	12.70	21.50
Subtotal	11.75	15.85	24.55	42.50
Total	14.70	18.65	26.75	47.00
Latin America				
Natural forest				
Logs	42.35	44.90	55.00	242.10
Cordwood	19.35	22.80	28.90	130.50
Subtotal	61.70	67.70	83.90	372.25
Plantations				
Logs	11.45	18.75	33.30	180.00
Cordwood	14.65	32.15	53.20	161.60
Subtotal	36.10	50.90	86.50	341.60
Total	97.80	118.60	170.40	713.85

[a] McGaughey and Gregersen, 1983;
Source: FAO, Jaakko Poyry estimates.
[b] Excludes nonindustrial fuelwood production.

to Japan. In 1978, Chile Forestal reported shipments of radiata pine logs to Korea and southern Japan and lumber to the Arab countries. Lumber shipments first began in the 1960s, going to Argentina. Shipments of Chilean radiata pine lumber to the United States (including Puerto Rico) have recently increased rapidly. In 1983, U.S. imports from Chile amounted to 2.2 × 10^6 board feet; in 1984, 11.3 × 10^6 board feet, and in 1985, 40.9 × 10^6 board feet (Random Lengths 1986). Random Lengths reports, "Chilean wood is likely to become more competitive in world markets in the next 15 years. By the year 2000, the country's radiata pine log harvest will increase more than fivefold, and projected annual lumber production will be more than seven

Figure 7-Pine nursery in state of Monagas, Venequela. (M90 0105)

times current levels.” On a more modest scale, some *Pinus caribaea* and *Eucalyptus spp.* are being grown in Mexico for paper and particleboard furnish (Zavala-Z. 1988). According to current projections, plantation forests will provide about 50 percent of total timber harvest from Latin America’s forests by the year 2030 (Table 2).

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Wood Resources

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A full understanding of the Latin American timber resource requires knowledge of the anatomies of woods, as well as the physical, mechanical, and chemical properties. The development of information in these areas, through research and use of the information in industry, is most important in an enlightened system of wood utilization. The following sections discuss the research that has been done and its use in the wood industry of Latin America.

Anatomy

The discussion of wood anatomy includes the characterization of wood through macroscopic, microscopic, and other means, and the classifying or identifying of the wood using this characterization. The earliest anatomical evaluation of tropical Latin American woods was probably done on mahogany by Nehemia Grew in England, although Antoni Van Leeuwenhoek did some early work on tropical woods that may have included some from Latin America (Baas 1982). Latham (1957) notes that the first mention of "mothongoney" in the English literature was in 1671 in the book America by John Ogilby. Grew was a contemporary of Ogilby and was most likely interested enough in this beautiful wood from the new world to examine it microscopically (Fig. 8).

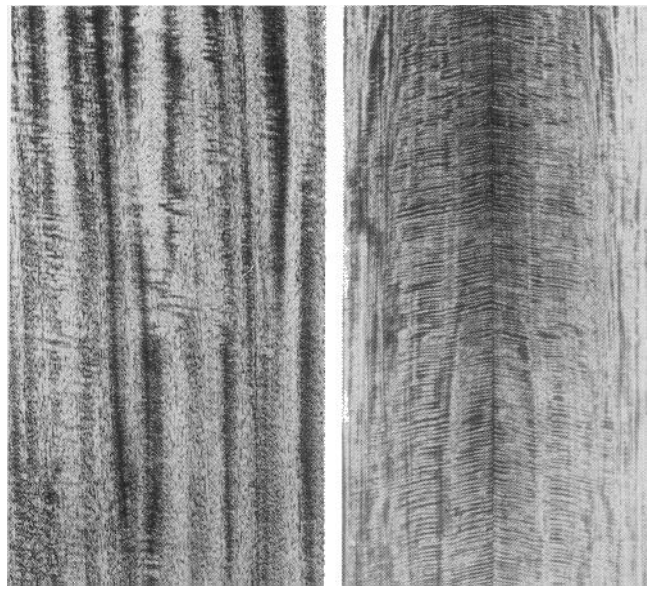


Figure 8-Ribbon grain (left) and fiddle back grain (right) patterns in mahogany. Photo courtesy of Taunton Press, Newton, CT, from Understanding Wood by R. Bruce Hoadley. (M90 0151, M90 0103)

Most of the early anatomy work for woods of Latin America was done in Europe and England. Solereder's (1908) classic work includes much information on tropical American woods gathered by his European contemporaries. Most of the wood analyzed came from early botanical expeditions in the 18th and 19th centuries. Williams (1936) lists names such as Ruiz, Pavon, Mathews, Spruce, Jussieu, Poeppig, Ule, Tessmann, and Weberbauer as botanical collectors of the 19th century. In the early 20th century, the collections were continued by people such as Bryan, Featherstone, Killip, Macbride, Mexia, Record, Smith, and Williams.

Naturalists were among the very first voyagers to the Americas and in the ensuing years were on far too many botanical expeditions to enumerate. Many of these people either performed anatomical analyses on the wood specimens they collected, or they provided specimens to other European scientists for evaluation.

Anatomical and related properties studies conducted within Latin America do not generally show up in the literature until the 20th century. Mainieri (1958a) cites a paper entitled "Configuration and description of the fundamental organs in the heartwood and sapwood of the principal woods of the Province of Rio de Janeiro (Configuracao e descricao do organos fundamentais das principais madeiras de cerne e brancas da Provincia do Rio de Janeiro)" by Jose de Saldanha de Gama Filho in 1864. The earliest dates that we found in our literature search were from the 1920s and 1930s (Blanco 1938; Howard 1934; Martinez 1928; Milanez 1936; O'Donell 1937; Pereira 1933; Roig 1935; Torricelli-D. 1937). However, Horn (1918) notes that data did exist, at the writing of his paper, in two documents from Brazil and one from Argentina. The documents are "Manuel de resistencia dos materaes," published by Escola Politecnica de Sao Paulo, and "Apontamantos sobre as madeiras do Estado de Sao Paulo" by Huascar Pereira. Horn did not cite the Argentinian document by title in his bibliography.

It should be mentioned that the literature listed is not in any sense exhaustive. Many documents in laboratories and universities in Latin America were not available to the authors for listing and do not appear in world literature sources.

The standard works on the anatomy of the woods of the world, including those of Latin America, are Metcalfe and Chalk (1950), Record and Hess (1943), and Solereder (1908). Numerous other documents exist for individual species, genera, families, countries, and regions; for example,

ARGENTINA-LEGUMINOSAE (Cozzo 1950)

BRAZIL (Detienne and Jacquet 1983; IBDF 1981a,b; Loureiro 1976; Loureiro and Silva 1968; Mainieri 1958a; Paula 1979; Pereira 1933)

BRAZIL-VIOLACEAE (Araujo and Mattos 1978)

CHILE (Diaz-Vaz 1979, 1983, 1984, 1986a,b; Diaz-Vaz and others 1986; Tainter 1968);

COLOMBIA (Abascal-Y. and Juyo-B. 1969; Casas-J. 1966)

COSTA RICA (Creemers and Lemckert 1981; Slooten 1968; Sotela and others, 1985)

CUBA (Babos and Borhidi 1978)

GUADALOUPE (CTFT 1985)

GUYANA (CTFT 1982; Detienne and others 1982)

LATIN AMERICA (Llach-C. 1969; Richter 1968)

MEXICO (Barajas-M. 1980; Barajas-M. and Echenique 1976; De la Paz-Perez 1974 De la Paz-Perez and others 1980)

MEXICO-PINES (Blanco 1938; De la Paz-Perez and Olvera-C. 1981) PERU (Williams 1936)

URUGUAY (Tuset and Duran 1970)

VENEZUELA (Mora, 1974; Perez–M. 1981; Pfeiffer 1926, 1927)

VENEZUELA-VERBENACEAE, (Acosta–Obando 1987)

SOUTH AMERICA-LEGUMINOSAE–ZIGOPHYLACEAE (Dechamps 1979, 1980, 1985)

MAHOGANY (Record 1941)

SAPOTACEAE, URBANELLA (Kukachka 1982)

An excellent bibliography of literature on wood anatomy and identification has been asgmbled by M. Gregory (1980) for the International Association of Wood Anatomists covering the period 1906-1978. The bibliographies of the referenced papers also add greatly to the information sources.

The documentation on anatomies of woods of Latin America is extensive and includes hundreds of species (FPL, in preparation). Not all species have been examined anatomically, but a tremendous background of information is available on the major species that would be encountered in normal utilization practices. The study of new species should be continued. However, serious consideration should be given before conducting work on species already studied. As an aid to the description of new species or the setting up of a wood collection, see references in Spanish by Acosta–Solis (1951, 1952a,b). A partial species list is found in the Appendix of this document.

A substantial number of institutions in Latin America are involved in the study of wood anatomy and wood identification. Such institutions may be found in Argentina, Brazil, Chile, Colombia, Costa Rica, Ecuador, Honduras, Mexico, Panama, Peru, Suriname, Uruguay, and Venezuela (Hilmi 1986; Stern 1978). For example, in Mexico, the following institutions are doing wood identification and anatomy research:

Centro National de Investigation Discipinaria sobre Ciencia y Tecnologia de la Madera (INIFAP-CENID-CITECMA), Puebla

Centro de Investigation Forestal y Agropecuaria (INIFAP-CIFAP), Uruapan, Michoacan

Universidad Autonoma Chapingo, Chapingo, Mexico

Ciencia y Tecnologia de la Madera, INIREB, Jalapa, Veracruz

Universidad Autonoma Metropolitana, Iztapalapa, Mexico, D.F, Mexico

Universidad National Autonoma de Mexico, Copilco, Mexico, D.F, Mexico

Instituto de Madera, Celulosa y Papel de la Universidad de Guadalajara, Guadalajara, Jalisco

Universidad Michoacana de San Nicolas de Hidalgo, Morelia, Michoacan

Laboratorios Nacionales de Fomento Industrial, Mexico, D.F, Mexico

During 1986, the FPL team visited three laboratories in Brazil; Instituto Pesquisas Tecnologicas (IPT) in Sao Paulo, Instituto Brasiliero de Desenvolvimento Florestal (IBDF) in Brasilia, and Centro de Pesquisas em Produtos Florestais (CPPF) in Manaus. These laboratories are well equipped and have well-trained staffs working in wood anatomy. All the facilities have substantial wood collections and good reputations for their research. In Ecuador, the team visited Centro Forestal de Conocoto in Conocoto. This facility has good equipment and personnel, producing good research. In Central America, the team visited numerous laboratories. In Costa Rica, the Instituto Tecnologico de Costa Rica, Cartago, has good facilities and personnel for anatomical studies of wood, and the Universidad de Costa Rica, Laboratorio de Productos Forestales, San Jose, has older facilities, but the personnel and their research are good. In Honduras, the FPL team visited the Escuela National de Ciencias Forestales (ESNACIFOR), Siguatepeque. This is a new facility that is well equipped with a new and well-trained staff. In Mexico, we visited the Universidad National Autonoma de Mexico at Chapingo. This facility was well equipped and staffed for anatomical research.

During 1987, the author visited the Universidad de1 Biobio and the Universidad Austral de Chile in Chile and found that they are both well equipped to do

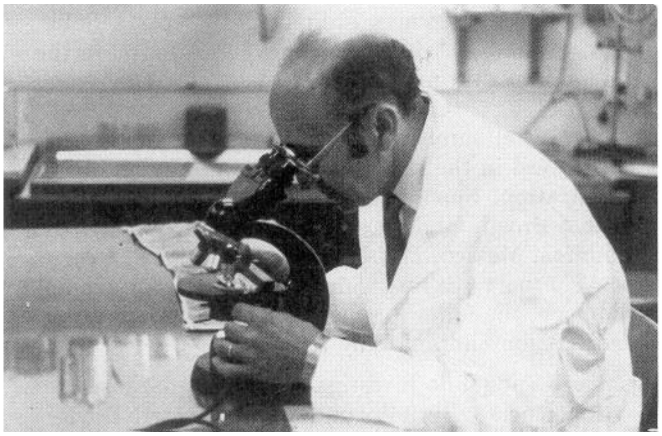


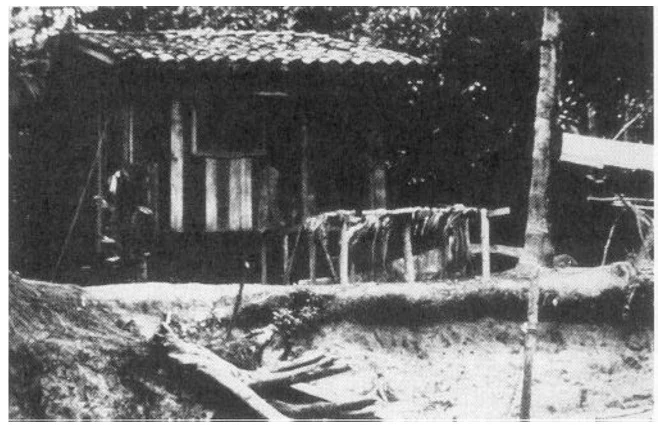
Figure 9-Professor Alirio Perez Mogollon identifying wood at Universidad de Los Andes, Merida, Venezuela. (M90 0127)

anatomical and identification work. In 1988, a team from the FPL visited the wood identification laboratory at the Universidad de los Andes at Merida, Venezuela. The laboratory is well equipped and staffed. The wood collection was especially well managed. The research produced from Merida is well respected (Fig. 9).

Mechanical and Physical Properties

While the anatomy of wood helps to classify and identify species and helps to define the usefulness of wood, the mechanical and physical properties will provide more direct evidence of how the wood may be used. In aboriginal communities, the people have traditional (qualitative) knowledge in the use of wood. In a more scientific community, we can provide quantitative information such as density, shrinkage, strength values, and other measures of wood properties to evaluate its usefulness (Fig. 10).

In the earliest documents on the use of wood, the qualitative-traditional type of information was given. For the last century or so, most technical reports have been based on quantitative data. The study of wood anatomy has often been accompanied with the study of mechanical and physical properties (Pereira and others 1970). The earliest reports on the physical-mechanical properties of Latin American woods done in Latin America are those noted by Horn (1918). Horn states that a series of preliminary tests were conducted by Escola Polytecnica de Sao Paulo in Brazil and reported in a publication “Manuel de resistencia dos materiaes.” Another study was conducted by Huascar Pereira, for the Department of Public Works of the state of Sao Paulo, entitled “Apontamantos sobre as madeiras do Estado de Sao Paulo.”



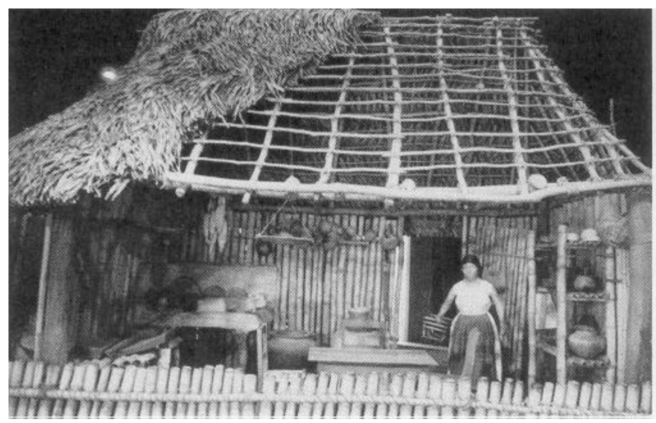


Figure 10-Use of wood in a modern application for housing and tradidional for transportation, Amazon River, Brazil (top). Traditional use of wood in housing and transportation, Amazon River, Brazil (middle). Diorama in Mexico City, Mexico, depicting traditional use of wood in housing (bottom). (M90 0152. M90 0104. M90 0128)

The group of research documents that discuss physical and mechanical properties are those that list the drying, machining, treating, and finishing properties of the wood in qualitative terms, although they are based on quantitative data (Arostegui-V. 1975a,b, 1976; Caceres-R. 1965; CORMA 1960; Echenique-Manrique and Diaz 1969; Gonzalez and others 1973; IBDF 1983; Julio-Leonardis 1975; Lincoln 1986). An internationally recognized document of this type is that of Record and Hess (1943). Other similar documents include Begemann 1968; Brown 1978, 1979; Chudnoff 1984; Lincoln, 1986; Rendel 1969).

Documents that give quantitative data on Latin American woods are, for example,

ANDEAN PACT COUNTRIES (Keenan and Tejada 1984)

ARGENTINA (Agueda-Castro 1985; Koehler 1928; Tortorelli, 1956)

BRAZIL (Almeida and Costa 1956; Horn 1918; IBDF 1981a,b, 1983; Mainieri 1958; 1978; Slooten and others 1971a)

BOLIVIA (Grupo Andino 1981)

CARIBBEAN (Longwood 1962)

CHILE (Karsulovic-C. and Navarrete-M. 1977; Perez-Galaz 1985)

COLOMBIA (Barghoorn and others 1967; Bublitz 1952; Robledo and Robledo, 1934)

COSTA RICA (Gonzalez and Gonzalez 1973; IICA 1968)

DOMINICAN REPUBLIC (Basilis 1978)

ECUADOR (Acosta-Solis 1960; CCIF 1981)

FRENCH GUYANA (Bena 1951; Benoist, R. 1933; CTFT 1983, 1984)

GUATEMALA (Beltranena-M. 1966, 1967, 1968; Kukachka and others, 1968)

MEXICO (Becerra-M. 1977; Cevallos-F. and Carmona-V. 1981; Crespo, Huerta 1963; Echenique-Manrique 1970; Echenique-Manrique and others 1975)

NICARAGUA (Brazier and Franklin 1967; Gonzalez and others 1973)

PANAMA (Braddy 1919; Slooten and others 1971b)

PARAGUAY (Migone and Preston 1955)

PERU (Arostegui-V. 1982; Arostegui-V. and Sobral 1986; Arostegui-V. and Valderrama 1986)

PUERTO RICO (Longwood 1961)

SOUTH AMERICA (FAO 1976)

SURINAM (Japing 1957; Surinam For. Serv. 1955; Vink 1965)

URUGUAY (Link 1954; Tuset 1958)

VENEZUELA (Arroyo-P. 1971; Corotbe 1960; Enrique 1969; LNPF, 1974: Vilela 1969)

A long list of information on physical and mechanical properties is found in FPL (in preparation).

A considerable body of literature has been developed for the research on exotic species and the effects of cultural treatment on both native and exotic species. Examples of this type of research are as follows:

ARAUCARIA, ARGENTINA (Cozzo and Cozzo 1974)

EUCALYPTUS, BRAZIL (Barrichelo and Brito 1983; Barrichelo and others 1984; Brasil and Ferreira 1973; Brasil and others 1977; Busnardo and others 1983a,b; Carpim and Barrichelo 1983, 1984; Della Lucia and Vital 1983; Ferreira, 1973, 1979; Ferreira and others, 1978, 1979; Foelkel and others 1975; Gonzaga and others 1983; Jesus and Vital 1986; Lima and others 1986; Rezdende and Ferraz 1985; Rodriguez 1951; Tomazello 1985a,b,c)

CHILE (Perez-Galaz 1982)

MEXICO (SARH 1978, 1981, 1985)

EXOTIC PINES, ARGENTINA (Guth 1968/69, 1970, 1983; Solari, 1952)

BRAZIL (Barrichelo and Brito 1979; Ferreira and others 1978; Higa and others 1973; Montagna and others 1970/80; Pereira and others 1983; Resch and Bastendorff 1978)

GMELINA, MEXICO (SARH 1978, 1981, 1985)

MAHOGANY, BRAZIL (Brazier and Lavers 1977)

NOTHOFAGUS, CHILE (Carabias and Karsulovic 1978)

PINE, CHILE (Diaz-Vaz and others 1986)

PINE, HONDURAS (Guevara 1981)

PINE, GUATEMALA (Eguiluz-Piedra and Zobel 1986)

PINE, MEXICO (Yanez-Marquez and Caballero-Deloya 1982)

POPLARS, ARGENTINA (Pujol and Arreghini 1982)

PSEUDOTSUGA, CHILE (Cuevas and Inzunza 1987; Devlieger and others 1986; Diaz-Vaz 1981; Diaz-Vaz and Cuevas, 1987; Diaz-Vaz and Ojeda 1980)

PSEUDOTSUGA, ARGENTINA (Rodriguez 1960)

PINE (Houkal 1982)

SALIX, ARGENTINA (Blanco and Crosio 1983; Guth 1984; Guth and Piussan 1987) SAPINDACEAE, ARGENTINA (Rodriguez 1958)

TACHIGALIA,SCLEROLOBIUM,CUPRESSUS, CHILE (Valderrama 1984; Vasquez and Diaz-Vaz 1985

Several authors or agencies in Europe and North America have, through the years, published reviews of Latin American timbers. These reviews have appeared in technical and trade publications. A few of the authors publications are Arkwright (1955); Brush (1938); Keylwerth (1951); Lamb (1951); Mechanisch-technologisches Institut [n.d.]; Schmidt (1949); and TTIC (1975).

The development of physical property data does not require sophisticated laboratory equipment, and most laboratories are able to develop such data. All laboratories visited in 1986 by the FPL team were equipped to do physical property analysis (Fig. 11). The determination of mechanical properties, however, takes more sophisticated equipment and personnel. Equipment, in some of the laboratories we visited, was not up-to-date. In the Brazilian laboratories, the testing equipment for mechanical properties was good. In general, the facilities and equipment in Central America were not new but quite suitable. At ESNACIFOR in Honduras, they had very good new equipment but admitted the need to train personnel to run the equipment.

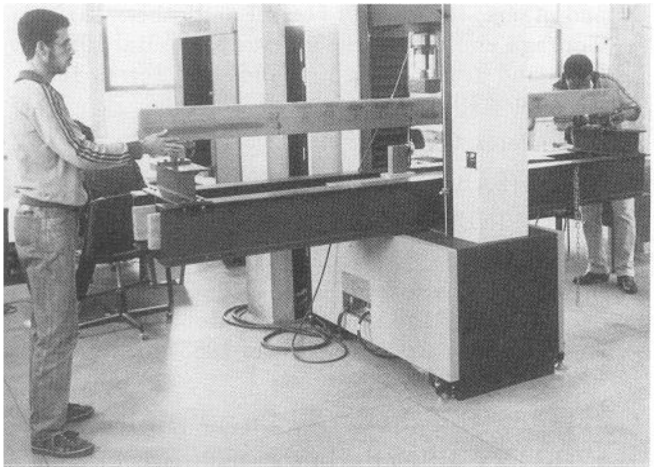


Figure 11-Testing wood strength in bending in Laboratorio Produtos Florestais. Brasilia, Brazil. (M90 0175)

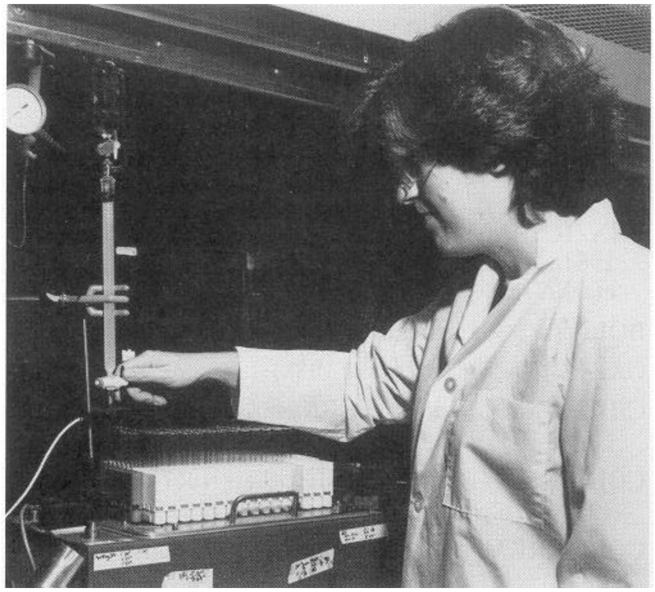


Figure 12-Chilean chemist in laboratory. (M90 0112)

All laboratories testing mechanical properties in Latin America needed a common standard on which to test the woods. Some of the laboratoaries are using standards such as the British BSI, the French AFNOR, the German DIN, or the North American Society for Testing and Materials (ASTM). Other laboratories are using the regional Comite Panamericano de Normas Tecnicas (COPANT) standards, and some used the local standards; Argentina-(IRAM), Brazil-Asociacao Brasileira de Normas Tecnicas (ABNT), Chile-INN, Colombia-ICONTEC. In Argentina, the Centro de Investigation Tecnologica de la Madera y Afines (CITEMA) does special testing on contract, using AFNOR, ASTM, BSI, and IRAM standards (INTI [n.d.]). A common standard would facilitate the use of materials where structural quality is needed. In 1954, 1958, and 1963, the United Nations Food and Agriculture Organization (FAO) held conferences on wood technology in which test methods for determining physical and mechanical properties data were discussed. None of the meetings resulted in agreement to establish uniform testing methods (FAO 1954, 1958, 1963).

Chemical Properties

For many uses of wood, the chemical properties are of great interest. For example, the area of pulping is dependent on the knowledge of wood chemistry. Other areas include chemical byproducts, distillation, finishing, and preservation. The discussion of chemical properties of wood in this paper are limited to defining properties such as pH, the content of cellulose, hemicellulose, lignin, extractives, and materials extracted for specific purposes. Discussion of the manufacture of specific chemical products are found in Part II, Chemicals (Fig. 12).

Several publications list physical, mechanical, and chemical properties in their discussions of Latin American woods. Some of these are

BRAZIL (Anon. [n.d.]; Barrichelo and Brito 1976; Busnardo and others 1983a; Foelkel and others 1981; Gomide and others 1975; Gonzaga and others 1983; Gottlieb and Magalhaes 1961; Rodriguez 1972

CHILE (Albin-A. 1975; Paz and Ceballos 1965)

MEXICO (Villalvazo-N. and Faix 1981)

PUERTO RICO (Pereles 1960)

TROPICAL WOODS (Anon. 1978b; Franklin 1978; Roth-Meyer 1972; Wagenfuhr [nd.])

The most common test of the chemical properties of wood is for extractive content. The extractive content can be determined using any of several solvents. The most common extractions are done with water, acetone, ethanol, or alcohol-benzene. The following are examples of papers containing information on the extractive content.

Brasil and others (1979)	*Eucalyptus grandis*
Fengel and Bocher (1984)	*Araucaria angustifolia*
Guth (1983, 1984, 1985)	*Pinus elliottii and Salix nigra*
Muner and Barrichelo (1983)	*Pinus taeda*
Petroff and Doat (1978)	*Gmelina arborea and Eucalyptus saligna*

Poblete and Zarate (1986) discuss extractive content as it affects the use of wood as a primary material for different products. Asenjo and others (1958), Carter and others (1975, 1983), Reis (1972), and Silva and Assumpcao (1970) have specifically extracted decay and insect resistant woods to isolate the effective compounds. Hausen and Simatupang (1979) have done extractions on several species to isolate allergenic quinones, which cause contact reactions to the woods.

Ninin (1969) studied effects of wood properties on the sawing process. He considered chemical properties, but he did not find a correlation between them and sawing. In a study of several species of the genus *Aniba*, Loureiro (1976) evaluated the chemical composition of essential oils found in the woods. An analysis of gums of various species of wood was facilitated by the use of thin-layer chromatography (Doat 1974). Doat (1977) related the calorific value of 67 Surinam woods to their chemical composition. She showed high calorific values related to high lignin or resinous extracts and low calorific values related to high cellulose and pentosans.

As previously mentioned, pulping is one of the prime uses of wood that requires knowledge of chemical composition. Considerable research has been conducted to evaluate the potential of various woods for pulp, some of those specifying chemical properties of the wood are

ARGENTINA-EUCALYPTUS (Guth 1984);

ARGENTINA-PODOCARPUS, Alnus (Valente and Rique 1960);

ARGENTINA-SALIX, Populus (Fiano 1976);

BRAZIL-EUCALYPTUS (Barrichelo and Brito 1976; Busnardo and others 1983a; Foelkel and others 1981);

BRAZIL-HOVENIA (Frizzo and others 1982);

BRAZIL-PINE (Muner and Barrichelo 1983);

COSTA RICA, many species (Inoue and others 1972); and

GUYANA, many species (Palmer and Gibbs 1978a,b).

Other research looking at chemical properties of specific woods follow:

ARGENTINA

Tannin content of some native species (Pardo and Ricci 1956)

Identification of *Schinopsis* spp. by tanstuffs (Pardo and Ricci 1957)

A new furocoumarin from *Helietta longifoliata* (Pozzi and others 1967)

Vegetable waxes of Argentina, wax of *Bulnesia retama* (Tinto and Pardo 1957)

Composition of oil of turpentine from *Pinus elliottii* (Valente and others 1968)

BELIZE

Pine oleoresin (Anon. 1960)

BRAZIL

Chemistry of *Fagara arenaria* (Machado 1949)

Occurrence of silica in wood of *Leguminosae* (Milanez and Mattos 1956)

Isolation of piperonylic acid from *Ocotea pretiosa* (Gottlieb and Magalhaes 1958)

Essential oil of the wood of *Aniba firmula* (Gottlieb and Magalhaes 1959a)

Occurrence of 1-nitro-2-phenylethane in *Ocotea pretiosa* and *Aniba calelilla* (Gottlieb and Magalhaes 1959b)

The chemistry of rosewood, isolation of cotoin and pinocembrin (Gottlieb and Mors 1958)

Physiological varieties of *Ocotea pretiosa*, containing safrol and methyleugenol (Mors and others 1959)

The alkaloids of *Aspidosperma* discolor (Ferreira and others 1963)

Triterpenoids from *Machaerium incorruptible* (Alves and others 1966)

Coumarins from the heartwood of *Brosimum rubescens* (Braz and others 1972).

Tovoxanthone from *Tovomita choisyana* (Gabriel and Gottlieb 1972)

Xanthones from *Tovomita macrophylla* (Oliveira and others 1972)

Porosin, a neolignan from *Ocotea porosa* (Aiba and others 1973)

Diarylpropanoids from *Virola multinervia* (Braz and others 1973b)

Xanthone from Lorostemon species (Braz and others 1973a)

Guianin, a neolignan from *Aniba guianensis* (Bulow and others 1973)

Terpenoids and phenolics of *Drimys winteri* (Cruz and others 1973)

Resin acids from two species of *Hymenaea* (Cunningham and others 1973)

6-phenylethyl-5,6-dihydro-2-pyrones from *Aniba gigantifolia* (Franca and others 1973)

Diarylpropanoids in Amazonian *Virola* species (Gottlieb and others 1973)

Flavonoids of *Cephalanthus spathelliferus* (Lima and Polonsky 1973)

Alkaloids of *Pandaca [Tabenaemontana] retusa* (Picot and others 1973)

Essential oils of Amazonia (Silva-M. and others 1973b)

Arylpropanoids from *Licaria puchury-major* (Silva-M. and others 1973c)

The chemistry of Amazonian plants (Anon. 1973a,b, 1974a,b,)

Terpenes of *Podocarpus lambertii* (Campello and others 1975)

The chemistry of Lauraceae (Diaz and others 1977)

The chemistry of Guttiferae (Gabriel and others 1977)

The chemistry of Quiinaceae (Gottlieb and others 1977)

The chemistry of Amazonian plants (Anon. 197813)

The chemistry of Amazonian plants (Anon. 1979)

The chemistry of the wood *Torresia [Torresea] acreana* (Cascon and others 1979)

Constituents of essential oil of *Commiphora guidotti* (Craveiro and others 1983)

BRAZIL, FRENCH GUYANA, SURINAM

Chemical properties of *Dicorynia guianensis* (Anon. 1978)

CHILE

Diterpenoids of *Podocarpus nubigena* (Silva and others 1973a)

CUBA

Composition of gum turpentines of pines (Mirov and Iloff 1956)

MEXICO

Forest products of arid zones (e.g. waxes) (Garduno 1959)

Monoterpenes of young cortical tissue of *Pinus radiata* (Zabkiewicz and Allan 1975)

PUERTO RICO

Isolation of cyloeucalenol from *Swietenia mahagoni* (Amoros-Marin and others 1959)

VENEZUELA

Essential oils of some Venezuelan *Croton* species (Bracho and Crowley 1966)

As seen from the previously listed literature, several research studies on the chemical properties of Latin American woods have been conducted, but because of the diversity of species, many more can and should be done. The diversity of the forests of the Amazon region, alone, leaves a vast field of work in this area of science. One of the areas of concentration should be the development of adhesives from the byproducts of timber species, such as is done with wattle. Further work should be done on the development of commercial preservatives based on the naturally occurring materials in decay and insect resistant species.

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Part II

Processing

Page

Pulping

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History

According to Dard Hunter (1978), the foremost historian of the pulp and paper industry, the ancient Mayans and Aztecs used a writing material somewhat related to the papyrus used by the Egyptians, Greeks, and Romans. The making of a beaten bark material, which was known as “huun,” went hand in hand with Mayan intellectual development, and with the advent of hieroglyphic writing, these ancient people actually constructed books. The Mayans made these hieroglyphic charts for centuries, even through the period of decline. When the Mayan civilization revived again in the 10th century, they had already begun to fold their huun paper into book form. During this period, they produced a sacred almanac of 40 pages still extant and known as the Codex Dresdensis. This polychromic book, called “Analteh” by the Mayans, is 8 in. high, 12-l/2 ft long, and folded screenwise to form distinct pages. It is written on huun paper made from the inner bark of the *Ficus* and was fashioned somewhere between A.D. 900 and A.D. 1000. Based on the Spanish chroniclers, this Codex was far from being the only manuscript produced by this ancient civilization. The Mayans had many books; in fact, they even had extensive libraries. The Spanish missionary, Diego de Landa of the Monastery of Izamel, Yucatan, writing in the 16th century, said, “We found a great number of books written with their characters, and because they contained nothing but superstitions and falsehoods about the devil, we burned them all....” It was the Aztecs, following the Mayans, however, who developed the beating of bark into paper from a minor craft into a sizable industry. The Aztec termed their beaten papers “amatl.”

Dard Hunter visited the Otami papermakers in southern Mexico in the early 1900s and saw the procedure of their bark-beating and papermaking in detail. Describing this procedure he said,

> The bark, an inch or more in width, is taken from the trees in as long strips as possible. The dark outer bark is then removed, leaving the fibrous inner bark as the usable material. The inner bark is boiled over a slow fire in a home-made cauldron containing water and wood ash. After boiling, the strips of bark fiber, having become disintegrated to some extent, are laid side by side upon a rectangular board that is a little larger in size than the dimensions of the paper being made. The strips of bark, each strip slightly overlap ping the next, are then pounded and smoothed with a stone. After the strips of bark have been beaten and united into a sheet, the board with its deposit of crude paper is placed in the sun to dry (Hunter 1978).

Papyrus, huun, and amatl are all in the same category. However, none of these substances is true paper made from disintegrated fiber upon porous molds, the technique conceived and used first by the Chinese Ts’ai Lun in A.D. 105.

Hunter further relates the following events in the Western Hemisphere, but he does not specifically follow the history in Latin America:

> 1575-1580 According to Relation de1 Pueblo de Culhuacan desta Nueva Espana, written January 17, 1580, the first paper mill in Mexico was established in Culhuacan.
>
> 1817 First papermachine erected in America, a cylinder machine operated in the mill of Thomas Gilpin, near Philadelphia.
>
> 1827 First Fourdrinier papermachine set up in America at Saugerties, New York, in the mill of Henry Barclay.
>
> 1841 Charles Fenerty, a Nova Scotian, produced in Halifax the first groundwood paper made in the Western Hemisphere.
>
> 1882 Sulphite pulp first made on a commercial scale by C.S. Wheelwright, Providence, Rhode Island.
>
> 1907 First kraft (sulphate) pulp made on this continent at the Brompton paper mills, East Angus, Quebet, Canada (Hunter 1978).

The use of wood for the production of pulp in Latin America was first reported in 1903 by S.A. Fabrica de Papel El Feniz in Campana, Province of Buenos Aires, Argentina. They produced a groundwood pulp using the poplars and willows from the Parana delta (Mussi and others 1977). By 1913, the Argentina General Census reports the existence of 11 paper mills. The pulping

Table 3–Pulp production for all of Latin America

Year	Pulp production (×103 t)
1937	25
1948	190
1956	500
1968	1,957
1978	2,004
1985	6,514

industry, however, did not accompany this development since 83 percent of the pulp was still imported. The primary reason for this lag is reported to have been the lack of rail and fluvial structure to permit the economical transportation of the wood. Regardless of transportation problems, the availability of the poplars and willows represented only enough wood for about 8 years of harvesting and raised the problems of reforestation and the jurisdictional uncertainty of land proprietorship.

Although the use of wood for the production of pulp began in Latin America shortly after the turn of the 20th century, growth of this industry was extremely slow until the 1930s. The rate of growth is shown in Latin American pulp production figures for selected years (Table 3).

State of the Knowledge

Natural Softwoods

The natural stands of softwoods found in Latin America were among the first woods evaluated for producing pulp. These softwoods include neuquen pine *(Araucaria araucana)* found in Chile and the Patagonia region of Argentina, (Fig. 13); manio *(Saxegothaea conspicua)* and alerce *(Fitzroya cupressoides)* from Chile; parana or Misiones pine *(Araucaria angustifolia)* found in the Brazilian states of Parana, Santa Catarina, and Rio Grande do Sul, the state of Misiones in Argentina, and in the southern mountainous regions of Paraguay; the hill pine *(Podocarpus palatorei)* found in the northern parts of Argentina; the true pines of Mexico and Central America, which include mainly *Pinus caribaea, P. oocarpa,* ***P.*** *patula;* and the Mexican fir, *Abies religiosa.* All of these native softwoods are known to produce excellent quality, long fibered, chemical pulps. The fibers of the Araucaria species are unique in that they are extremely long, up to 7 mm, and thicker than most softwood fibers. These pulps exhibit outstanding resistance to tear, but are low in tensile and bursting strengths when compared to most softwood pulps. The combination of long and thick fibers is also reported to decrease screening capacity by about 50 percent. Hill pine was chosen early for use in making mechanical pulps (FAO 1955). The pines of Mexico and Central America have been studied extensively and are similar to the North American southern pines in regard to ease of kraft pulping, pulp bleachability, and pulp properties (Chidester and Schafer 1956a, 1958b, 1961; Chilson and Laundrie 1966; Chilson and others 1960a, 1962; Kirsch 1911; Matsuno and Akino 1972; Palmer and Gibbs 1975, 1976a,b; Rodriguez-Romero 1975). The Mexican fir, *Abies religiosa,* was among the first species chosen for pulping because it was thought to be plentiful and could be used to produce not only kraft pulp, but also sulfite and mechanical pulp because of its low density, light color, and lack of resinous material commonly found in the pines. However, as demand for paper in Mexico increased, the stands of fir were found to be less extensive than needed, and the species was not very conducive to the establishment of plantations. Today, most of the wood pulped in Mexico is from the natural pine stands.

Plantation Softwoods

Because natural regeneration was poor, parana pine has been planted in the five southern states of Brazil since 1944. By 1955, it was reported that some 14,000 ha of parana pine had been established (FAO 1955). Planting of parana pine in Argentina also began about the same time. However, many difficulties occurred in establishing parana pine plantations. Parana pine has an extremely long tap root, which made handling in the nursery extremely difficult. Attempts were also made to expand the natural range of parana pine into the natural prairie area, or *campo limpo,* of Brazil, but growth was variable and poor. McGaughey and Gregerson (1983) stated that the natural Araucaria forests of Latin America have been heavily exploited and probably will be of little economic importance in the future. They made no mention of the old parana pine plantations that started in 1944. Although parana pine produces an excellent pulp, its future in Latin America seems to be limited. However, in Argentina a plantation of 25,000 ha of *Araucaria angustifolia* produced 82,000 m^3 in 1984 (Tinto 1988).

The outstanding success in establishing exotic softwood plantations contributed to the demise of parana pine for pulp. Pines such as *P. elliottii, P. taeda,* and *P. caribea* in Brazil and Argentina have exhibited growth rates of 15 to 25 m^3/ha/year and *P. radiata* in Chile, growth rates of 20 to 30 m^3/ha/year. These growth rates are much higher than those of parana pine.

Large scale planting of radiata pine has gone on in Chile since 1935, mainly in the provinces around the city of Conceptcion. By 1955, it was reported that some 173,000 ha of radiata pine had already been established (FAO 1955). Today, almost the entire wood pulping industry of Chile is based on radiata pine. In 1988, the pine plantation area in Chile was about 1.2×10^6 ha; with new plantings, this area could expand to 2×10^6 ha by the year 2000 (Han-R. 1988; Neumann 1988). It is estimated by INFOR-CORFO

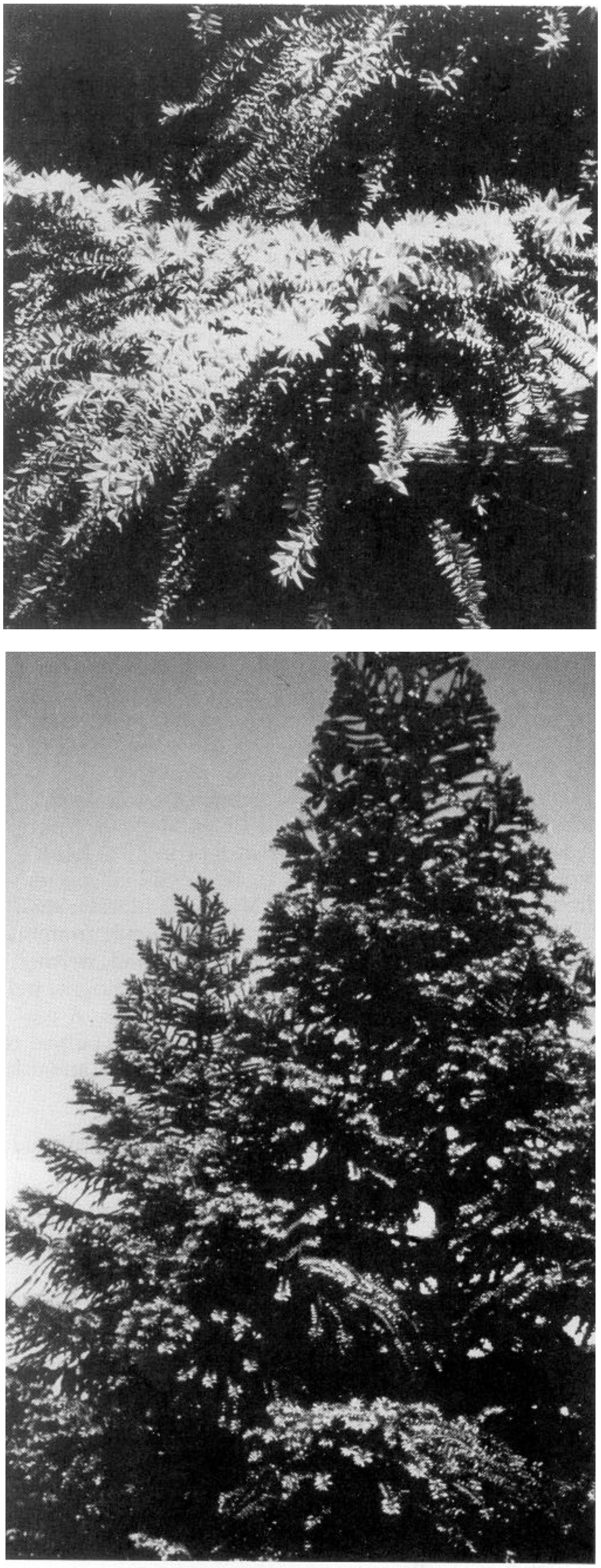

Figure 13-Araucaria foliage and trees, Chile. (M90 0136, M90 0160)

(1987) that the area to be planted annually between 1985 and 2005 will be, on the average, 57,000 ha. The pulps produced from *P. elliottii* and *P. taeda* grown in Brazil and Argentina are similar in properties to those made from the same species grown in the southern United States. The pulps produced from the *P. radiata* grown in Chile are reported to be similar in properties to those made from the Scandinavian pines (Anon. 1958a; Barrichelo and others 1979; Martin and Kingsbury 1947; Muner and Barrichelo 1983; Sanyer and others 1961).

Considerable research has been conducted on the pulping of radiata (insigne) pine in Chile (Casals and Melo 1969; Fleming and Melo 1969; Melo-S. and Madsen 1966; Moreno and Melo-S. 1969; Oestreicher and Melo-S. 1969; Paz and Rueda 1981). Also, Gaytan and others (1981) have studied the effect of anthraquinone on the yield of pulp from juvenile radiata pine.

Natural Hardwoods-Temperate

Since about 1903, the poplars and willow found in the Parana delta region of Argentina have been used to produce mechanical pulps. The poplars, originally thought to be native, were later identified as *Populus nigra, var italica* and *P. angulata.* These poplars were greatly affected by rust and were soon replaced with Italian and other hybrids. The willow, *Salix humboldtiana,* native to Latin America, was used and cultivated for the production of mechanical pulp. But, its use and cultivation has been abandoned in favor of various hybrids of Salix that are being used to produce newsprint. With the introduction of weeping willow, *Salix babylonica,* there was a spontaneous crossing with the native willow, providing a hybrid under the commonly used generic name, *Salix X argentinensis.* This hybrid, along with the willow-poplar, *Salix alba, var calva,* is planted widely in the Parana delta region, and both are used today for the production of mechanical pulp (Losoda and others 1973).

Tinto notes that Populus is another genera that is cultivated extensively in Argentina, especially in the Parana delta and zones of the region. He states that the combined plantation areas for Salix and Populus is about 180,000 ha with a 1984 production of 10^6 m^3 of roundwood.

During the early years of development of the pulping industry in Latin America, consideration was given to the largest and best natural stands of temperate hardwoods found in the Chilean Andes (Fig. 14). As early as 1915, samples of these woods were sent to the FPL in Madison to be evaluated for their potential as raw materials for producing soda pulps (Wells 1915a,b). Additional pulping studies of these woods were also made by the FPL (Bray and McGovern 1942; McGovern and Hyttinen 1948; Simmonds and Kingsbury 1951). The later studies involved mechanical, kraft, and sulfite pulping and conversion of some pulps to viscose-rayon. More recent studies of the native Chilean hardwoods are reported by Asenjo (1975).

Figure 14-Dense Chilean hardwood rain forest near Valdivia, Chile. (M90 0113)

The temperate oak stands in Mexico and Central America were also considered early in the development of the pulping industry. But, an industry based on these resources never developed, primarily because of the availability of the softwood species and nonwood fibers in these areas and the lack of demand for short fibered pulps. However, some work has continued on the use of oak from Mexico for pulp and paper (Villalvazo-N. and others 1981).

Natural Hardwoods-Individual Tropical Species

Evaluations of individual tropical hardwoods from Latin America for use in the production of wood pulp first reported by the FPL are those of Bray and Martin (1930) and Curran and others (1929). Since 1930, numerous other evaluations have been made by the FPL, (Chilson and others 1958; Keller and others 1958; Martin 1957; Schafer and Hyttinen 1954; Yunis 1949). More recently, individual tropical hardwoods have been evaluated in Latin American laboratories (Alcalde-Melandez 1979; Anon. 1971; Barrichelo and Brito 1979; Barrichelo and Foelkel 1975; Caceres-Rojas and others 1977; Fairest 1964; Foelkel and Barrichelo 1976; Gomide and others 1972, 1975; Melo and Alves 1974; Melo and Huhn 1974; Paula 1980; Pereira and others 1982; Porres and Valladares 1979), in England (Palmer 1974a,b, 1978), and in Japan (Inoue and others 1982).

Although much is already known about the pulping properties of individual tropical species from Latin America, this industry, to a large extent, has failed to develop. The main reason for this lack of development is that tropical hardwoods are seldom found in pure stands and the quantities of any one species are low in a given location. Most species are found only in mixture with many other species. One example of the use of mixed hardwoods was at Jari, in Brazil. Jari contracted with North Carolina State University to test a mixture of about 30 selected tropical hardwood species. Acceptable species were used as a mix with plantation grown wood on a commercial basis. Selective harvest of any one species for pulp is not practical; however, selective harvest of several species with similar properties may be practical (Posey 1988).

Natural Hardwoods-Mixed Tropical Species

By far, the largest volume of natural hardwoods are found in the tropical areas of Latin America. Brazil alone has over 340×10^6 ha of natural mixed tropical hardwood forest. The pulping industry has traditionally preferred to utilize single species of hardwoods or closely controlled mixtures of hardwoods to reduce the variability of the pulp produced. Because of this tradition and for other reasons, such as remoteness of the resource, utilization of the mixed tropical hardwoods for pulp has been slow to develop. However, much is already known about the quality of pulp that can be produced from mixed tropical forests of Latin America. For example, in 1952, the FPL in Madison studied the kraft pulping characteristics of tropical hardwood mixtures containing up to 48 individual species from the Yucatan peninsula of Mexico (Chidester and McGovern 1952). A bleached kraft pulp made from one of the mixtures was made into printing, bond, writing, tissue, and toweling papers that were clean, bright, well formed, and fully acceptable in other qualities, A corrugating medium made from another mixture pulped to 69-percent yield, which fully met commercial standards (Koning and others 1978).

The FPL in Madison also evaluated tropical hardwood mixtures containing

1. 32 species from Nicaragua (Chidester and Brown, 1954; Chidester and Schafer 1954; Martin and others 1954; McGovern and others 1952),
2. 31 species from the Magdalena river area of Colombia (Chidester and Schafer 1956b, 1958a),
3. 22 species from the Opon forest and 26 species from the Buenaventura forest of Colombia (Chilson and others 1960b, 1961),
4. 39 species from Venezuela (Sanyer and others 1965), and
5. 17 species from another area of Colombia (Fahey and Laundrie 1978; Koning and others 1978; Laundrie 1978).

A review of the literature quickly reveals that many others, besides the FPL in Madison, have contributed

Figure 15-Harvesting in Gmelina plantation at Jari, Brazil. (M90 0137)

to the knowledge regarding the use of mixed tropical hardwoods for pulp. Some of the more prominent contributors, by country of origin, include the following:

Brazil	(Anon. 1973; Correira 1984; Correira and others 1974)
Colombia	(Caradenas 1978; Gomez 1978; Gomez and Mondragon 1974)
France	(Petroff 1978; Staeplaere and Ginsburger 1978)
United States	(Becker and Caldwell 1974)

Exotic Plantation Hardwoods

Numerous Eucalyptus species, widely grown in Latin America, have been studied to determine their pulping properties. The first known evaluation of pulp from Eucalyptus grown in Latin America was made by the FPL in Madison, Wisconsin, in 1926 (Anon. 1958b). Additional pulping, bleaching, and papermaking studies were revealed in unpublished reports by the FPL (Brown and Kingsbury 1955; Brown and others 1954; Fahey and others 1959; Kingsbury and others 1957; Laundrie and others 1961). Review of the published literature since 1975 shows that many others have been involved in the evaluation of Eucalyptus grown in Latin America (Barrichelo and Brito 1976 a,b,c; Barrichelo and others 1983; Busnardo and others 1983; Cruz and others 1978; FAO 1975; Foelkel and others 1975; Foelkel and Zvinakevicius 1980; Gonzaga and others 1983; Guth 1984; Melo-S. and Paz 1980; Pacini 1978; Redko 1983; Yoda 1975).

Gmelina *(Gmelina arborea)* (Fig. 15) is another exotic hardwood grown in Latin America that has been evaluated for its pulping characteristics (FAO 1975; Palmer and Gibbs 1974; and Redko 1983). The poplars have also received extensive evaluation to determine their pulping properties (FAO 1975; Fiano 1976; Guth and Ragonese 1980).

Figure 16-Locations of pulpmills in Latin America.

Commercial use of these exotic hardwoods is now well established in many pulp mills in Latin America. Some examples include Aracruz in Brazil pulping eucalyptus, Jari in Brazil pulping gmelina, and Celulosa Argentina pulping the poplars. Extensive knowledge and experience already exists in the use of these particular exotic hardwoods for the production of wood pulp.

State of the Art

In 1986, a total of 129 pulp mills were in Latin America (Fig. 16). Annual production capacity for these 129 mills was 7.71×10^6 t with nearly 90 percent being found in only four countries. Brazil has the largest capacity with 4.00×10^6 t, followed by Mexico with 1.03×10^6 t, Chile with 0.90×10^6 t and Argentina with 0.84×10^6 t. Total pulp production in 1985 was 6.51×10^6 t with 83 percent being chemical pulp, 4 percent mechanical pulp, and the remainder classified as other pulp. Much of the pulp classified as other is based on nonwood resources such as sugar cane bagasse.

Today, most of the wood pulp produced in Latin America is made in modern pulp mills using state of the art technology (Fig. 17). By way of example, Haas (1979) has described seven modern pulp mills in Brazil and three modern pulp mills in Chile to illustrate the state

Figure 17-Jari pulpmill (top center) at Monte Dourado, Amapa, Brazil.

of the art in the pulping of Latin American woods. Following are brief descriptions of the seven modern mills that produce about half of all pulp produced in Brazil. The first commercial use of plantation grown eucalyptus for the production of wood pulp in Brazil began in 1957 by Industria de Papel Leon Feffer in Suzano, about 50 km from Sao Paulo. This first mill had a design capacity of 50 t/day. In 1961, a subsidiary of Industria de Papel Leon Feffer (Industria de Papel Rio Verde) commercially produced for the first time in the world writing and printing papers from 100 percent bleached eucalyptus kraft pulp. In 1969, after several expansions, the Suzano mill reached a pulp production capacity of 300 t/day. With further expansion of the 300 t/day mill and the addition of a new, modern 500 t/day mill, total eucalyptus pulping capacity reached 900 t/day by 1977. In 1978, this company produced 25 percent of all the bleached eucalyptus kraft pulp made in Brazil.

The Cia do Celulose do Sul Riocell mill is located in Guaiba, about 30 km from Porto Alegre, the capital city of the state of Rio Grande do Sul. Riocell forests in 1978 consisted of 54×10^6 eucalyptus trees planted on 35,000 ha of land within a radius of 60 km of the mill site. Riocell produces 720 t/day of paper grade pulp or 515 t/day of dissolving pulp. This pulp, unbleached and unscreened, is shipped to Borregaard in Norway for bleaching and subsequent shipment to the EEC and Scandinavia. Bleaching will be carried out in Norway until 1981 when a bleach plant now under construction in Guaiba will come on stream.

Aracruz Celulosa SA began in 1967 with the foundation of a forest company, Aracruz Florestal SA, which started acquiring land in the state of Espiritu Santo for establishing eucalyptus plantations. In 1976, only 9 years after its start, Aracruz had acquired 74,500 ha of land on which 59,000 ha was planted with eucalyptus. Eleven thousand ha of native tropical forest area was maintained. The forest is divided into two separate forests: the first, Aracruz, has 33,000 ha with an average distance from stump to the mill of 17 km, and the second, Sao Mateus, has 26,000 ha with an average transport distance of 150 km. The cycle from planting to cutting is 7 to 8 years and yields about 36 m^3/ha/year. Aracruz established a forest research center in 1973, where it conducts extensive research in the areas of seed selection, grafting, vegetative propagation, planting techniques, disease and insect elimination, and soil improvement. Based on the results of this research, Aracruz expects future yields to be 60 to 70 m^3/ha/year. Construction of the pulpmill began in August 1975 and was completed in September 1978. The pulpmill has a capacity of 480,000 t/year of bleached eucalyptus kraft pulp sold primarily on the European market. An expansion scheduled for completion in 1991 will set capacity at 1.025×10^6 t/year.

Celulosa Nipo-Brasileira SA (CENIBRA) was established in September 1973 as a result of an association of Cia Vale do Rio Doce (CVRD) and Japan Brazil Paper and Pulp Resources Co. The CENIBRA mill is located in Belo Oriente in the Rio Doce valley, about 400 km from the Atlantic coast and 200 km from Belo Horizonte, the state capital of the state of Minas Gerais. Construction of the 750 t/day pulp mill was completed in 1977. The CVRD railroad played a major role in determining the location of CENIBRA, because much of the wood comes from the CVRD eucalyptus forests in the state of Espiritu Santo by the rail line. The railroad also ships CENIBRA market pulp to the coast for export. Other factors determinining the location of the mill include proximity to the highway connecting the mill to Belo Horizonte, Rio de Janeiro, Vitoria, and the northeast area of Brazil; proximity to the Rio Doce river, which supplies all the mill's water; and room for future expansion (Haas 1979).

Champion Papel e Celulose (CPC), a wholly owned subsidiary of Champion International, was established in 1957. Their pulp mill, located at Mogi Guacu in the state of Sao Paula, started making bleached eucalyptus kraft pulp for the market in 1960. Paper production began in 1965. The CPC owns or controls some 40,000 ha of eucalyptus forests. The pulp mill has a production capacity of 650 t/day of bleached eucalyptus kraft pulp. All of the pulp is now used internally for the production of wood-free printing and writing papers primarily for the domestic market in Brazil. About 30 percent of their paper production is exported (Miller Freeman 1986a).

Papel de Impresa (PISA), a joint venture involving two major Brazilian newspapers (O Estado de Sao Paulo and Jornal do Brazil) and a forest management company, Flantar SA, began newsprint production in December 1984. Their mill is located in Jaguariaiva in the state of Parana. Pulp production at this mill is 350 t/day of stone groundwood pulp (SGW) and 200 t/day of thermomechanical pulp (TMP), using plantation grown loblolly pine *(P. taeda).* Process pulp for the production of newsprint is mixed in the ratio of 30 percent TMP and 70 percent SGW. This mix is blended with 15 percent imported bleached softwood kraft pulp and used as the furnish to produce newsprint. An excess of about 36,000 t/year of TMP is sold on the domestic market. Wood demand is 500,000 m^3/year of loblolly pine for the SGW and TMP lines. A wood-fired boiler uses another 200,000 m^3/year of eucalyptus plus 200,000 m^3/year of sawmill waste and bark from the loblolly pine. The entire wood supply is within a radius of 130 km of the mill (Miller Freeman 1986a).

The pulp mill of Jari Florestal e Agropecauria, located at Munguba in the state of Para, Brazil, is another new, modern pulp mill based originally on gmelina *(Gmelina arborea)*. This mill had its beginning in 1967 when U.S. shipping magnate, Daniel K. Ludwig, reportedly paid US$3 $\times 10^6$ for 1.6 $\times 10^6$ ha of tropical forestland on the Rio Jari, the easternmost, south-flowing tributary of the Amazon. Forestry operations began in 1968, and by 1970, plantations of gmelina were being established rapidly. Because two distinct soil types were found in the area-clays in the north and sandy soils in the south-it soon became evident that pine should also be planted. The first major scale planting of pine in the sandy soils took place in 1973. In 1979, Jari introduced *Eucalyptus degluptga* and *E. urophylla*, which do well on the transitional soils between clay and sandy soils. By 1980, there were 64,000 ha of gmelina, 32,000 ha of pine, 3,000 ha of eucalyptus, and 1,500 ha of experimental species. Jari estimates that ultimately there will be 25,000 ha of gmelina, 42,000 ha of pine, and 32,000 ha of eucalyptus for sustained operations of the pulp mill.

Ludwig had the pulp mill completely constructed on two floating platforms at the Kure shipyard in Japan. By January 1978, the two platforms arrived safely at the mill site after a tow across the Indian and Atlantic Oceans and up the Amazon and Jari Rivers. This unique approach is estimated to have saved at least 2 years of construction time over transporting materials and equipment and then building the plant on site. Laboratory pulping trials by Jari have shown that some native species are compatible with gmelina. Since 1980, these native species have been introduced into the pulp mill. In 1984, it was reported that Jari had completed technical data on 257 species of trees regularly encountered in their cutting operations. The entire production of 750 t/day bleached kraft pulp is sold as market pulp.

Pulping in Chile

Most of the wood pulp mills in Chile utilize plantation grown radiata pine. Following are brief descriptions of a few of the modern, up-to-date pulp mills. Because of the changing corporate arrangements, some of the data may not be totally current. Current status may be obtained by reading such publications as Chilean Forestry News or Celulosa y Papel.

Compania Manufacturera de Papeles y Cartones SA (CMPC) (now Papeles y Bosques Bio-Bio) started in 1957 with a SGW mill at Laja in Bio-Bio province. The entire production of 54,000 t/year is used internally to produce newsprint. In 1959, CMPC started a kraft pulpmill in Laja with a capacity of 70,000 t/year. In 1967, capacity of the Laja mill was expanded to 220,000 t/year, in 1981 to 280,000 t/year, and in 1988 to 300,000 t/year. Most of the pulp from Laja is fully bleached and sold as market pulp. The CMPC also has a SGW mill at Puente Alto with a capacity of 15,000 t/year and another SGW mill at Valdivia with a capacity of 6,000 t/year. The pulps from the Puente Alto and Valdivia mills are used internally to produce a variety of paper grades. Another mill at Bio Bio pro duces 50,000 t/year of mechanical pulp and newsprint paper.

Industrias Forestales SA (INFORSA) was founded in 1956 and started producing sulfite and SGW pulps in Nacimiento in 1964. This is still the only sulfite mill in all of Chile. In 1986, production was 25,000 t/year of sulfifte pulp and 88,000 t/year of SGW pulp, used principally by INFORSA for the production of newsprint.

A mill originally partly owned by INFORSA, Papeles Sudamerica (now Sociedad Forestal e Industrial Santa Fe S.A.), which was to begin production in 1985, is located adjacent to the INFORSA mill in Nacimiento. The mill was still under construction in 1988 and expected to go on line in 1990. The capacity of this new mill is to be 140,000 t/year, producing primarily fine papers based on short-fiber input (Chilean Forestry News 1988a).

Celulose Arauco y Constitucion (CELARAUCO) was formed in 1979 with the merger of Celulosa Arauco SA and Celulosa Constitucion SA. Celulosa Arauco SA was started in 1968, at Arauco, as a 150,000 t/year pulp mill producing fully bleached market kraft pulp. Work in progress in 1988 will expand this mill to a capacity of 180,000 t/year, and a new unit with a capacity of 250,000 t/year (Arauco II) is planned for 1992. Celulosa Constitucion SA was started at Constitucion in 1976 as a 210,000 t/year pulp mill producing unbleached market pulp. All of the pulp produced now by CELARAUCO is sold as market pulp.

A recently formed company, Celulosa de1 Pacifico (CELPAC), a joint venture of CMPC and Productos Industriales y Forestales S.A. (PROFOR), with Simpson Paper Company (United States) plans to begin construction of a new mill in 1989. The CELPAC mill will produce bleached kraft pulp at a capacity of 315,000 t/year and will go on stream in 1992 (Chilean Forestry News 1988b).

Although not expected on line until 1991, at the earliest, a major (200,000 t/year) pulp mill to manufacture newsprint will be established near Ciudad, Guyana, in the state of Monagas in Venezuela. The mill will be a joint venture of Venezuelan and North American interests. The resource will be *Pinus caribaea* from the Corporacion Venezolana de Guayana plantations in Monagas (Miller Freeman Publ. Inc. 1988c).

Table 4-Pulp mills in Latin America[a]

Country	Wood based					Nonwood based	Not defined in references	Total
	Kraft	Sulfite	Soda	Mechanical	NSSC			
Argentina	8	1	3	4	9	2	3	21
Bolivia	0	0	0	0	0	0	0	0
Brazil	16	2	2	9+44[b]	1	12	14	100
Chile	3	1	0	4	0	0	1	9
Colombia	1	0	1	0	2	3	0	7
Costa Rica	0	0	0	1	0	0	0	1
Cuba	0	0	0	0	0	3	0	3
Ecuador	0	0		0	0	0	2	2
Guatemala	1	0	0	0	0	0	0	1
Mexico	8	0	1	2	0	5	5	21
Peru	0	0	3	0	0	0	0	3
Uruguay	2	1	1	1	1	1	0	7
Venezuela	2	0	0	0	0	1	0	3
Latin America	41	5	11	65	4	27	25	178

[a]Miller Freeman 1989a,b.
[b]The 44 mechanical mills are very small units.

A complete list of the pulp mills in Latin America is presented in Table 4 by type of mill. These data were primarily for 1987.

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Chemicals

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Chemicals from forest trees have been an integral part of life for native Americans. Some of these chemicals and related materials continue to be prominent industrial products such as tannins, alcohol, charcoal, naval stores, and a host of small-volume products including essential oils, dyestuffs, and medicinals. The importance of such materials is attested in that the country name Brazil was derived from the reddish brazilwoods [from the Portugese "braza", the glow (color) of coals], which was an important source of a dyestuff. Not included in this chemical classification is the direct burning of wood for energy.

The production of chemicals from wood in Latin America consists mainly of (1) tannin from quebracho *(Scbinopsis quebracho-Colorado)* (Fig. 18), (2) alcohol from a variety of species, (3) charcoal from a variety of species (Fig. 19), and (4) naval stores from the direct tapping of pine trees and as a secondary product from the kraft pulping of pines. Other chemical materials of more limited production may rise to greater importance with the need for renewable resources.

Figure 18-Quebracho in Argentina to be extracted for tannin (early part of century). Photo courtesy of Samuel J. Record collection at U.S. Forest Products Laboratory, Madison, Wisconsin. (M90 0114)

History

Quebracho Tannin

In the early 1870s) a German tanner in Buenos Aires observed that the water near a certain sawmill had become red from a deposit of quebracho sawdust. He thought that this discoloration might be caused by tannit acid. Experimentation proved the accuracy of his assumption, thus, he became the first quebracho tanner. The first Latin American factory for the extraction of quebracho was established in 1889 at Puerto Galileo, Paraguay. The first extraction plant was established in 1899 at Calchaqui, Argentina. Domestic consumption of quebracho extract in both Argentina and Paraguay was slow to develop, primarily because the leather industry was also slow to develop. However, the export market to Germany, Italy, France, the United Kingdom, and the United States flourished. By 1913, the Quebracho export of both logs and extract had grown substantially as shown by the following:

	Logs (t)	Extract (t)
Argentina	383,964	79,864
Paraguay	13,067	11,720

During World War I, imperative demands for leather were made that prompted an increase in the manufacture of leather in Argentina. The leather industry soon grew into an exporting business. The quebracho industry in Argentina was strong into the 1930s. Couto and others (1980) state that a general decline in the industry existed between 1937 and 1978, while competetive tanstuffs gained in importance.

Other phenolic materials can be obtained from Latin American species, such as parana pine (Anderegg and Rowe 1974) and wallaba (Farmer and Campbell 1952), but they have not attained commercial importance.

Charcoal

According to Earl (1974), wood charcoal has been used for 6,000 years for the smelting of metals. The knowledge of charcoal has been used by both aboriginal and

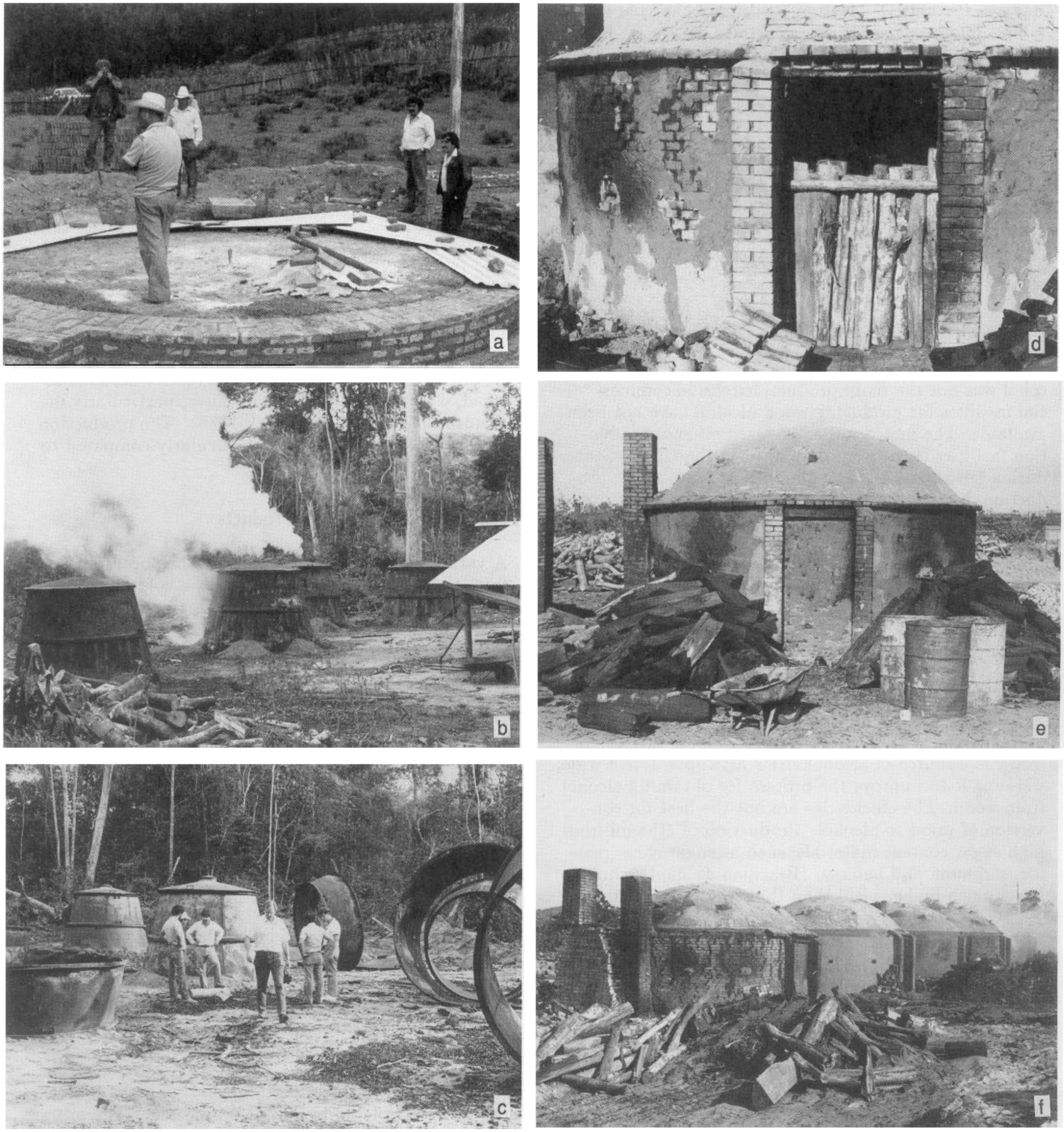

Figure 19-Building of a brick charcoal kiln at La Selva, Veracruz, Mexico (a). Steel charcoal kilns in Venezuela in various stages of operation (b) and assembly (c). Brick charcoal kiln in Venezuela, showing a kiln nearly loaded and ready for bricking shut (d), with door sealed ready for burning (e). Battery of brick charcoal kilns in Venezuela in various stages of operation (f). (M90 0138, M90 0162, M90 0121, M90 0145, M90 0169, M90 0122)

advanced societies. The manufacture of charcoal in simple pits continues today as it most assuredly did in past millenia. The charcoal industry now, however, has advanced in the ability to get more product from the resource. Much of the current effort in charcoal research and manufacture is in improving the yields of charcoal and byproducts. A renewed interest in the use of charcoal has arisen because of the uncertainty of the oil supplies. Brazil, in its effort to be energy independent has developed a new charcoal industry to supply its growing metals industry.

Alcohol

The technologies for producing alcohol (methanol and ethanol) from wood have been known for decades. Except in emergency situations and situations where alcohol was not the main product, extensive commercial facilities for producing wood alcohol have not been available. The first commercial-sized ethanol production facilities (two) were developed in the United States during 1915 to 1921. The plants closed as lumber production declined because of the decreased availability of sawdust. During World War II, ethanol production was developed in Germany because of the emergency fuel situation experienced by the Germans late in the war. After World War II, the development of alternative fuels overshadowed the need for wood alcohol.

A number of industrial-scaled plants operate in the U.S.S.R., but their principal product is animal feed, and alcohol is simply a byproduct (Beattie 1979).

The oil crisis of 1973 once again stimulated interest in wood as a source of alcohol. New attempts, world wide, were made to improve the process for obtaining alcohol from wood. The efficiencies are not the best for conversion of wood to alcohol. Production of ethanol from high sugar content materials, such as sugar cane, manioc, sorghum, and babassu (Brazilian coconut palm), has a much higher yield than that from wood (Ribeiro 1979).

Naval Stores

Although the production of naval stores materials was an early endeavor in the European settlement of North America, commercial development of this industry came several hundred years later in Latin America, beginning in Mexico at the last turn of the century (Barrineau 1921). Production has since extended into Guatemala, British Honduras '(Belize), Honduras, Nicaragua, and the southernmost extent of the natural distribution of pines *(Pinus spp.)* in the Americas. Although several Latin American countries produce naval stores and the modern commodity products of turpentine and rosin, the dominant forces are Mexico and Brazil, which was once an importer and now is self-sufficient and an exporter (Assumpcao and Jordao 1978; Carreno 1980; Duchene 1987; Sanz 1989; Smith 1982; Tapia 1986; Taylor 1985).

Naval stores are obtained by the traditional methods (Zinkel and Russell 1989): (1) Wounding pines and collecting the oleoresin exudate (commonly known as turpentining), followed by processing to turpentine and rosin-called gum naval stores and specifically, gum turpentine and gum rosin; (2) Extraction of highly resinous wood, such as stumpwood (stem heartwood is also a potential raw material (Zinkel 1985)–the products are known as wood turpentine and wood rosin; and (3) Recovery and processing of byproduct streams from kraft pulping of pine-these byproducts are tall oil, further processed by distillation to tall oil rosin and tall oil fatty acids, and sulfate turpentine. Most of the production has been gum naval stores derived, with lesser amounts coming from stump extraction and pulping byproducts.

At one time, a number of tree-derived resins, such as copal, were gathered for various uses, particularly in varnishes (Tschirch and Stock 1936). The production now of such resins is minor, particularly compared to naval stores materials.

Other Chemical Natural Products

A variety of chemical-type products has been obtained from forest trees, although not in the volumes of areas previously discussed. Some of the major classifications of products are latexes, essential oils, and dyes.

One group potentially of greatest volume are the latexes, of which the precursor to rubber is the most important. Although the production of natural rubber began in the Americas, the introduction of *Hevea brazilensis* seedlings by the British into other countries has led to predominance of the industry in Southeast Asia. Production of rubber from plantations expanded during World War II (Bangham 1947), and plantation rubber is still produced in Latin America, but the production is overshadowed by that from Southeast Asia. Balata, produced from the latex of *Mimusops balata,* is of little importance industrially, although it is used in the manufacture of golf balls and other molded objects (Serier 1986). Chicle, from the latex of *Manilkara zapota = Achras zapota,* at one time was a component of most chewing gums and of consideration for further research (Egler 1947), but its use has been almost completely replaced by synthetic materials.

Essential oils are the odorous essence of plant material and are isolated by physical processes. The oils are used in perfume, food flavoring, and medicine. Some of the notable oils from Latin American woods are Brazilian sassafras oil *(Ocotea pretiosa = O. cymbarum),* bois de rose oil *(Aniba rosaeodora),* guaiacwood oil *(Bulnesia sarmienti), Cedrella odorata* oil, and cabreuva oil *(Myrocarpus* spp.). The exudates of *Copaifera* spp. (copaiba or Copahu balsam), *Myroxylon pereirae* (Peru "balsam"), *M. balsamum* (Tolu "balsam"), and *Liquidamber styraciflua* (storax or styrax) can be distilled to obtain volatile oils or used directly. Substantial volumes of eucalyptus oil are produced in Brazil, not from the wood but from the foliage of several species. Each species yields an oil with definitive type-composition and characteristics.

As noted in the introduction to this section, Latin American woods have been the source of important commercial dyes. In addition to the brazilwood dyes, logwood extract *(Haematoxylon campechianum)* was also of major importance at one time also as a dye (Record and Hess 1943), for writing ink, and as a biological stain (Conn 1961). Fustic, a yellow-gold dye from *Morus tinctoria* wood, and annatto, a dye and food-coloring from the seed covering of *Bixa orellana,* are among the natural dyes still being produced in limited amounts.

In addition to the previously-listed groups, a wide variety of other chemical raw materials is available from the forest (Duke and others 1989). When such areas are discussed, one of the foremost is medicinals. Certainly one of the most prominent is the cinchona alkaloids from the barks of *Cinchona* spp., quinine for the treatment of malaria, and quinidine for treatment of heart arrhythmia. Although the alkaloids were obtained from Latin America during World War II (Hodge 1948), the primary source of supply now is the East Indies. Waxes, although from the foliage and not the wood, are still important commercial products. One of these tree-derived waxes is carnuba wax obtained from the fronds of the palm *Copernicia prunicia.*

State of the Knowledge

Quebracho Tannin

As noted in the History section of this chapter, the quebracho industry in Argentina and Paraguay has diminished to a very low state. In an effort to put this resource back into use, the Camara Argentino-Paraguaya de Productores de Extracto de Quebracho entered into a program to find alternative uses of quebracho (Camara Argentino 1960) beyond the traditional use in the leather industry. Some of the alternative uses for the tannins that have been developed include uses in oil drilling, ceramics industry, boiler-compound blocks, and dyeing of fishing nets and lines (Serrano 1960). Quebracho tannins are also being considered for use in adhesives (Roux 1989; Hemingway 1989). Other information is being developed on the chemistry and morphology of tannin in quebracho (Fenge 1989). The only indication in the literature that the industry is really looking to develop the processing of quebracho is the work cited on the testing of a new quebracho log debarker (Lombardi and Churin 1972). Research is being conducted on the use of tannins in the manufacture of adhesives, using the extracts of black wattle bark from plantations of the tree (Coppens 1979).

Charcoal

Although considerable knowledge about charcoaling has carried through the ages, extensive research has also been done in recent years. Many of the papers in recent literature are really technology transfer or “how to” documents. Other papers deal with improving the efficiency of the charcoaling operation, examining different species to find the best charcoal producers, and recommending charcoal production for struggling economies.

In an example of the technology transfer-type paper, Rubbo and Milans (1980) discuss the construction of an open or “abierto” kiln for making charcoal. This is one of the first above ground type of kilns used. Florestal Acesita (1982) discusses several types of kilns including simple pit designs, kilns made from 55-gallon steel drums, brick kilns, and steel “Blackrock kilns.” In a similar type of document, Wartluft and White (1984) describe several kiln designs for potential use in the Caribbean. However, they not only describe the kilns and their operation but also present data on the efficiency of each type of kiln. The lowest efficiency is for the simplest pit type, and the most efficient design is the Tongan kiln. The differences in efficiency run from less than 40 percent to nearly 80 percent. Simmons (1963) describes many different kilns, but all of a commercial type. The kilns include cinder block-Hickock and Olsen type, brick beehive type, poured concrete-Missouri type, and several metal retort types. Simmons also discusses the use of thermocouples to monitor the operation. From Brazil, Bastos and others (1986) tell of the development and evaluation of another metal kiln for charcoal production. They claim quick heating, low heat loss, and fast cool down, combined with performance as good as traditional brick kilns.

Torres-Z. (1981) describes the use of portable metal kilns in Ecuador. While demonstrating the capabilities of the kiln, Torres also evaluated 23 native and exotic species for charcoal quality and efficiency in manufacture. Another study to evaluate species for charcoal production was by Senyszyn (1980), who examined seven eucalypts. The wood with the highest green density also had the highest charcoal density *(Eucalyptus paniculata).* Other species evaluated in descending order were *(E. citriodora; E. tereticornis; E. punctata; E. rostrata; E. robusta; E. saligna).* Paula (1982) studied 53 species from Brazil and their acceptability for energy use including charcoal.

Another group of publications delves into the finer details of charcoal manufacture and looks at conditions in the process. Vital and others (1985a) examined the drying time necessary for eucalyptus wood to be charcoaled. They give data based on green moisture content and log size to estimate drying time. In another paper on eucalyptus, Vital and others (1985b) discussed the effect of tree age on the quality of charcoal. They note that the increasing density with age increased the charcoal yield and quality. In yet another study on eucalypts for charcoal, Valente and others (1985) demonstrated that the temperature of carbonization affects the yield and properties of charcoal. In this study, they showed increasing temperature increased wood tar content, charcoal content, and production of pyroligneous acid and uncondensable gases. The temperatures tested were 300°C, 375°C, 450°C, 525°C, and 600°C.

Maldonado (1983) discussed the advantages of charcoal manufacture for the Caribbean area, and Park and others (1983) suggested it as an option for Nicaragua.

Alcohol

The Brazilians, in an attempt to become energy self-sufficient, have probably made the greatest world advances in developing a wood-based alcohol industry. But, even with their incentives and effort, the industry will not become a major producer of alcohol for fuel until technical and economic problems are overcome (Beattie 1979). The problems are the low yields of simple sugars from the wood carbohydrates and the expected high cost of equipment needed to withstand the high pressures and acidic conditions. In the dilute acid process, the yield of sugars is favored by high temperature and pressure conditions. This results in short reaction times for hydrolysis but means expensive process equipment. For an enzyme hydrolysis process to make sugars from wood, the yield of sugars is greater but the enzyme costs presently are high.

Naval Stores

Much of the knowledge of naval stores production and utilization is from the developed countries and is set forth in a recent book (Zinkel and Russell 1989). This knowledge, nevertheless, is directly applicable as many of the commercial pine species are exotics (to Latin America) that have been extensively investigated. Gum production methodology has also been the subject of considerable research at the Instituto Florestal, Sao Paulo (e.g., Rebas and others 1984; Garrido and others 1984).

As noted previously, most of the production of naval stores materials is by tapping, with little being obtained as pulping byproducts. Of the native pine species, several are used as sources of gum naval stores, particularly in Mexico (Tapia 1986). In other central American countries, gum naval stores are derived from *Pinus caribaea* and *Pinus oocarpa.* Rosin from the latter is less desirable because of the higher content of neutral components and the resulting lower acid number.

The composition of the commodity turpentines and rosins can be important in end use. The pinenes are ususally the most desired turpentine components. Although the *b*-phellandrene content (10 percent to 25 percent) in *P. caribaea* turpentine has potential for the synthesis of menthol, sufficient quantities of the turpentine are not available. The turpentine of the exotic *Pinus radiata* is known for its high content of *b*-pinene (Mirov 1961), a preferred material for many chemical products. By-and-large, the composition of the resin acids, the major fraction of the various rosins, differ little. All contain similar proportions of abietadenoic acids and pimaric-isopimaric acids. Rosins derived from slash pine and *P. caribaea* contain up to 5 percent of the labdane, communic acid, which has little effect on utilization of the rosins.

Other Chemical Natural Products

Because of the widespread usage, the production of rubbers from latexes has received much attention. A review of the extensive encylopedic and scientific literature is beyond the scope of this work. The commercial value of *Hevea* rubber is attributable to the cis stereochemistry of the polyterpenes comprising the latex (the polyterpenes in balatta are trans) and the ease in modification for desirable physical characteristrics in the processed products.

The compositions of essential oils have been detailed in recent years by the analytical technique of gas chromatography, e.g., *Cedrella odorata* oil (Lawrence 1987), cabreuva oil (Maurer and Hauser 1988), Bois de rose oil (Lawrence 1984), and sassafras oil (Lawrence 1985a). Although the detailed knowledge of composition can lead to the formulation of synthetics, it can also result in more effective use of an essential oil and the development of new markets. The properties and characteristics for many important essential oils have been reviewed (Arctander 1960; Guenther 1948-1952).

The chemistry of the active dye components in brazilwood and logwood has been known for almost a century. The active component, hemetoxylin, of logwood dye is a hydroxy derivative of the colored chroman, brazilin, found in brazilwood *(Haematoxylon brasiletto)* dye. The colored principles in annato, however, are considerably different and are carotenes, a type of polyisoprene terpenes.

The alkaloids of *Cinchona* spp. have long been a component of native medicine. The isolation of pure quinine was achieved in 1820 and the elucidation of the structure led to the later synthesis of analogs having effective antimalarial activity.

State of the Art

Quebracho Tannin

As Latin America is the source of quebracho tannin, their methodology of tannin production is the state of the art. Approximately 200,000 t of quebracho tannin are produced annually (Porter and Hemingway 1989).

Charcoal

A summary of the production of firewood and charcoal for all of Latin America and by each country is given in Table 5.

As with the pulp industry, the current state of the art is practiced in charcoal making in Brazil, Argentina, and other Latin American countries. Most of the impetus for using charcoal is in the metals industry, where

Table 5–Production of fuelwood plus charcoal for hardwoods and softwoods by Latin American countries 1961-1984[a]

country	Production ($\times 10^3 m^3$)																			
	1961-1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
Bahamas																				
Belize	43	55	60	60	65	65	65	70	66	68	70	72	74	77	79	79	79	79	110	126
Costa Rica	1476	1688	1770	1830	1900	1980	2050	2130	1838	1882	1926	1986	2044	2111	2173	2235	2302	2362	2428	2489
Cuba	1882	1682	1654	1700	1798	1457	1500	1500	2154	2030	2020	1937	1698	1978	2834	2774	2802	2850	2747	2747
Dominican Republic	1680	1800	1800	1800	1800	1840	1840	1840	416	428	440	451	462	473	483	897	926	938	951	963
El Salvador	2628	2296	2296	2296	2296	2296	2296	2296	3295	3387	3486	3586	3695	3802	3919	4037	4152	4275	4404	4530
Guadeloups	32	25	19	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
Guatemala	3430	3750	3700	3900	4000	4050	4100	4300	4920	5074	5233	5395	5562	5733	5908	6086	6270	6457	6648	6844
Haiti	3090	3280	3345	3410	3482	3570	3660	3750	4236	4336	4437	4544	4648	4760	4876	4996	5121	5248	5385	5522
Honduras	2680	2900	3000	3100	3200	3300	3300	3100	3005	3106	3210	3324	3444	3568	3698	3831	3967	4107	4249	4393
Jamaica	1	1	1	1	1	1	1	1	7	7	7	7	7	7	7	7	7	13	31	37
Martinique	13	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Mexico	9126	9180	9180	9170	9150	9120	9080	9020	9880	10207	10542	10860	11183	11507	11834	12163	12489	12823	13160	13501
Nicaragua	1890	1950	1950	2000	1900	1800	1800	2000	1865	1926	1988	2045	2102	2160	2221	2288	2361	2439	2524	2611
Panama	1466	1150	1150	1200	1250	1300	1350	1400	1380	1419	1460	1500	1543	1588	1633	1671	1708	1708	1708	1708
Trinidad	19	14	19	10	15	15	15	15	19	19	16	16	16	16	16	16	16	16	16	16
Total (Central America and Caribbean)	29456	29781	29954	30502	30882	30819	31082	31447	33106	33914	34860	35748	36503	37805	39706	41105	42225	43340	44386	45512

Table 5–Production of fuelwood plus charcoal for hardwoods and softwoods by Latin American countries 1961-1984[a]–con.

Country	Production ($\times 10^3 m^3$) 1961-1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
Bolivia	4322	4600	4000	4000	4000	4000	4000	4000	853	873	893	920	943	966	990	1020	1046	1072	1105	1133
Brazil	117000	130000	130000	135000	135000	135000	140000	140000	127714	130806	133978	137153	140380	143672	147014	150414	153868	157370	160921	164507
Chile	3200	2760	3000	3000	3000	3000	3000	3000	4978	5064	5145	5236	5327	5415	5510	5607	5699	5798	5898	5992
Colombia	22040	22000	22000	22000	22000	22000	22000	22000	11245	11492	11743	12251	12519	12788	13067	13351	13646	13940	14243	
Ecuador	1602	1200	1030	1080	1200	1325	1454	1585	3753	3866	3982	4101	4229	4360	5496	5524	5556	5580	5800	5996
French Guiana	16	16	16	16	16	16	16	16	13	19	25	31	43	48	54	60	66	66	66	66
Guyana	72	34	30	28	47	20	19	14	9	9	10	10	10	10	11	11	11	11	11	12
Paraguay	1727	2095	2793	2926	2394	2527	2660	2491	3359	3573	3780	3985	4046	4132	4230	4320	4350	4380	4410	4440
Peru	4178	4500	4650	4800	4950	5100	5250	5420	5101	5239	5387	5531	5680	5834	5999	6164	6335	6513	6519	6519
Surinam	27	19	15	9	7	5	5	3	17	15	20	33	30	31	33	32	28	13	13	13
Uruguay	1050	1050	704	792	748	748	748	704	1310	1360	1460	1580	1716	1766	1872	1322	1403	2756	2756	2762
Venezuela	5180	5750	5950	6050	6250	6450	6650	6900	469	486	504	522	541	561	581	601	622	643	664	686
Total (South America)	168905	183745	183828	188551	188462	188901	195102	194133	164967	169039	173257	177524	181717	185928	191284	194946	198902	204281	210457	214777
Total (Latin America)	198361	213526	213782	219053	219344	219720	226184	225580	198073	202953	208117	213272	218220	223733	230990	236051	241127	247621	254843	260289

[a] FAO 1978,1986.

the charcoal is used for making steel. Brazil, because of the shortage of oil reserves, is using their vast timber resource to supplement other energy sources. Several articles detail the use of charcoal in the steel industry (Anon. 1964; Beijer 1982; Florestal Acesita 1982b). The Acesita (1982b) paper discusses, in general, the charcoal industry in Brazil, but the author also gives details on two industries using charcoal for energy production and the steel industries' use of charcoal. Others discussing the state of the art in charcoaling in Brazil are Osse (1971), Guerra (1973), and Karstedt and Simioni (1979). While the manufacture of charcoal is done on a vast scale in the state of Minas Gerais, note that most of the wood used is coming from eucalyptus plantations (Beijer 1982). Data on the production of charcoal in Brazil are presented in Potma and others (1976).

Harris and Arnold (1973) give information on the status of wood charcoal use in Argentina. Another report on charcoal use in Argentina is presented by Booth (1974).

In Mexico, enthusiasm has been renewed for the production of charcoal. The USAID is involved in training sessions on the use of portable New Hampshire kilns. In the La Selva ejido in Veracruz, the members of the ejido are building a 7-m-diameter brick kiln with a capacity of near 50 cords of wood.

Alcohol

In Brazil, an attempt was made to produce ethanol from wood in the 1980s using a dilute sulfuric acid hydrolysis percolation process and eucalyptus species. The process was not successful and the hydrolysis portion of the plant was abandoned. Interest continues, however, but with a two-stage dilute sulfuric acid hydrolysis process that has the ability to coproduce furfural. The yield of ethanol from wood is about 1 liter/metric ton (Harris and others 1985). Another process that is technically feasible but presently not economical is a thermomechanical-chemical pretreatment followed by enzyme hydrolysis to produce sugars. The yield of ethanol is greater from this process as compared to a dilute acid process but the enzyme production cost is high. For a hydrolysis process, species selection is not too important but it may be necessary to segregate certain species if the chemical compostion and hydrolysis rates vary excessively.

Naval Stores

Improvements have been made in the gathering of pine oleoresin (Coppen 1984; Greenhalgh 1982; McReynolds and others 1989), including the selection of high-yielding slash pine (e.g., Duchene 1989; Shimizu 1978) as has been done in the United States. Many of the "gum" processing plants are modern and are based on the Olustee process. Most, if not all, are batch operations. Some of the plants are of new construction and others have been relocated from the United States. One stumpwood extraction plant was moved from Oregon to Mexico (Anon. 1976); a new plant, completed in 1963 in British Honduras (now Belize) (Anon. 1963) is now located in Nicaragua. Kraft byproducts contribute little to Latin American naval stores production. Although some sulfate turpentine is recovered, most of the soap skimmings are burned and little is recovered for processing to tall oil (mostly in Mexico). Recovery of soap and conversion to tall oil should greatly increase the supply of naval stores materials and the unrealized potential would be attained from species such as loblolly pine that are not ammenable to productive "gum" production. Information on current production and utilization can be found in published presentations from International Naval Stores meetings and in the Naval Stores Review International Yearbook (most recent is for 1988, Anon. 1989a).

Other Chemical Natural Products

Because of the importance of natural rubber, gathering the latex has been extensively investigated. A number of excellent treatises have been published (e.g., Roberts 1988).

The basic process for recovery of wood essential oils is distillation, steam and or water distillation of wood material, or direct distillation of some exudates. The degree of sophistication in distillation equipment and operation and the handling and quality of the precursor material can greatly affect the quality of the product essential oil. General information on distillation methodology has been published by Guenther (1948). Production data on essential oils are difficult to obtain, but a paper including several wood oils from Latin America was published by Lawrence (1985b). Production for 1984 Brazilian sassafras oil was 450 t; bois de rose oil was 160 t in Brazil and Paraguay; cabreuva oil was 10 t from the same countries; guaiacwood oil was 60 t, almost entirely from Paraguay; *Cedrella odorata* oil was 150 kg; copaiba balsam was 80 t of which half was converted to oil; and Peru balsam was 75 to 80 t of which somewhat greater than half was converted to oil. One of the major uses for Brazilian sassafras oil is the synthesis of the perfumery material, heliotropine (a component used at the level of 2 to 4 percent of the ingredients in U.S. perfumes) from safrole, the main component of the oil (Anon. 1989b). A potential but unrealized market for heliotropine is for the synthesis of dopa, a pharmaceutical used for the treatment of degenerative diseases. Calvin (1987) suggested that Copaiba balsam from *Copaifera multijuga*, because of the high content of sesquiterpenes, can be used directly as a petroleum fuel replacement in diesel engines.

Wood dyes are obtained simply by extraction with water or alcohol. Logwood dye, obtained from the heartwood, is still used as a black dye for silk.

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Sawmilling

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This discussion of sawing research is limited to the initial breakdown of logs into lumber and the subsequent sawmill operations dealing with lumber manufacture. These operations may include edging and trimming of boards and resawing of cants.

History

The following historical account of the sawmilling industry in Latin America was published by the United Nations, Food and Agriculture Organization (FAO) (1970).

> It is not known exactly when or where the first sawmill was established (Fig. 20). A description of a water-driven sawing machine was made in England in 1245, and Nelson C. Brown says in his book *Lumber*[1] that the first sawmill in the USA was reported to have been built in 1625. There can be no doubt, however, that the desire to cut trees into planks and boards goes back much further in the history of mankind. Thus, a sawblade made from bronze and more than three thousand years old has been found in Egypt.
>
> Nor has it been established when the first sawmill or sawing machine came to Latin America; but this occurred most probably during the colonization period of the region. History has it that mahogany planks from Central America went to England in 1595, and that more than 500,000 bf of "sawn" mahogany was exported from Jamaica in 1793.
>
> It is a fact that sawmilling is the oldest of the forest industries in the region. Even to-day it is possible to find all the stages of the evolution of this industry, from the most primitive hand-driven pit-saw to the most modern automatic sawmill. A large number of pit-saws are still operating in Colombia and Ecuador; water-driven sawmills can be seen in Brazil and primitive and home-made reciprocating horizontal bandsaws [sic] in Paraguay.
>
> Early sawmilling operations were undertaken by small and mostly mobile sawmills, mainly to satisfy local demands for sawn lumber. Larger mills (i.e., real sawmilling industries) scarcely existed in Latin America before World War I and, paradoxically, many of the larger and better organized mills were set up to satisfy export markets rather than to cover the needs of the region, which in many places were met by imported goods.
>
> Thus Brazil started to export its sawn Parana pine only around the beginning of World War I when the Southern Brazil Lumber and Colonization Company built what was at that time a modern sawmill in Santa Catarina. However, this mill stopped operating many years ago for lack of raw material.
>
> Several of the hardwood-producing countries of the region experienced a boom during the Second World War, when supplies of sawnwood to the United States of America from the Far East and from Africa were interrupted. This resulted in the establishment of a number of new sawmills which, together with those already existing, covered a substantial part of the United States' consumption of tropical hardwoods.
>
> Technically, this period was a turning-point in the sawmilling industry of the region, because most of the new mills that were built were equipped with bandsaws which, at that time, were practically unknown as mainsaws in Latin America.
>
> In the post-war period, when the sawmilling industries in other regions (especially Europe) were busy with rebuilding and expansion, little change took place in this sector in Latin America; judging by the number of new wood-based panel industries which were built in those years, some of the countries of the region were busier in this field than in sawmilling.
>
> A new era for sawmills in Latin America began in the sixties. Enjoying a fast-growing prosperity, North America and Europe increased their demand for sawnwood beyond the point of self-sufficiency, and more and more timber was imported from the developing countries. This situation gave rise to the first modern, adequately-equipped sawmills in Latin America. Several such mills have been installed in the coniferous areas in Chile, Honduras and Mexico, and new hardwoods mills have since appeared in Brazil, Chile, Paraguay and in some places in Central America.

[1] Brown, N.C. 1958. Lumber. 2nd ed. New York: John Wiley and Sons. 379 p.

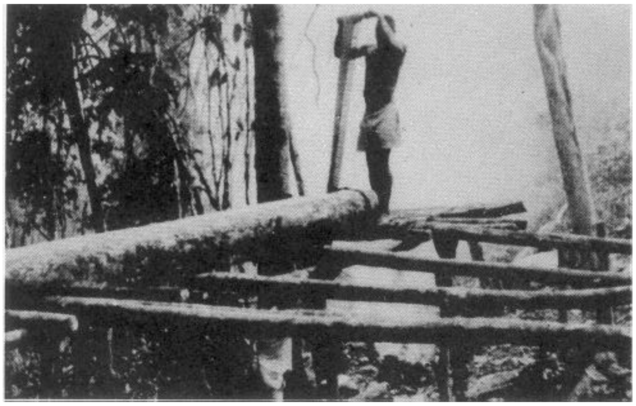


Figure 20-Pitsawing is still done in Latin America. (M90 0146)

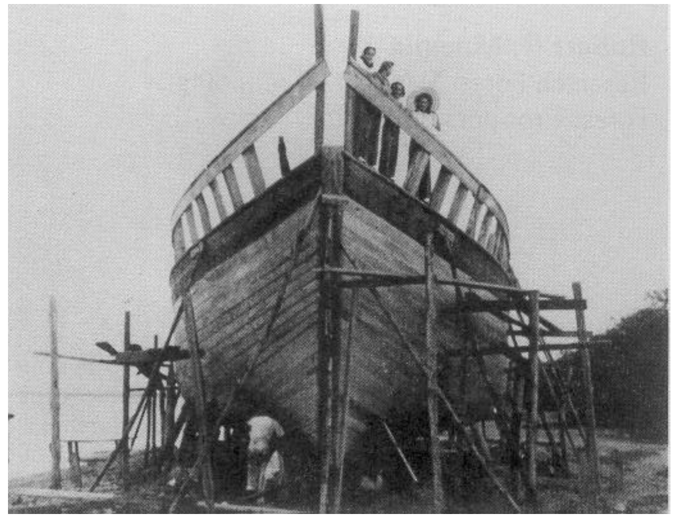
> A large number of new and modern mills are likely to be built in the next few years, but they will hardly change the general picture of the sawmilling industry of the region, consisting as it does of some 18,000 installations, the majority of which are small, underpowered and poorly equipped. (FAO 1970)

With the beginning European presence in the Americas, undoubtedly shipwrights and carpenters were aboard the ships. They most likely used native timbers in ship repairs. This most assuredly involved the handsawing of timbers. As early as 1535, the Spanish had begun shipbuilding operations on the west coast of South America. By 1602, the shipbuilding industry, using hand tools for construction, was well established at what is now Guayaquil, Ecuador (Teesdale 1945) (Fig. 21).

In an historical account of the sawmilling industry in Ecuador, it is noted that the arrival of the conquistadores brought metalworking tools and the exploitation of the "harder and thicker species." They state

> At the end of the 19th century a partial and slow development took place thanks to a century long development of the motor and the steam engine in other continents. The first mechanized saw mills were installed in Ecuador during this last decade.
>
> We know of a very large saw mill established around the year 1890 in the township of Limones in the Esmeraldas Province.
>
> We can assume that similar ones were also established during this year in and around Guayaquil (AIMA 1985).

Latham (1957) lists London imports from Jamaica of mahogany lumber (plank) in the years 1729 and 1730. Although it is not known how these planks were cut, it is likely that they were pit sawn. We know that pit saws are still used for the manufacture of lumber and squared timbers in Latin America. We were told of



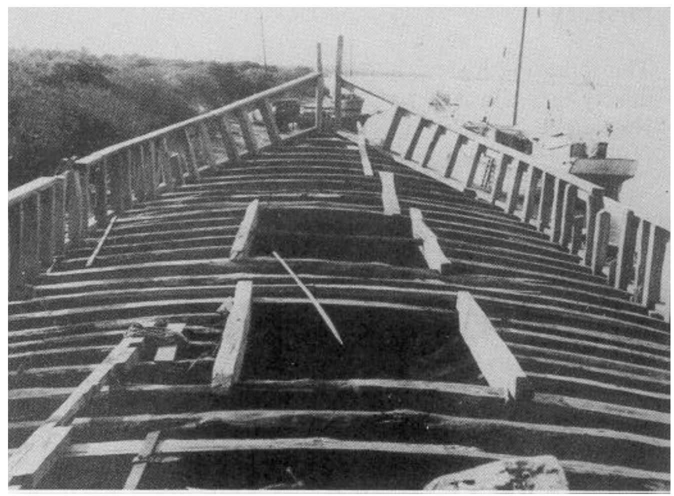


Figure 21-Wooden shipbuilding from trap ical woods, Ecuador (1940s). (M90 0170, M90 0123)

their current use in Guatemala. Teesdale (1945) referred to the use of "whip saws" for the preparation of timbers in Ecuador in 1945. Simmons (1916a, 1916b), writing about the lumber industry on the coasts of South America, noted that whip saws and other handsaws were being used, also "up-to-date" circular saws, band saws, and gang saws were being used. Today, the same situation exists with the full range of sawing methods. In some cases now, however, the pit saw has been replaced by the chain saw.

Although the primitive types of sawing are still in existence in Latin America, the major production is from the more modern and better equipped mills.

State of the Knowledge

The state of the knowledge about sawmilling in Latin America is primarily the state of the knowledge as developed in Europe, North America, Australia, and Japan (Pahlitzsch 1962). In our search of the literature, limited work was cited by Latin American researchers. One important area of research that has been worked on in Latin America is that of sawing dense tropical woods (Ninin 1970, 1980). Noack and Frühwald (1980), working in Germany, have also studied the effects of high density and other wood properties on the sawing of tropical woods. This subject is discussed by Chardin (1960) and Hasek (1960), in their papers on choosing the correct type of sawmill for tropical regions. All of these authors suggest the use of special saw teeth, such as carbide, chrome, or stellite, to cut the very dense or siliceous woods. Most of the research on carbide, chromium, or stellite tipping of saw teeth has been done in Australia (Jones 1963, 1965; Krilov 1976), Canada (Halvorson and Stuart 1963; Kirbath 1979, 1985; Kirbach and Bonac 1981; Kirbach and Bonac 1982a, 1982b; Kirbach and Chow 1976), Europe (Anon. 1974, 1975, 1977; Antoine 1963; Chardin 1971), Japan (Okumura and others 1978; Sugihara and others 1979), Russia (Dunaev 1977; Sanev and others 1977; Solov'ev and others 1986), and United States (Anon. 1980; Hallren 1985; Norlander 1985; Segal 1975; Stewart and others 1986; White 1976).

Other areas of research have included sawing and machining studies on individual species (Bailon 1981; Bejar-M. 1982; Olguin-Q. and Bailon-H. 1984; Saldarriago 1979), yield studies for sawmills (Wettling and Planas 1965), an evaluation of the effects of physical, mechanical, and chemical properties of wood on the sawing process (Ninin 1969, 1970), tests of different power sources for sawmills (Terreros 1965), and status reports on the sawmilling industry (Bruce 1976; Dijkmans 1961; Gonzalez 1975; INDERENA 1972; INFORCORFO 1984, 1985; Melchor-Marroquin 1984; Stahelin and Everard 1964; UNDP/FAO 1968).

The use of small portable mills for social development has also been investigated in the tropics (Davis 1985; Page 1978; Plumtre 1978; Saravia 1978; Silva and others 1978) (Fig. 22). Although social development is not technical in the sense of processing or machinery, it is important in the structure of the industry in the various countries and in the distribution of timber products to the market. It also affects the way the forests are managed.

A major part of the state of the knowledge is expressed in technology transfer. In this area, some good documents are available on sawmilling. The documents mentioned earlier by Chardin (1960) and Hasek (1960) on choosing the right type of mill for tropical woods are good sources of information for selecting and designing sawmills. Sanchez (1983) describes techniques for siting sawmills in Mexico.

Two good manuals from Chile describe the setup of circular and band sawmills and the maintenance of equipment (Quesada and others 1969; Quesada and Roseberry 1969) (Fig. 23). Other documents on the maintenance of band saws (Martinez 1976) and circular saws (Castaneda 1985) have been published in Mexico. Ninin (1974, 1975) describes the form and function of

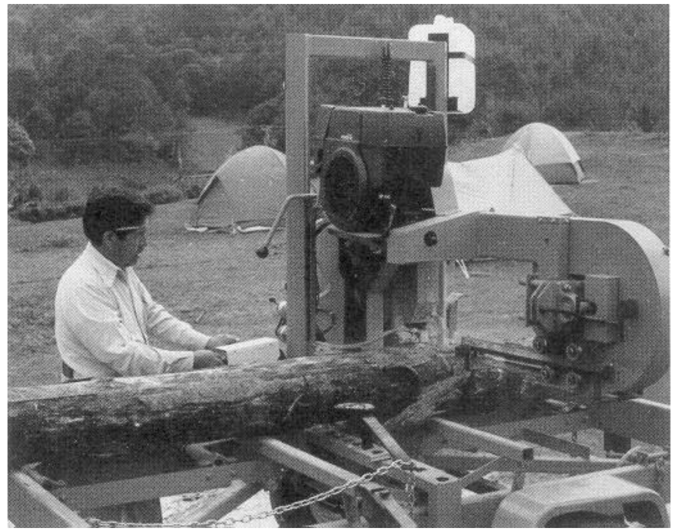


Figure 22-Portable bandsaw operation in Veracruz, Mexico. (M90 0147)

a band saw and how band saw blades fail. And, a complete manual from Centre Technique Forestier Tropical (CTFT) in France on sawing, including tropical woods as used in French Guyana, includes sawing techniques and saw maintenance information (Dalois 1977).

Further documents are available in the area of sawmilling from FAO as follows: Small and medium sawmills in developing countries (FAO 1981); Frame saw manual (FAO 1982); Circular saw manual (FAO 1983); Cost estimating in sawmilling industries: guidelines (FAO 1984); and the Sawdoctoring manual (FAO 1985).

Although little research literature on sawmilling was found from Latin America, undoubtedly a great deal of basic knowledge about sawing the various species is available from sawyers. If this empirical knowledge could be combined with a better understanding of equipment and materials, the state of the knowledge could be advanced greatly.

State of the Art

Although it is redundant, it needs repeating. The state of the art in sawing in Latin America covers a full range, from primitive to very advanced. As mentioned earlier, pit sawing is still practiced in many Latin American countries. The next step up from pit sawing is the use of chain saws for lumber or cant production.

In Ecuador, and undoubtedly in many other countries, chain saws are being used to cut cants in the forest (Fig. 24). These cants are limited in size because of handling and transportation considerations. Most of the cants are in the range of 8 to 10 cm thick by 15 to 30 cm wide by about 2.5 to 4 m long. This size limitation is because mules are used to carry the cants from the forest, and they cannot handle anything larger.

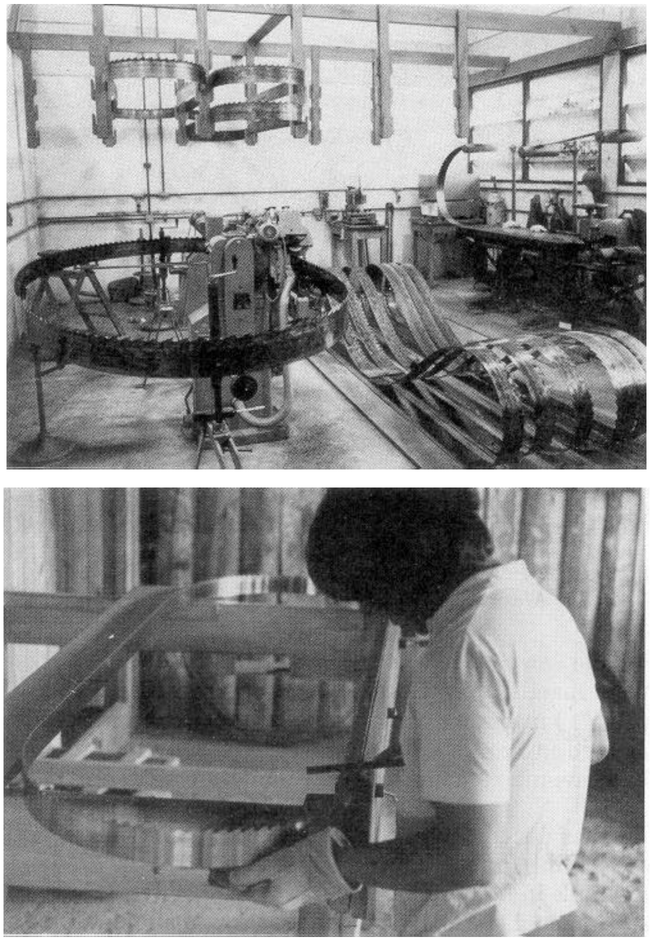


Figure 23-Typical bandsaw filing room in Brazil (top); hand-filing a bandsawblade in La Selva Ejido, Veracruz, Mexico (bottom). (M90 0171, M90 0124)

Occasionally, larger pieces are cut and pulled out singly by the mules. These pieces are tapered on the front end (boat shaped) to facilitate pulling. Chainsaw cutting is inefficient because of the large kerf. Also, the *campesinos* who do the cutting usually get only three or four of these pieces from a log and generally cut only five or six pieces per day.

The process is even more wasteful because the cants may lie in the forest for 3 weeks to 3 months before being transported to a user. This delay allows for end checking of the pieces and a substantial degrade. In Quito, we observed such materials in both furniture factories and lumberyards. At the furniture factories, workers are usually able to recover only one 2.5-cm-thick piece of suitable lumber from a cant. This yield is extremely wasteful of the resource and needs to be corrected.

The next level up from the pit saw and the chain saw is the small circular sawmill. This type of sawmill is still found throughout Latin America, more in some areas than in others (Fig. 25). These circular sawmills are generally, but not always, low-production, low-quality mills that are poorly maintained and inefficient. In

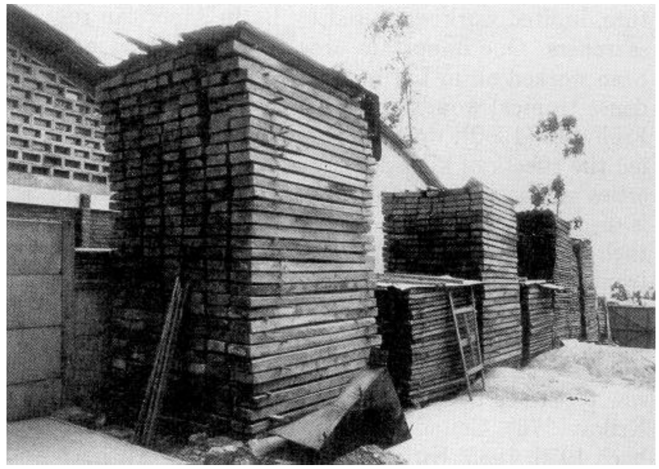


Figure 24-Cants cut with chain saw *in Ecuador; recovery of one 25-mm-thick board per cant is typical. (M90 0148)*

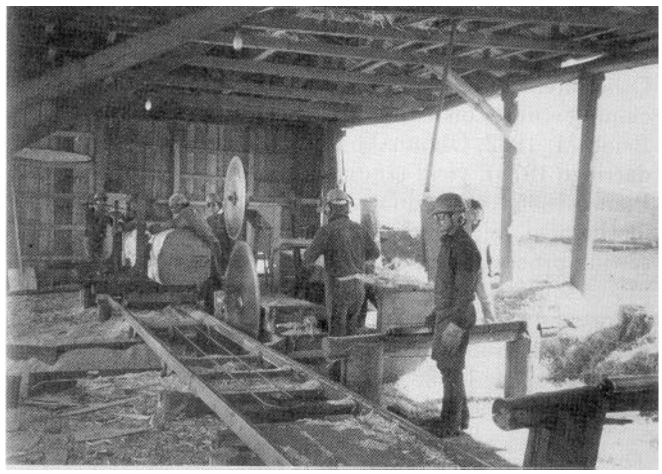


Figure 25-Circular sawmill in Talcahuano, Chile. (M90 0172)

1971, 76 percent of the sawmills in Colombia were circular mills (INDERENA 1972), while in Paraguay, few circular sawmills existed in 1968 according to Lunstrum (1968). The mix of sawmill types in Chile in 1983 was nearly 50/50 for circle and band mills (INFOR-CORFO 1983). The major problems with the circular sawmills are lack of blade maintenance and misalignment of the carriage with the saw. We noted a circular sawmill at one location that had very good equipment but the saw wobbled, almost violently, through each cut. Tensioning of the blade was nonexistent. The manager of the mill acknowledged that the blade had not been worked on since it was installed. Many of the mills use heavy 6- to 8-gage saws with normal kerfs to 8 mm. With no maintenance of the blades, the kerf expands even more. Misalignment of the carriage adds to the manufacture of poor-quality lumber and reduces the efficiency of the mills.

Other saw types currently in use at different locations in Latin America are sash gangs (Fig. 26), reciprocating

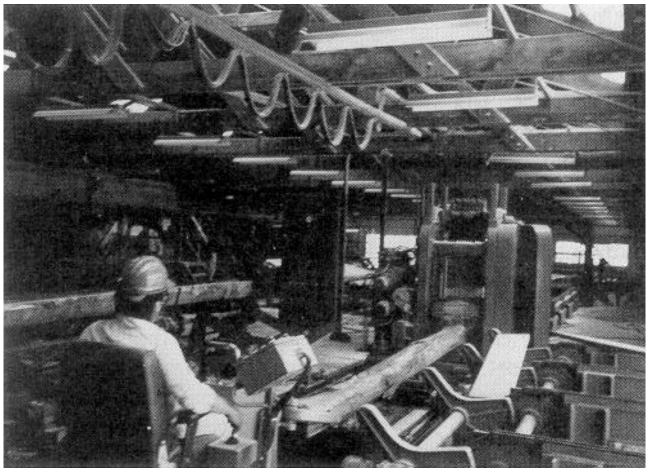


Figure 26-Sash gangsaw cutting eucalyptus at Lota, Chile. (M90 0125)

drag saws, and horizontal and vertical band saws. The reciprocating saws are dwindling in number as are some of the older style sash gangs and horizontal band saws. Even with the replacement of the older equipment, however, virtually every status report on sawmilling in Latin America comments on the poor operating conditions of the mills. One of the biggest problems is the lack of ready parts for the maintenance of machines. Another major problem is the underpowering of mills. These problems, when added to the misalignment and lack of saw doctoring, which occur with other saw types as well as with circular saws, result in mismanufactured lumber and a waste of resource (Bruce 1976; Compton 1965; FAO 1970; Kernan 1951; Lunstrum 1968).

The currently preferred type of sawmill for most tropical operations is the vertical band mill (Fig. 27). Lunstrum (1968) notes that because of the weight of many of the logs being cut in the tropical areas, heavy duty equipment is needed. He noted that in 1968, most of the band saws had blades that were less than 5 in. (12.5 cm) in width. This is too narrow for the best performance. In most of the temperate world, minimum blade width in band headsaws is 8 in. (20 cm), but many mills are using blades to 14 in. in width (35 cm). Chardin (1960) recommends band saws as the most versatile. He states, “There is practically no sawing operation that they cannot handle.” However, he warns that, “Selection of the size of the saws is made commensurate with the stress to which it is subjected.” This advice agrees with that of Lunstrum and of Hasek (1960), who commented, “I am in favor of big sawmills. For heavy tropical timbers only heavy and expensive equipment is suitable. The capital expenditure is out of proportion for small and medium size sawmills. For the dense abrasive timbers only larger band saws with wider than standard blades are satisfactory.”

Industrial reports indicate the use of band saws for sawing both dense hardwoods and softwoods in Latin America (Blackman 1980a,b, 1981; Ogle 1981, 1982).

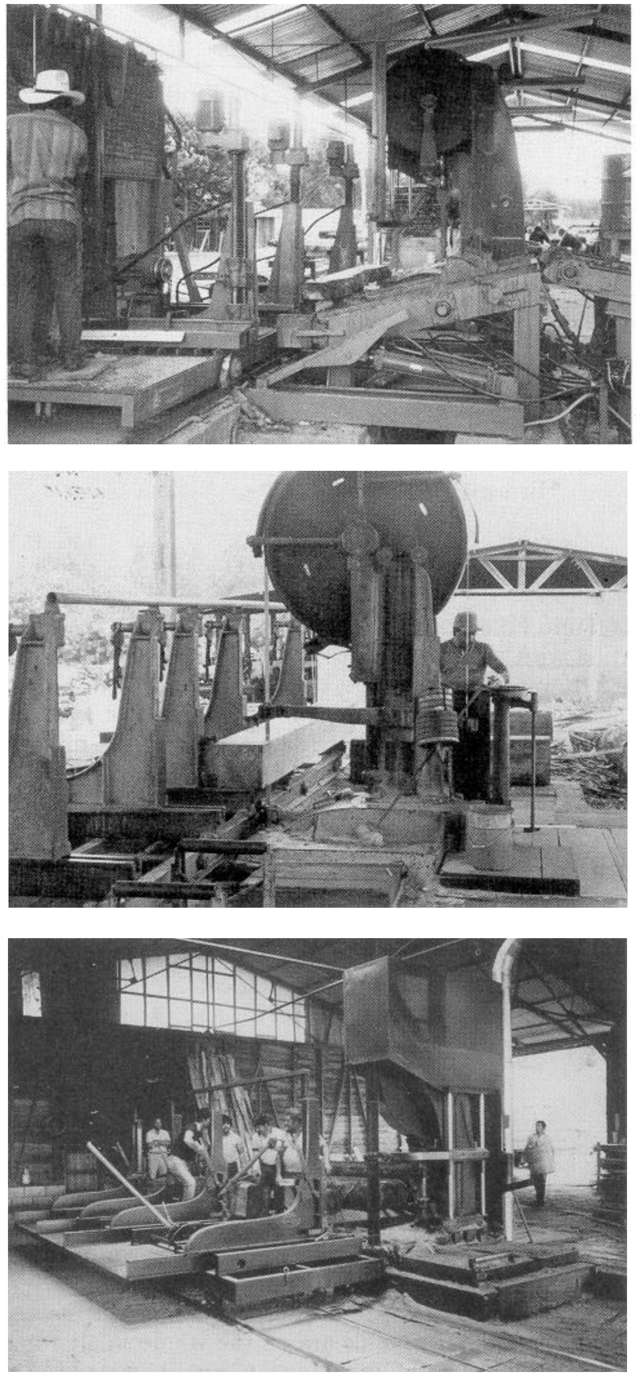


Figure 27-Bandmill cutting oak in El Salto, Durango, Mexico (top). Bandmill at Matemoros Sawmill, Upata, Venezuela (middle). Bandsaw at Paso Llano S.A. Sawmill, Costa Rica (bottom). (M90 0149, M90 0173, M90 0115)

Sash gang saws are used in the tropical areas but as head saws, they are quite slow. They are quite fast for resawing cants, however. In some locations, like Chile where softwoods are the principal timber, gang saws are used to good advantage especially on smaller dimension logs (Blackman 1983). Combinations of band saws and gang saws are also reported in Chile (Blackman 1984).

Table 6–Number and percentage of sawmills in the Amazon region of Brazil[a]

Annual production of sawnwood (100 m^3)	Total mills	
	Number	Percent
1- 15	118	39
16- 30	42	16
31- 45	23	8
46- 60	26	10
61- 75	23	8
76-150	42	15
151-225	9	3
226-300	4	1
Total	287	100

[a]Bruce 1976.

Argentina

Jose Tinto (1988) says there are 1,600 sawmills in Argentina with a production capacity of 2,200,000 m^3 per year. However, he indicates that in 1984 they cut only 930,000 m^3. Although a breakdown on mill size was not given, it is assumed that the majority of the mills are small, producing on the average less than 600 m^3 per year.

Brazil

In Table 6, sawmill data are shown for the Amazon region of Brazil. These data are from a 1973 survey (Bruce 1976). From these data, you can see that the small sawmill predominated in 1973, and the situation is the same today in most of Latin America.

Chile

The 1984 survey of sawmills (INFOR-CORFO 1985) shows a situation in Chile similar to that of the Amazon region a decade before (Table 7). As seen in Table 7, the production of the two largest sawmill categories (which represents only 2 percent of the mills) represents 43 percent of the total production. In the Chilean situation, the mills are on the whole smaller than those in the Brazilian Amazon, but the trends are similar. In 1987, INFOR-CORFO reported the 1986 statistics on the 20 principal sawmills in Chile (INFOR-CORFO 1987b). The production of the mills varied from 16,500 m^3 to 119,000 m^3 per annum, with a total production for all 20 mills of 2,025,000 m^3. In 1987, the Chilean production of sawn products increased to 2,677,082 m^3 (Anon. 1988). INFOR-CORFO (1988) shows 84 mills producing over 5,000 m^3 per year (61 percent of national production) and 1,172 mills producing less than 5,000 m^3 per year (39 percent of national production).

In December 1987, we visited several sawmills in central and southern Chile. The mills ranged from very small steam-driven mills to large high-production mills sawing both pine and hardwoods.

In the city of Talcahuano, the pine mill Aserraderos San Vicente Ltda. was visited. The mill combined modern capital intensive equipment with low-labor requirements and a second side with older more primitive equipment with high-labor requirements. The equipment in the small, modern high-speed log mill was German Linck, and it included chipper canters and a circular gang saw. The principal product at the time of our visit was l-in. lumber for export. The production of the older circular mill was cants and 2-in. lumber, also for export. Cants were sawn, from large logs, on a Chilean-made circular head saw with overhead blade. Cants, 100 to 150 mm thick were edged on a circular saw with linebar and manual feed. Edged cants were resawn on two band saws with linebars, one Chilean made and one Swedish made. Employment at the mill was about 200 with more than half in the older mill.

Near the city of Lota, we visited the eucalyptus mill Forestal Rolcura S.A. This is an integrated sawmill and veneer mill. The sawmill consisted of two sides, for large and small logs. The small side used a German Linck sash gang, and the large log side used a German Canali band saw. Production was l- and 2-in. lumber primarily for export. Small amounts of *Acacia melanoxylon* and *Cupressus sempervirens* were also being cut and processed into paneling and flooring. Saw blades were sharpend with Forano equipment and hand tensioned.

A mill owned by the Universidad Austral de Chile, in Valdivia, processes 11,000 m^3 of logs per year. The head saw is a German Linck sash gang used for canting and live sawing boards. Logs larger than 25 cm are canted, and those smaller than 25 cm are live sawn. The species being cut are primarily *Pinus radiata* and a much smaller amount of tepa *Laurelia phlippiana.* The pine is made into board products, and the tepa is made into broom handles. All processing of these products is done in the mill. Cants are resawn on a German linebar band resaw. Some of the sash gang blades are laser incised to eliminate tensioning (Fig. 28). The manager said that this is working very well. Band and gang saws were filed on Volmer equipment. Near the city of Lance, a steam powered mill was visited. This was a small mill cutting roble *Nothofagus obliqua.* The power source was a British steam engine, with a belt driving a circular mill with topsaw and a small circular rip saw. The product was generally wide 1-in.-thick boards of quite high quality. The production was small and had a large workforce. The manager noted that the mill was typical of many small sawmills in southern Chile.

Colombia

In the proceedings of the First National Congress of Industries Derived from Wood (Primero Congreso National de Industrias derivadas de la madera) in

Table 7–Sawmills in Chile, production and corresponding percentages[a]

Annual production of sawnwood (1,000 m^3)	Production 1984		Total mills	
	Volume (1,000 m^3)	Percent	Number	Percent
0- 1	215	11	1,243	78
l- 2	219	11	151	9
2- 5	463	23	143	9
5-10	249	12	38	2
10-18	113	6	8	1
18 and greater	-738	37	14	1
Total	1,997	100	1,597	100

[a]INFOR-CORFO 1985, 1987a.

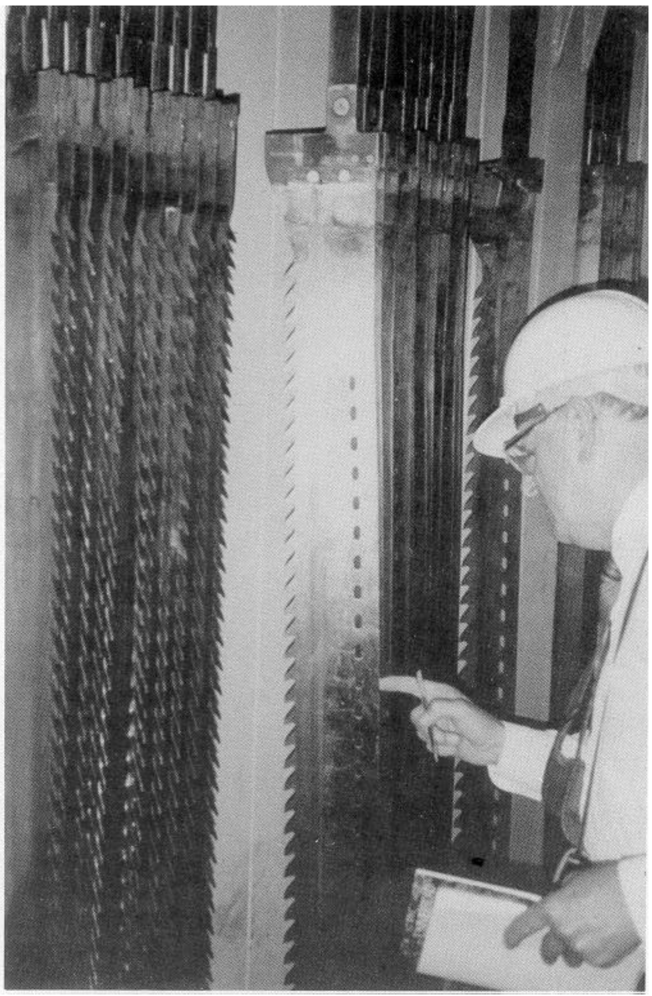


Figure 28-Laser-incised sash gangsaw blades at Vniversidad Austral de Chile sawmill, Valdivia, Chile. (M90 0139)

Medellin, the state of the sawmilling industry was given (Valdes-S. 1983). Valdes states that the sawmill industry in Colombia is generally composed of small mills (by international standards). The mills, for the greater part, have old equipment that is obsolete and functions poorly. Valdes also says there are many management problems; for example, material flow, cutting technology, product classification, subsequent treatment of product, repair and maintenance of equipment, and training of personnel.

In regard to sawmill production statistics, Valdes states that there were about 4,200 sawmills in 1983 with an installed capacity of 1,146,600 m^3. He also states that only 300 mechanical sawmills were in the country with the remainder being manual sawmills. The production of the manual mills was 43 percent of the total wood sawn. Although Valdes shows capacity for production as 1,146,600 m^3, the actual production was only 75 percent or 860,000 m^3. Table 8 shows the 1983 production as 721,000 m^3.

Costa Rica

In some countries, such as Costa Rica, there are no large production sawmills, in the sense of those found in Brazil or even in Chile. In 1975, Costa Rica reported 163 sawmills (Gonzalez 1976). Of these mills, 60 percent produced less than 10 m^3 per day (about equivalent to 2,500 m^3 per year) and 25 percent produced between 20 and 40 m^3 per day (Table 9).

Venezuela

In March 1988, an FPL team visited Venezuela where we spoke with Julio Centeno, Director of the Instituto Forestal Latinamericano (IFLA). Centeno noted that 70 percent of the Venezuelan sawmills are small, but the newer and larger mills are beginning to take over the national market.

We visited several sawmills in or near the city of Upata in the Guayana region. All the mills were band mills, most of them Brenta mills of 1.4 to 1.8 m diameter, with bands of 10 to 15 cm width. The Asseradero Matamoros mill was stelliting saw teeth for extended wear, and said they had done it for 20 years. All the mills were cutting a mix of tropical hardwoods with greatly varying density and silica content. Other than sharpening blades and some tensioning, blades required

Table 8–Production of sawnwood plus sleepers for hardwoods and softwoods by Latin American countries 1961-1984[a]

Country	1961-1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
	Production (× 10^3 m^3)																			
Bahamas	6	6	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Belize	38	26	23	32	17	21	18	18	25	18	16	20	16	17	18	41	38	42	33	38
Costa Rica	288	333	341	351	375	405	435	414	547	519	612	513	689	689	364	524	534	376	306	412
Cuba	144	106	82	77	116	96	105	105	105	105	105	105	105	105	101	112	108	107	107	107
El Salvador	15	20	20	20	20	20	20	20	20	30	38	31	34	33	37	37	47	45	39	39
Guadeloupe	3	4	4	3	3	3	3	3	3	3	3	3	2	2	1	1	1	1	1	1
Guatemala	136	162	172	197	198	204	205	217	236	207	222	326	353	346	138	93	136	130	104	103
Haiti	18	16	15	13	14	13	14	14	14	14	14	14	14	14	14	14	14	14	14	14
Honduras	582	545	442	518	524	457	455	656	731	579	551	598	628	633	624	560	560	489	468	427
Jamaica			1					34	34	34	34	30	29	24	25	25	25	25	23	31
Martinique	2	4	5	3	3	2	2	3	3	3	3	3	1							
Mexico	1243	1548	1645	1658	1624	1572	1534	1803	1938	2055	1986	2147	2259	2299	2109	1991	1928	1669	1827	1711
Nicaragua	125	131	145	152	162	197	272	301	351	351	402	402	402	402	402	402	402	402	222	222
Panama	49	51	74	50	45	44	46	47	47	53	50	81	33	12	12	53	53	53	53	53
Trinidad	47	45	48	35	50	64	57	35	40	41	32	32	32	32	32	33	33	28	22	21
Total (Central America and Caribbean)	2696	2997	3018	3110	3152	3055	3167	3671	4095	4013	4071	4304	4597	4609	3878	3873	3880	3382	3220	3180

Table 8–Production of sawnwood plus sleepers for hardwoods and softwoods by Latin American countries 1961-1984[a]-con.

	Production (× 10^3 m^3)																			
Country	1961-1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
Argentina	847	1042	868	863	923	736	760	594	388	335	480	631	859	640	908	883	047	1192	1237	1237
Bolivia	35	55	66	71	90	95	101	103	153	150	140	143	109	167	233	220	172	117	97	97
Brazil	5791	6072	6618	6965	7476	8035	8100	7550	7109	7642	10129	11243	12643	13337	14070	14881	15852	15852	15852	15852
Chile	1029	1130	952	1140	1078	1075	1093	1134	1059	1478	1320	1223	1267	1478	2199	2186	1735	1176	1610	2001
Colombia	1013	1005	1025	1060	1052	1100	1180	1258	1261	934	954	934	934	934	983	970	1006	721	721	721
Ecuador	352	579	555	585	644	704	770	796	836	835	747	752	852	762	830	905	986	980	1142	1212
French Guiana	7	12	16	17	14	12	7	8	9	9	10	10	10	14	19	19	19	19	19	19
Guyana	70	89	84	83	92	87	73	69	68	82	66	82	75	51	61	70	70	70	70	70
Paraguay	104	136	137	154	213	214	213	230	269	325	340	345	314	380	524	655	655	655	655	655
Peru	186	338	306	237	240	245	260	384	391	467	516	786	476	486	546	611	653	577	577	577
Surinam	45	56	53	57	64	53	63	45	58	48	79	59	64	68	90	79	63	61	61	61
Uruguay	70	70	74	78	80	73	57	66	72	80	105	117	107	104	99	99	100	47	16	16
Venezuela	219	205	201	250	311	328	328	326	332	378	349	349	349	349	349	349	349	220	210	210
Total (South America)	9767	10790	10956	11560	12267	12757	13005	12563	12007	12763	15234	16673	18058	18770	20911	21926	22707	21687	22267	22728
Total (Latin America)	2463	13787	13974	14670	15419	15812	16172	16234	16102	16776	19251	20977	22655	23379	24789	25799	26587	25069	25487	25908

[a]FAO 1978, 1986.

Table 9–Distribution of sawmills by their daily capacity and production for Costa Rica[a]

Mill size (m^3/year)	Total actual production		Total production capacity	
	Number	Percent	Number	Percent
0.0- 4.9	41	26	26	16
5.0- 9.9	52	33	46	29
10.0-14.9	28	18	28	18
15.0-19.9	12	7	20	13
20.0-24.9	11	7	12	8
25.0-29.9	5	3	7	4
30.0-34.9	5	3	2	1
35.0-39.9	5	3	4	3
≥40	–	–	13	8

[a]Gonzalez 1976.

a minimum of maintenance. A mixture of swedged and set teeth was used. The YOCOIMA mill was in the process of rebuilding and changing from an older Brenta mill to a numeric controlled Primultini. They used set teeth and intend to continue using them with the new mill. This mill also had a Schiffer band mill made in Brazil. The sharpeners that we saw were Vollmer.

North of the Orinoco River is a large pine plantation and a sawmill for processing pine. Both are owned by the Corporation Venezolana de Guayana. The mill is a Linck, two-saw scragg canter, followed by a circular gang. This is a new mill capable of processing 11 logs per minute, cutting either cants, boards, or structural lumber. The mill manager expressed the definite need for saw doctoring. They are currently processing thinnings but later expect to go into full log production and even expand the mill.

To put the production of lumber in better perspective, Table 9 shows the production of sawn wood and sleepers in Latin America from 1961 to 1984. The table also separates the figures for Central America and the Caribbean from those for South America.

It can generally be said that many small sawmills operate at a low level of efficiency throughout Latin America. This, however, is also true of the rest of the world. Some larger and more efficient mills are in operation, which produce the major portion of timber that is sawn in Latin America. Overall, sawing practices and maintenance of equipment need to be improved. The lack of ready parts for machinery, the lack of saw doctoring capabilities, and the poor layout of mills are hurting the efficient operation of the Latin American sawmill industry. There are exceptions, of course, where mills are modern, well designed, and well maintained, they produce at a high and efficient level. Several schools in various countries are attempting to provide training in the areas of saw doctoring, saw maintenance, and saw operation. Examples are Instituto Technologico de Costa Rica (ITCR) in Cartago, Costa Rica; Universidad National de Colombia in Medellin, Colombia; Escuela National de Ciencias Forestales (ESNACIFOR) in Siguatepeque, Honduras; and ITF in El Salto, Durango, Mexico. There may be other training centers of which we are not aware.

Perhaps the key words to express the needs of the Latin American sawmilling industry are quality control–quality control over mill maintenance and quality control over products.

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Drying

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History

The need for proper drying of wood to avoid distortion or to achieve the desired strength properties was undoubtly known by early peoples. As soon as the tree is cut and/or the log is opened and the wood is exposed to the air, drying begins. Even in ancient times, observant workers recognized that they could exert some control over the drying and thereby get better results in their finished products. As far as we know, the Egyptians were among the first cultures to make rather sophisticated items of wood, and they undoubtly learned these concepts in the process. About 2,500 years ago the Greek builder, Hesiod, and the Roman builder and architect, Vitruvius, among others, ordered the piling and drying of wood before they used it in their structures.

Early New World peoples likely discovered that drying occurred when a tree was felled or when an article was carved, although we do not have records of their taking specific actions to intentionally dry wood before use. It is likely that craft workers making items requiring close fitting joints, such as furniture, musical instruments, or boats, were the first to discover that wood changed as a result of drying. Those craft workers concerned with use of poles or heavy timbers were probably later in discovering the effect of drying.

Some of the more advanced Indian cultures (e.g., Mayans and Aztecs) used wood as decorative items in their elaborate stone pyramids, temples, and in structures atop the pyramids. Columbus found the Indians of the Caribbean using dugout log canoes, shaped or carved wooden paddles, and wooden stools or benches, some decorated with carving. These people undoubtly learned by trial and error which woods to use for different items to get the best results. They probably also found which woods had the most or least shrinkage, and that dry wood was stronger than fresh cut or green wood.

Discovery of the New World brought discovery of mahogany, since known as one of the world's fine woods. The earliest piece of wood bearing the marks of the European craft worker is a rough mahogany cross in the Cathedral in Santo Domingo dated 1514. On his second trip to the New World, Columbus established Santo Domingo as the capital of the first Spanish colony in the New World in 1496. The Cathedral, finished in 1540, contains mahogany used as structural members and decorative pieces.

Other early evidence of the use of wood and obvious processing is in the shipbuilding in Guayaquil, Ecuador, in 1535. By 1602, this industry was well established. In that year, two large galleons were launched for the Spanish government.

State of the Knowledge

Interest in gaining specific data on the drying of wood apparently originated in the gathering of data on the physical properties of wood. Our earliest evidence of interest in accurately determining the physical properties, which includes drying and shrinkage data, began at the FPL around 1910 to 1915 (Horn 1918; Maudlin 1917). In these early works, concern for information on drying and shrinkage properties of the woods was generally less emphasized than strength properties. This was also the case of early work done in Latin America (Colombia) (Robledo-U. and Robledo-U. 1934). The earliest data on air-seasoning of local Latin American species appeared when results of air-seasoning 22 species, in a covered shed, were published by the Trinidad Forest Department (Anon. 1926; Brooks 1931). By the 1960s, it became common in research to note the drying characteristics and the time required to air-dry lumber from the green condition to some nominal air-dry condition (e.g., 20 percent moisture content).

The earliest scientific reference found on kiln-drying Latin American woods is work done at the FPL on five species from Brazil (Brewster 1920). From 1920 to 1935, studies involving drying characteristics of numerous woods from Brazil, Argentina, and Cuba were conducted at the FPL (Heck 1920, 1935; Koehler 1927, 1928). The earliest publication noted on kiln drying originating in Latin America was from the Instituto de Pesquisas Technologicas (IPT) in Sao Paulo, Brazil (Brotero 1941, 1948).

Following World War II, studies on over 140 species from Ecuador, Costa Rica, Panama, and Chile were conducted at the FPL, with emphasis on specific gravity and shrinkage (Baudendistel 1946; Baudendistel and

Paul 1946; Dohr 1947, 1949; Dohr and Drow 1948). From the Escuela Nacional de Agricultura in Chapingo, Mexico, a lengthy report on air drying was presented as a thesis by Carreon (1947). Only one study specifically on kiln drying was noted in the FPL records of the 1940s; it covered two species from Chile, one native (coigue) and one introduced (eucalyptus) (Torgeson 1947).

Only one publication was found in the U.S. literature in the 19509, and that involved drying *Ocotea rubra* (Dickinson 1950). Literature from Latin America included reports from Argentina (Garcia and Garcia 1956, Tinto 1957), Mexico (Parra and others 1953), Surinam (Japing 1957), and Venezuela (Slooten and Martinez-E. 1959).

During the 1960s, the number of publications on drying Latin American woods increased greatly. These were largely from Chile and Argentina. In Chile, general articles appeared on drying (Cuevas and Franco 1968; Han-R. 1964; Kauman and Mitlak 1966), the problems of shrinkage and collapse in eucalypts (Bluhm and others 1965, 1967; Cuevas 1965), and a manual on kiln drying of timber (Sahlman and Han-R. 1963). In Argentina, air drying of both lumber and posts with attention to eucalypts was the center of attention (Chiani 1965; Cozzo 1965; Garcia 1962; Labate 1964; Tinto, 1961). Tinto (1963) also published a manual on air drying of timbers. In Colombia and Mexico, specific kiln schedules were suggested for selected woods (Caceres-R. 1965; Echenique-Manrique and Diaz 1969; Perez-R. 1965). Also in Mexico, a kiln-drying manual was published by a private source (Fernandez 1962). This was essentially a translation of a U.S. dry-kiln operator's manual (Rasmussen 1961). A Spanish translation of a manual "Seasoning Lumber" prepared by the FPL for the U.S. Agency for International Development (USAID) was also published (USAID 1965). United States efforts for this period included collecting data on woods of Puerto Rico (Boone and others 1969; Chudnoff and Goytia 1967; Chudnoff and others 1966; Englerth 1960; Longwood 1961; Maldonado and Peck 1962; McMillen 1960) and woods of the Caribbean area (Longwood 1962). Other articles discussed problems of using Virola (Rice 1966).

Starting in the mid-1950s, several detailed studies were sponsored by the United Nations Development Program, Food and Agriculture Organization (UNDP/FAO). These studies focused primarily on the physical and mechanical properties of woods of Latin America but contained drying information. The research was conducted at several laboratories and institutions in Latin America.

Representative publications in the 1960s resulting from UNDP/FAO efforts include information from Nicaragua (Brazier and Franklin 1967), Guatemala (Kukachka 1968), Costa Rica (IICA 1968), and Venezuela (Enrique-V. 1969).

In the 1970s, the number of publications on drying Latin American woods more than doubled from the previous decade. Over 50 articles from 12 Latin American countries and the United States were found: Brazil (10), Costa Rica (7), Peru (5) Argentina (4), Colombia (4), Chile (4), Mexico (4), USA (4), Panama (3), Venezuela (2), Guyana (2), Nicaragua (l), and Uruguay (1).

Brazil became a major contributor to the wood drying literature in the 1970s after being unpublished since the 1940s. This literature from Brazil represents efforts of researchers at several institutions. During this period, the decision was made to establish two Federal laboratories in Brazil, supported by UNDP/FAO funding, one in Brasilia and one in Manaus. The research conducted at these two institutions contributed substantially to the total research from Brazil. Topics covered in the literature from Brazil varied from general characteristics and properties affecting drying (Paula 1979; Slooten and others 1976) to specific kiln schedules for native and plantation species (Galvao 1976; Mendes 1977). Other topics included general kiln drying articles including high-temperature drying (>l00°C) (Tomaselli 1976), solar drying (Vital 1976), concern about moisture gradients (Fernandes and Galvao 1977), and the influence of extractive content on the equilibrium moisture content of wood (Jankowsky and Galvao 1979).

In Costa Rica, research in drying was essentially from one group of researchers working in San Jose and Turrialba. Much of their research was done in the 1960s and supported in part by UNDP/FAO. The work ranged from describing the physical properties affecting drying (Gonzales-T. and Gonzales-T. 1973; Slooten and Gonzales-T. 1971; Gonzales-T. and others 1971a, 1971b) to specific topics (i.e., drying and preservation properties of eucalyptus posts) (Gonzales-T. and Krones 1974). A report to the government of Costa Rica discussed local woods suitable for the construction of prefabricated homes with details on drying, working, and nailing properties (Slooten 1972).

In Peru, a major effort was launched to describe the technical characteristics and uses of over 175 Peruvian woods, including information on drying (Arostegui-V. 1974, 1975a, 1975b). Another effort describes kiln drying of casuarina (Gonzales-F. and Campos-R. 1970).

A pattern was noted: early works from a country generally gave physical and mechanical property data, followed later by papers specifically on drying. Examples are Argentina (Keer 1978; Labate 1973, 1975), Colombia (Anon. 1970; Anon. 1978; Hoheisel and Lopez-G. 1973; Martinez-S. 1973), Chile (Cuevas-I. 1972; Galdames-Casorzo 1979a, 1979b; Perez-G. 1978), Venezuela (Anon. 1973; Arroyo-P. 1970), Guyana (Anon. 1979b; Mason 1971), Panama and Nicaragua (Gonzalez-T. and others 1973; Llach-C. 1971; Richter 1971; Slooten and others 1971a), Mexico (Echenique-Manrique 1970, 1971; Echenique-Manrique and Barajas-Morales 1977; Echenique-Manrique and others 1975), Uruguay (Duran 1972).

During the 1970s, U.S. wood drying literature included papers on kiln-drying Colombian woods (McMillen and Boone 1974), drying and preservation of Costa Rican woods (Johnson and Gonzales-T. 1976), a general book on tropical timbers of the world (Chudnoff 1979), and a paper describing a solar dryer design suitable for tropical areas of the world (Tschernitz and Simpson 1979).

Literature from the 1980s showed Brazil to be the most productive Latin American country in developing drying research reports. Papers include one on the general properties of Amazonian woods (IBDF 1981), two papers on air drying and kiln drying of species from the Amazon (Martins and Oliveira 1984; Martins and others 1985), a review of the drying process (Tomaselli 1980), drying lumber in a solar kiln (Santini 1983), and moisture gradient and stress development during kiln drying *Pinus caribaea* (Jankowsky and Henriquez 1983).

From Peru, publications appeared as a part of the Andean Pact. These reports included a primer of construction with wood, including information on drying and preservation prior to construction (Tejada-V. 1980), a paper on drying and preservation of 105 woods (Anon. 1983), a compilation of information on 60 Peruvian woods (Arostegui-V. 1982), and a book describing characteristics and use of 34 timber species (Anon. 1981a).

Drying research and literature from other countries include documents from Bolivia, Chile, Ecuador, Guatemala, Mexico, and the United States.

Information on 20 Bolivian woods was published by the Andean Pact organization (Anon. 1981b). In Chile, drying research centered on drying radiata pine, their principle plantation species (Albin-A. and Jaramillo-L. 1980; Lisboa 1983). As a result of the FPL team visit to Ecuador in 1986, we found three rather recent publications (not generally distributed) on drying and general properties of Ecuadorian woods (Toledo-E. and others 1981; Orbe-V. 1986; Orbe-V. and Valarezo-G. 1981). In Guatemala, a practical manual was produced on air drying of wood, designed for the small- and medium-sized business (Valladares 1981), and an undated pamphlet on solar drying of wood was also issued from Instituto Centroamericano de Investigacion y Tecnologia Industrial (ICAITI) in Guatemala City (ICAITI about 1980). Three publications from Mexico on drying were noted: a compilation of data on pines, several other conifers, and two hardwoods (Cevallos-F. and Carmona-V. 1981); drying characteristics of five Mexican oaks dried by dehumidification, conventional kiln drying and air drying (Bejar-Maldonado 1983); and recommendations for air drying (Barretero-J. and Murguia-P. 1982; Lopez-P. 1985; Pedraza-M. 1984). From the United States, Simpson and Tschernitz (1984) updated their solar drier information, complete with floor plans. A report containing suggested dry-kiln schedules for over 500 commercial world woods, both temperate and tropical, was assembled by Boone and others (1988).

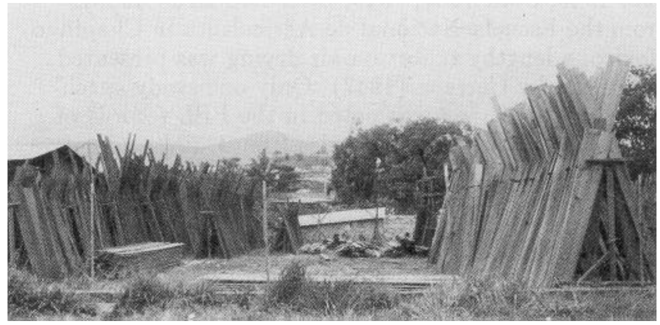

Figure 29-Vertical stacking of lumber for air drying in Honduras. (M90 0163)

Perhaps the most significant publication to come out of the Andean Pact group (supported by the Canadian IDRC) was a summary of research to develop technology for using the forest resources of the region as building materials (Keenan and Tejada-V. 1984). Information on drying (Anon. 1983) included measuring drying time and noting quality of dried stock of both air-dried and kiln-dried material. Woods were subjected to severe, moderate, and mild kiln schedules. Noting the drying degrade, 81 species were classified as to which schedule seemed to give the best results. Considerable technical information for choosing and using local species for building make this document very useful for the Andean Pact countries, and the principles and approaches could be transferred to similar projects in other parts of the world.

State of the Art

As with sawmilling, drying of lumber in Latin America varies from no drying or very primitive to state-of-the-art controlled drying. Controlled drying means the drying process is manipulated to achieve the best drying conditions possible for given products or end uses of the wood. Unlike most other forms of wood processing (e.g., sawing, pulping, or preservation), drying occurs for better or worse on its own. The objective of proper drying should be to control the process to one's advantage. The objectives are generally (1) to produce a moisture content in the product that is suitable for the end use conditions expected and (2) to prevent, or at least minimize, drying degrade (warp, splits, cracks) while drying to the desired moisture content. In many cases, this means a tradeoff between quality of the product and the time, energy, and investment required to achieve the desired moisture content.

In too many wood processing operations in Latin America, there seems to be only a minimal concern for proper drying. Most of the poor drying is done in small operations (Fig. 29). The large mills generally do a better job of drying (Fig. 30). This is not unique to Latin America, but occurs throughout the world.

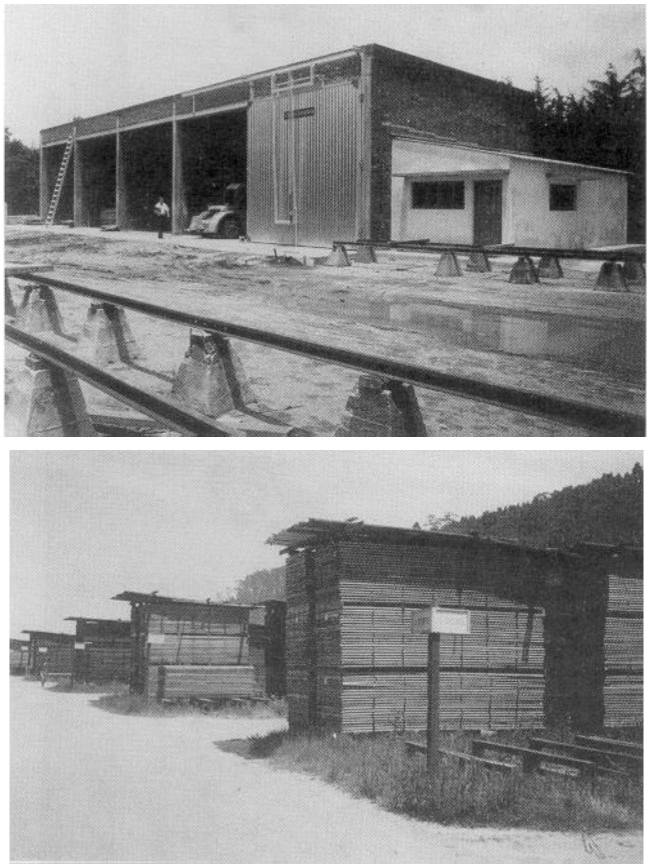

Figure 30-Modern steam kilns in Guatemala (top). Air drying of eucalyptus lumber Lota, Chile; Forestal Rolcura, S.A. Eucalyptus globulus) (bottom). (M90 0116, M90 0140)

Lumber drying by primary manufacturers is not good, but the lumber has a second chance in secondary processing. However, even in the furniture industry, which usually has a better understanding of moisture in wood and the need for good drying, there seems to be a lack of understanding. The FPL team visited a furniture factory that produced nicely constructed furniture with a substantial amount of hand carving. They were experiencing severe splits and cracks in panels, due to poor drying. Other drying problems were also evident in the form of shrinkage and warp while still in the factory. The concept of drying lumber to proper moisture content before adding the expenses of fabrication and labor did not seem to be understood. Even more knowledgeable furniture manufacturers, who produce quality furniture for local use, are frequently unprepared for the more stringent moisture content controls required for export to Europe, North America, or temperate zones of South America (Fig. 31).

For many products or uses, air drying is quite acceptable. However, the quality of air-dried products can be improved if established techniques are used. With air drying, proper pile locations, foundations, stacking, and protection from direct sun and rain are very important for the best product quality. We observed a wide

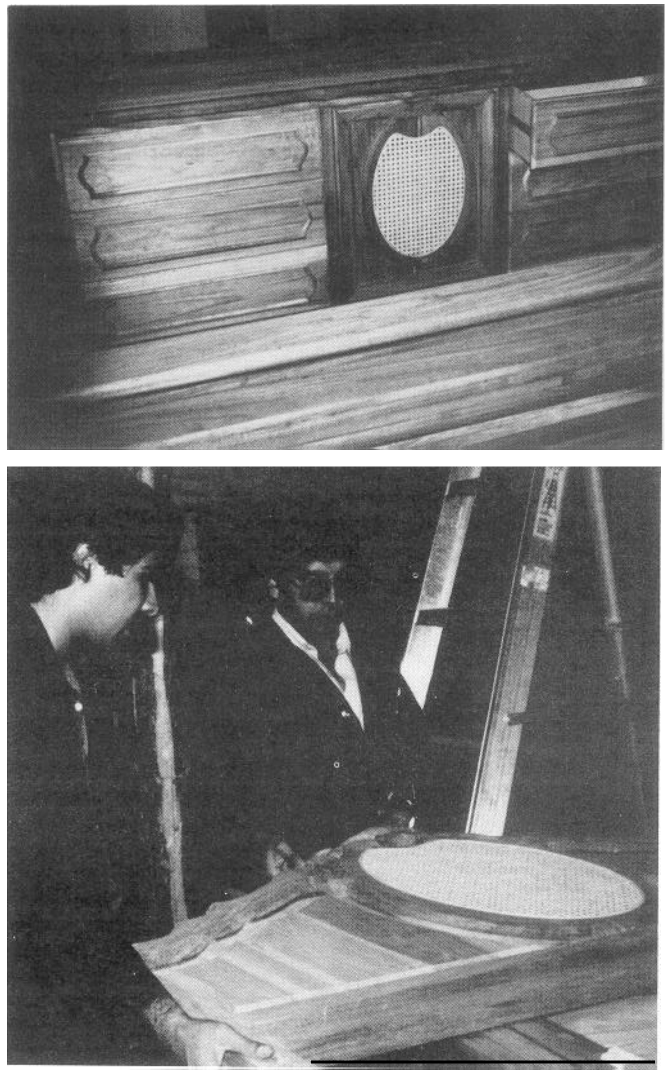

Figure 31-Furniture at Heritage Muebles, Quito, Ecuador. (M90 0164, M90 0117)

range of attention to these details. A notable amount of end racking is still used to air-dry lumber. This often causes ground contact rot of board ends and does not sufficiently control warp. We also observed triangular stacking (crib piling) of lumber in horizontal piles. This is a better means of drying but requires a lot of space for the inventory during drying and gives minimal support to the lumber. This type of stacking needs a good foundation or rotting of lower boards and excessive warping will occur because the lumber is only supported on the ends. Air drying of lumber is practiced extensively in some of the drier areas, especially with pine, but is usually practiced by the smaller operators with less available capital.

Numerous solar kilns are located throughout Latin America (Fig. 32). These units are low-investment kilns with small capacity. A variety of designs are used. A recent consulting trip to Mexico, by an FPL scientist, involved discussions of a' solar pre-drier for pine. The Instituto Centroamericano de Investigacion y Tecnologia Industrial (ICAITI), Guatemala City, has

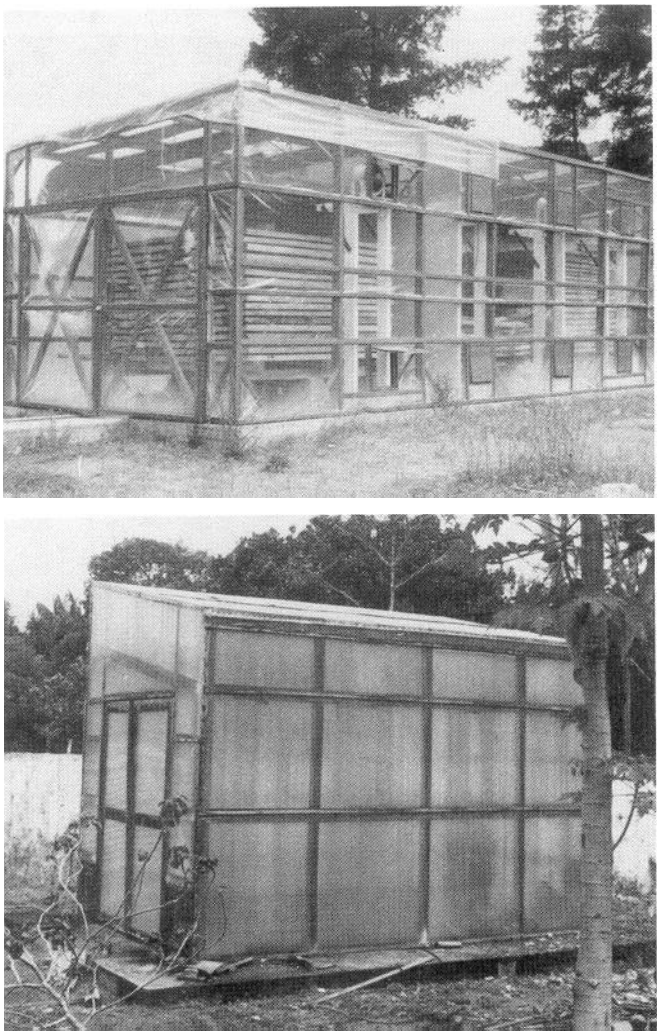

Figure 32-Solar kiln in Conocoto, Ecuador (top). Solar kiln in Manaus, Brazil (bottom). (M90 0141, M90 0165)

done considerable design work on solar kilns and has placed some into use.

Several small- to medium-sized furniture factories that we visited had homemade hot box or furnace-type lumber kilns, fired with wood waste or, in some cases, oil (Fig. 33). Lack of proper operating procedures (i.e., knowledge of temperature and humidity conditions in the kiln and of the moisture content of the wood entering the kiln) diminishes the quality of lumber dried in these units. With the addition of semiautomatic control instruments (recorder controllers) or close attention to manual control, using sample boards, the quality of lumber being dried in hot box kilns can be satisfactory for most in-country uses and for some export.

The use of dehumidification kilns seems rather common in Latin America. We observed that several of the research related institutions have smaller units (Instituto Pesquisas Technologicas (IPT) Sao Paulo; Instituto Brasiliero de Desenvolvimento Florestal Brasilia (IBDF), INPA Manaus). We also saw larger units at industrial processing operations in Manaus, Brasil, and in Costa Rica and Guatemala. Mario Han (1988) notes

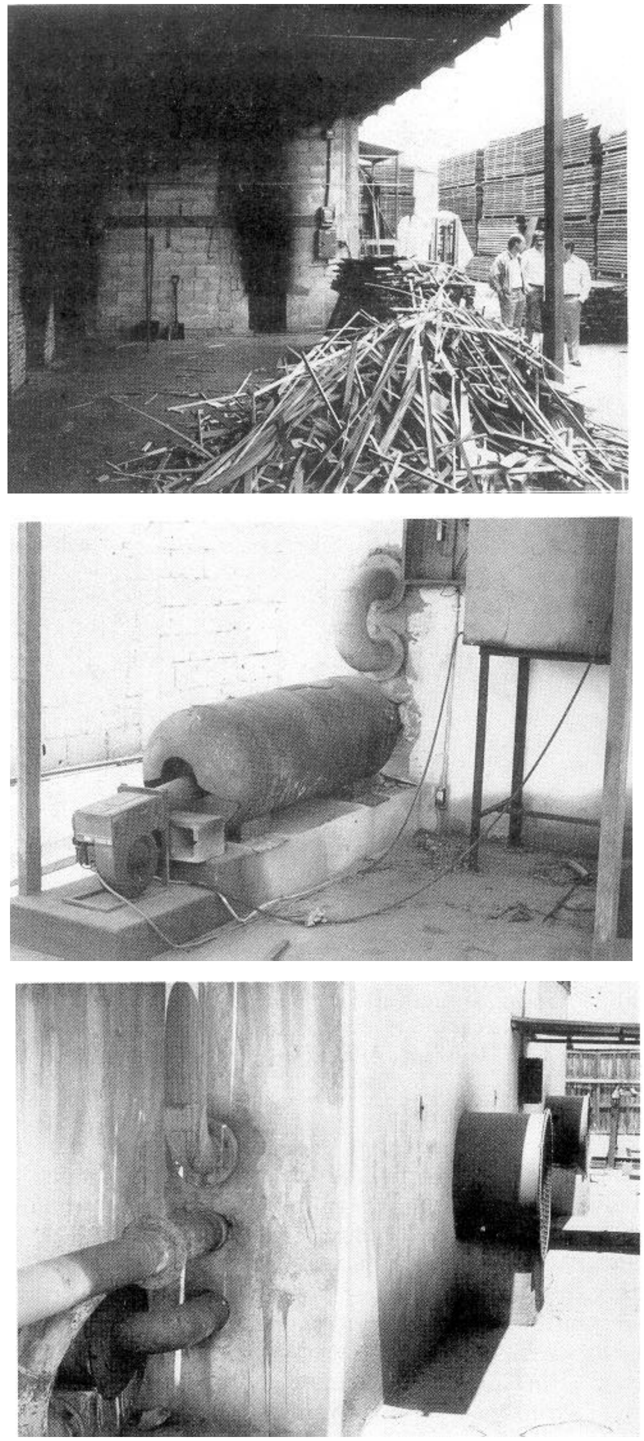

Figure 33-Wood-fired hot box kiln in Guatemala (top). Oil-fired heater for hot box kiln (middle), and venting an oil-fired hot box kiln (bottom), Upata, Venezuela. (M90 0118, M90 0142, M90 0166, M90 0119)

that dehumidification kilns have diminished in use in some areas because of their slowness and high electricity cost. They continue to be used in small operations in cities but not in most large operations.

The primary users of lumber dry kilns in Latin America appear to be lumber manufacturers for the export market and furniture manufacturers, both for export and in-country use. Producers of rough lumber for export, such as the larger mills in Amazonia, Chile, Colombia, Venezuela, Honduras, and Mexico, and the balsa producers in Ecuador are usually required to dry their lumber to moisture contents of 30 percent or less (although some pine manufacturers in Chile are exporting green lumber). This is usually done in conventional steam-heated dry kilns or in dehumidification kilns, with some air drying done as well. A few of the pine producers have kilns capable of drying at high temperature (above 100°C). Exported hardwood lumber is typically finish dried (to final moisture contents suitable to the region and/or end use of the wood) in the receiving country. Latin American producers of furniture, furniture parts, and moulding are typically required to dry to 10 percent moisture content or less for export and 15 to 18 percent or less for in-country use.

Most of the commercial kiln equipment is obtained from Canada, Europe (largely Germany and Italy), and the United States (Anon. 1971, 1979a; Blackman 1980; Blackman 1985; Davis 1973; Mason 1976; Ogle 1982a,b). Some commercial kiln equipment is manufactured in Argentina, Brazil, and Chile. Three firms manufacture kilns in Argentina. They produce both dehumidification and steam kilns.

Information from the two largest manufacturers of lumber dry kiln equipment in the United States shows that since 1940, over 250 kilns have been shipped to 19 countries and Puerto Rico in the Latin American and Caribbean region, with Mexico, Ecuador, Colombia, and Brazil receiving the most.

As suggested previously, different levels of drying sophistication are available and applicable for various needs (use, end products, export requirements). Most researchers and government officials we spoke with were aware of this and the advantages of using controlled drying rather than viewing drying as something that happens anyway, so why bother controlling it.

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Veneer and Plywood Manufacture

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Research discussed in this chapter deals with the primary manufacture of veneer and plywood, including conditioning of logs, peeling, slicing, and clipping of veneer, and lay-up and pressing of plywood.

History

Although the use of mahogany veneers was quite common in Europe in the 17th and 18th centuries, none was known to be produced in Latin America at that time. The logs for producing veneer were shipped to England, France, and Spain for processing. In the 1800s, logs frequently were shipped to the United States for manufacture before reshipment to England and Europe. In 1838, the Williams family of New York began producing mahogany and other tropical wood veneers. A century later in 1932, the Williams company acquired the Astoria Importing and Manufacturing Co., Inc. (AIMCO). The AIMCO operated a veneer mill on the Amazon River in Peru, at Iquitos (Callahan 1985). Although most of the early veneer and plywood manufacturing facilities in Latin America were owned or operated by foreign firms, in Chile, the MOSSO group at Curacautin began plywood production in 1940. Their production was 10,000 m^3 per year of *Araucaria araucana*. The installation of these mills was completed with current technology at the time of installation. Then, as now, many of the veneer and plywood mills were pretty much state-of-the-art operations (Fig. 34).

In Ecuador, the first plywood plants were established in 1962 in Quito and Guayaquil (AIMA 1985; Anon. about 1985; Blackman 1979b).

The FAO (1970) shows that the production of plywood in Latin America doubled between 1957 and 1968. Between 1968 and 1983, plywood production tripled, going from 487,000 m^3 to 1,559,000 m^3 (World Wood 1985). In 1984, the plywood production of Latin America dropped slightly to 1,532,000 m^3 (World Wood 1986). In 1968, when *World Wood* began tabulating veneer sheet production, Latin America produced 37,000 m^3 (World Wood 1970). In 1983, the veneer sheet production had grown to 433,000 m^3 (World Wood 1985), but production dropped slightly in 1984 to 374,000 m^3 (World Wood 1986).

The veneer and plywood industry in Latin America has generally kept current with the technology of the world and operates at a high level. Most of the plywood is nonstructural, aimed mainly for use in the furniture and casegoods market.

State of the Knowledge

Although the industry began with state-of-the-art equipment, and still uses state-of-the-art equipment and technology, most of the mechanical knowledge is that from Europe, Japan, and North America. However, much of the technological information on veneer and plywood manufacture came from Latin America. Results of several research studies were published in Latin America from the late 1960s through the mid-1970s. Those research papers deal with properties, technical attributes, drying, and plywood manufacture. Research for those papers was conducted on local species of timber at several locations throughout Latin America.

Several publications deal with properties of wood and their effects on veneer and plywood manufacture (Anon. 1971b; Arroyo-P. 1985; Beekman 1958; Bonnemann 1967; FUDECO 1971; Gilmore 1974; Jankowsky 1978; LABONAC 1974; Lella 1960, 1966; Lelles 1977; Morales and Johnston 1974; Rivera 1969; Slooten 1970). Most of these papers also cover drying and other processing considerations.

One of the most comprehensive documents on veneering and plywood manufacture of Latin American woods is from the International Union of Forestry Research Organizations (IUFRO 1976). In this report, there are findings on 153 separate species of Latin American woods. Findings of five Laboratories are given on performance of the woods as veneer and plywood.

Other areas cited in the literature are (1) a computer model to predict the veneer yield of circular and elliptical logs (Briggs 1977); (2) developing plywood and veneer industries baaed on plantation resources (Camara Argentina 1972); (3) a comparison of structures made of solid wood to plywood (Fernandez 1974); (4) an analysis of theories on the drying of veneer (Gonzalez-T. 1970); (5) developing of kraft paper over-

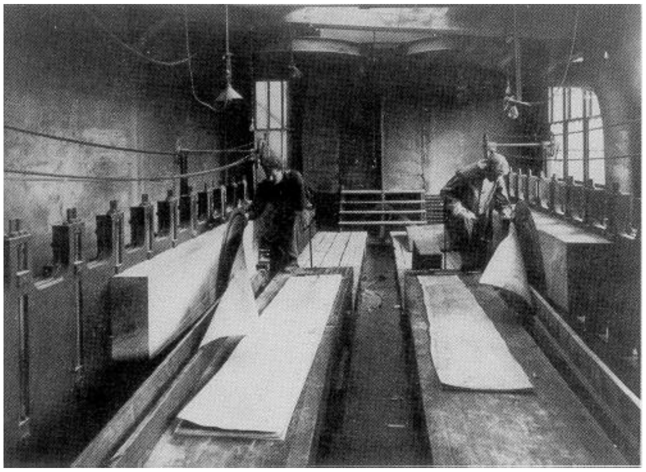


Figure 34-Sawing mahogany veneer in New York, early 1900s. Courtesy of John C. Callahan. (M90 0143)

layed plywood (Mason 1977); and (6) discussion of other products such as boxes and crates from veneer (Rivera 1969).

Numerous documents on the veneering process have been published that may be quite helpful to researchers and producers. These include studies on the following topics: the mechanism of veneer cutting (Boulloud 1972; Devlieger 1986); the effects of lathe checks on the strength of plywood (Devlieger and Becerra 1986); spin-out of veneer blocks during rotary cutting of veneer (Lutz and Patzer 1976); techniques for peeling, slicing, and drying veneer (Lutz 1974); wood and log characteristics affecting veneer production (Lutz 1971); and how to reduce buckling in veneer (Lutz 1970).

State of the Art

Brazil

Brazil is the country with the largest production of veneer and plywood in Latin America (Tables 10 and 11). The production of veneer in Brazil increased 600 percent between 1961 and 1983. During the same period, plywood production increased 450 percent.

Many veneer and plywood mills can be found throughout the country. In the past, because of the concentration of industrial capability and the concentration of population, much of the industry was in the southeastern part of the country; for example, the states of Sao Paulo (Anon. 1977; Mason 1975; Ogle 1980b), Parana (Mason 1976), and Rio Grande do Sul (Mason 1977). However, many of the increased production facilities, since the 1970s have moved closer to the resource.

Based on an extensive field study in the Amazon basin begun in 1973, Bruce (1976) reported on the status of the industry. He noted that only four veneer and plywood plants existed in 1972, one in Macapa, two in Manaus, and one in Portel (Fig. 35). The oldest was started in 1959. Bruce also noted that expansion of the industry was expected to occur shortly. A fifth plant was to begin production in 1973 (in Belem) and another was planned for 1975. Bruce also estimated a doubling of production capacity for the Amazon region by 1975. Mills are located at numerous sites along the Amazon and its tributaries, with major facilities at Belem, Manaus, and Santarem. As with the lumber industry, the veneer and plywood industries are largely dependent on river transport of logs, thus, the concentration of plants along the rivers. Even though machines are used in harvest, roads for transport of logs are few. Most of the logs are harvested during the dry season and then transported, in rafts, during the rainy season. Fraser (1980) discusses a salvage operation at Belem in Para state, based on recovery of sinker logs lost during river transport.

Bruce (1976) reported that only two species of major importance were being processed in the Amazonian veneer and plywood mills; however, a total of 12 species were being processed in the individual mills. The species listed and their proportions for 1972 were virola, 57.6 percent; muiratinga, 24.1 percent; samauma, 9.4 percent; paricarana, 2 percent; caucho vermelho, 1.4 percent; sumauma vemelha, 1.4 percent; copaiba, 1.4 percent; cauchorana, 1.1 percent; assacu, 0.6 percent; hevea, 0.6 percent; arapira, 0.2 percent; and caramuri, 0.2 percent. Other species added to the pro cessing list in 1973 were freijo, macacauba, andiroba, muiracatiara, sucupira, mogno, and cedro vermelho.

During the FPL team's visit to Manaus, we visited a veneer and plywood plant. The plant, one of several in the Manaus area, was an older facility, producing rotary cut veneer for shipment to the Sao Paulo area for manufacture into plywood and furniture (no sliced veneer was produced at this mill). The plywood plant was producing panels for export primarily to Europe and the United States. Production was limited to about five species. The plant was operating 24 hours a day on three shifts. Technology of the plant was reasonable but not the most up-to-date. Waste wood was being burned to provide steam for both plant operation, veneer drying, and log conditioning. Two categories of logs were being peeled. One category consisted of the very large (1 to 2.5 m diameter), high-quality logs that were cut to length in the storage pond. The other category consisted of long length, lower quality logs of smaller diameter (not more than about 0.6 m). The long logs were brought full length into the mill and then cut to length in the mill. The veneer being shipped appeared to be of very high quality, mostly clear. The plywood that we saw had all clear faces. We were told that the plywood was for the furniture market.

Mexico

The second largest producer of plywood in Latin America is Mexico. In 1984, Mexico produced 286,000 m^3, but in 1982, 313,000 m^3 (Table 11). In 1978, Mexico

Table 10–Production of veneer sheets by Latin American countries 1961-1984[a]

Country	Production ($\times 10^3$ m^3)																			
	1961-1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
Bahamas																				
Belize																				
Costa Rica	7	9	6	5	6	3	3	4	4	4	5	5	5	3	5	5	8	8	5	7
Cuba																				
El Salvador																				
Guadeloupe																				
Guatemala									2	5	2	2	1	2	2	2	1	1	1	1
Haiti																				
Honduras																				
Jamaica																				
Martinique																				
Mexico					1	1	1	1	4	4	4	7	6	28	16	8	14	10	8	2
Nicaragua																				
Panama																				
Trinidad																				
Total (Central America and Caribbean)	7	9	6	5	7	4	4	5	10	13	11	14	12	33	23	15	23	19	14	10

Table 10–Production of veneer sheets by Latin American countries 1961-1984[a]-con.

Country	Production (× 10^3 m^3)																			
	1961-1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
Argentina	1	3	3	2	2	4	5	5	6	10	10	9	2	2	7	3	4	5	6	6
Bolivia												3	18	16	19	22	22	22	22	22
Brazil	39	65	77	80	90	96	116	152	188	175	154	169	190	190	200	216	234	234	234	234
Chile	1	2	4	6	5	5	2	2	1	2	2	3	5	6	7	7	8	8	9	9
Colombia	4	3	3	4	4	5	5	9	5	4	4	4	4	4	4	9	7	7	7	7
Ecuador											1	3	3	2	2	2	2	3	33	
Fr. Guiana			3	8	6															
Guyana																				
Paraguay					1	8	9	6	5	8	8	9	14	22	37	63	63	63	63	63
Peru	1	7	5	12	11	14	11	12	12	8	3	6	24	24	28	35	38	20	20	20
Surinam																				
Uruguay																				
Venezuela																				
Total (South America)	45	81	95	112	118	132	147	186	219	206	182	206	260	266	304	357	379	362	364	364
Total (Latin America)	52	90	101	117	125	136	151	191	229	219	193	220	272	299	327	372	402	381	378	374

[a]FAO 1978, 1986.

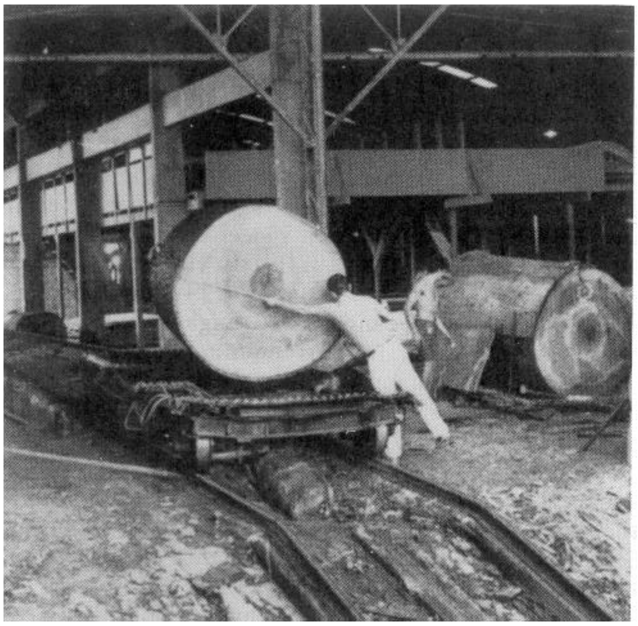
Table 11–Production of plywood by Latin American countries 1961-19840[a]

Country	Production ($\times 10^3$ m^3)																			
	1961-1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
Bahamas																				
Belize																				
Costa Rica	6	13	16	15	20	22	25	25	25	25	40	40	44	30	31	31	26	33	23	25
Cuba		3	4	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
El Salvador																				
Guadeloupe																				
Guatemala	2	2	2	2	1	1	3	3	3	4	4	4	4	4	4	4	3	1	1	1
Haiti																				
Honduras	2	3	3	4	5	6	6	12	12	11	10	11	13	14	14	11	11	5	6	8
Jamaica																				
Martinique																				
Mexico	53	69	79	78	78	96	99	104	118	111	110	139	171	188	206	254	304	313	286	286
Nicaragua	lo	13	15	13	13	16	17	17	17	17	10	10	10	10	16	14	14	22	14	14
Panama	3	12	18	21	24	26	26	10	10	6	7	8	12	12	12	12	12	12	12	12
Trinidad																				
Total (Central America and Caribbean)	76	115	137	135	143	169	178	173	187	176	183	214	256	260	285	328	372	388	344	348

Table 11–Production of plywood by Latin American countries 1961-1984[a]-con.

Country	1961-1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
	Production (× 10^3 m^3)																			
Argentina	44	58	53	48	48	48	56	56	61	70	61	58	50	47	53	53	50	47	48	48
Bolivia	1	1	1	1	2	1	1	1	1	2	2	2	3	1	4	6	6	1	1	1
Brazil	200	240	270	290	300	342	431	606	659	655	660	695	698	722	762	826	902	902	902	902
Chile	8	9	7	12	12	13	16	17	15	10	13	7	9	13	16	20	18	10	15	20
Colombia	39	48	55	60	65	52	57	62	58	45	50	75	75	75	52	52	40	48	48	48
Ecuador	3	11	15	19	20	20	24	26	29	30	38	38	40	50	55	59	65	65	65	65
Fr. Guiana																				
Guyana																				
Paraguay	2	1	1	1	3	7	7	7	9	11	8	2	3	3	4	4	4	4	4	4
Peru	3	5	12	11	14	22	22	48	51	48	49	76	39	24	38	49	40	37	37	37
Surinam	17	13	16	18	19	18	19	20	20	13	13	18	15	17	18	17	19	20	20	20
Uruguay	5	5	14	11	12	12	5	5	6	6	6	4	5	6	7	7	7	3	4	4
Venezuela	11	14	20	27	30	33	35	37	43	37	40	40	29	22	50	55	69	37	47	47
Total (South America)	331	404	461	498	524	567	671	885	951	927	939	1014	966	961	1059	1148	1219	1174	1191	1196
Total (Latin America)	407	519	598	633	667	736	849	1058	1138	1103	1122	1228	1222	1221	1344	1476	1591	1562	1535	1544

[a]FAO 1978, 1986.



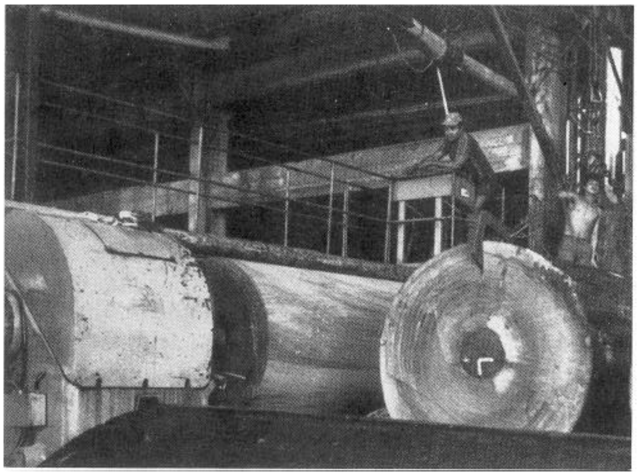


Figure 35-Measuring veneer log to locate center, Manaus. Brazil (top). Feeding logs into rotary lathe in Manaus, Brazil (bottom). (M90 0120, M90 0144)

was also the second largest producer of veneer sheets in Latin America. This production, however, has dropped from 28,000 m^3 per year in 1978 to only 2,000 m^3 per year in 1984 (Table 10).

The production of plywood is limited to just a few locations: Anahuac, Chihuahua; Llano Grande, Durango; Mexico City; and Oaxaca. The production grew from 1,000 m^3 in 1969 to a high of 313,000 m^3 in 1982.

Perhaps the first veneer and plywood mill in Mexico was Chapas y Triplay S.A. begun in 1936 in Ayotla, State of Mexico (SARH 1982). The modern mills were led by Triplay de Oaxaca S.A., which began production in 1956. By 1972, Triplay was producing 110 m^3 per day, on a two-shift schedule, for the Mexican market (Davis 1972). In 1978, Triplay was an integrated facility with sawmill, plywood, and particleboard plants using seven species of pine (Anon. 1978b). In 1977, the largest plywood producer in Mexico, Plywood Ponderosa de Mexico, at Anahuac, Chihuahua, doubled its production capability. This was done by installing a new peeling line including driers and a veneer recovery section using automated clipper control (Blackman 1979c). One of the smaller Mexican plywood mills (Forestal Halcon) is located at Llano Grande, in the state of Durango. Ogle (1983) reported the addition of hot water vats to soak the pine being peeled at the Forestal Halcon mill. This addition increased both the quality and yield of veneer from their logs. The company was producing 1,500, 1.2-m by 2.5-m by 6-mm panels per day. The facility in Mexico City using veneer is Maderas Conglomerados S.A. In 1975, they were laminating mahogany to thin particleboard. The veneers were peeled in their plant (Anon. 1975).

Ecuador

The third largest producer of plywood in Latin America is Ecuador; in 1984, they produced 65,000 m^3. However, in veneer sheet production, they were far behind Paraguay, Peru, and Bolivia, producing only 3,000 m^3 in 1984.

Plywood Ecuatoriana was formed in 1962 in the city of Quito, probably the first mill in Ecuador (AIMA 1985; Anon. about 1985; Blackman, 1979b). In 1979, the company was producing 15,000 m^3 of plywood per year. The species being used were cuangare, sande, sangre de gallina, copal, chalviande, as well as other species (AIMA 1985). Subsequent plywood mills were established in Ecuador in 1969, 1970, 1973, 1975, and 1982 (Anon. about 1985).

The FPL team visited CODESA, a state-of-the-art mill, in 1986. We were informed that they were peeling and slicing 16 species of tropical woods for plywood. Most of the species were related to virola or had densities about the same as virola. The AIMA (1985) (Asociacion de Industriales Madereros Ecuador) lists six species that CODESA was processing, including cuangare, sande, sangre de gallina, anime, copal, chalviande, and others. The sliced veneer went into decorative plywood, and the peeled stock was used for standard plywood panels. None of the plywood was for structural purposes. Most was destined to be used in furniture and casegoods, and a large portion was to be exported. The equipment used in this mill came from Europe and the United States.

In 1976, another plywood plant was established in Quito by ENDESA (Enchapes Decorativos S.A.) (Anon. 1978d). By 1981, ENDESA was called Ecuador’s plywood leader by Ogle (1981). Using woods from the western coastal tropical forest, the company produced a variety of panel products and was trying to expand its export sales. The species used by ENDESA are tangre, laurel, mascarey, saman, marfil, canelo, cedro, and balsamo (Ogle 1981). The FPL team also visited the ENDESA mill in Quito. This is a very modern mill. Logs are stored in either a log pond or under an overhead spray in a log storage yard. Logs to be sliced are taken to the sawmill for flitching, and then to the heated conditioning vats. Logs to be peeled go directly to the heated conditioning vat. Equipment in the mill comes from Finland, Germany, Italy, Japan, and the United States.

The AIMA (1985) and Anon. (about 1985) describe another plywood manufacturer besides those previously described. The firm is FORESA (Forestal Esmeraldena S.A.). The plant is located in Santo Domingo Los Colorados and manufactures plywood and blockboard from sande, copal, coca, tangre, and other species. Anon. (about 1985) lists two more plywood and veneer producers; Chapas y Maderas, which was formed in 1969 in San Lorenzo, Province de Esmeraldas; and CEMAC (Ecuatoriana de Maderas Cotopaxi CIA. LTDA.), which was formed in 1982, and is located in Latacunga, Province of Cotopaxi. Other mills in Ecuador are located in Guayaquil, San Lorenzo Province of Esmaralda state.

Peru

One of the most concentrated areas of veneer and plywood production in Latin America has been Iquitos, Peru. That area has consistently maintained a high level of quality and production through many decades. As noted earlier in this chapter (History), an operating veneer mill was taken over by the Williams Co. of New York in the 1930s. Long before that, veneer was produced at Iquitos. The continuation of the Iquitos operation of Chapas Astoria has been noted in trade journals (Hedges 1966; Anon. 1978a). In recent years, other mills are joining in the production at Iquitos, such as Madereras de Loreta S.A. (Anon. 1972a), Laminadora Iquitos S.A. (Anon. 1972b), Iquitos Plywood (Anon. 1978a), and Triplay Enchapes S.A. (Blackman 1980a). Other centers for production of veneer and plywood in Peru are at Pucallpa, IMOSA (Industrias Maderas del Oriente) (Mason 1974; Ogle 1980a), Plywood Peruana, S.A., (Han-R. 1988), and in Lima, Estudio 501 S.A. (Blackman 1979a).

The equipment used in the various Peruvian mills is manufactured in North and South America and in Europe. Often a mix of machinery is found in one plant.

Other Countries

Two countries, Paraguay and Bolivia, produce 63,000 and 22,000 m^3 of veneer per year, respectively, but little plywood (Table 10). A number of countries produce from 20,000 to 48,000 m^3 of plywood per year. These include, in order of production, Colombia, Venezuela, Argentina, Costa Rica, and Surinam (Table 11).

Colombia

Colombia has, for decades, had a quality veneer and plywood industry. In 1974, five plywood plants, one plywood and veneer plant, and one veneer plant were operating in Colombia (Morales-V. and Johnston 1974). World Wood stated in 1971 that Maderas y Chapas de Narino S.A. of Tumaco was "probably the most modern, high production veneer operation in South America..." (Anon. 1971a). In 1971, the firm was producing 20,000 fbm per year of plywood. Production was of virola, sande, sajo, tangare, and seven or eight other species. At Barranquilla, Triplex Pizano S.A. has been producing for quite a long time. This operation is unique among the tropical plymills because they produced 97 percent cativo and 3 percent abarco (Davis 1973). Most of the tropical mills produce a number of species of plywood, as noted for the other countries. In 1982, the mill was still producing 95 percent cativo, with a production rate of 130 m^3 per day (Anon. 1982). Valdes-S. (1983) states that the production capacity of the eight plywood plants was 93,700 m^3 but that the actual production was only about 40 percent of capacity at 38,800 m^3. For the 11 veneer mills, the capacity was 13,000 m^3 and production was 5,400 m^3. Problems noted by Valdes were difficulties getting veneer logs of suitable quality, high cost of production, and prices that were not competetive with those of other countries.

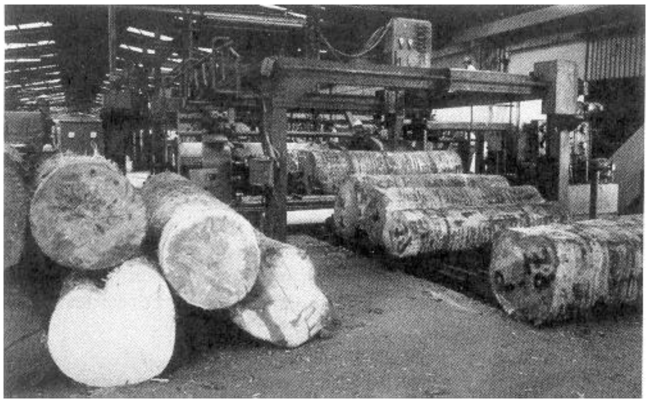
Venezuela

Some of the plywood mills in Venezuela include Contrachapados Tachira C.A. (CONTACA) near San Cristobal, Finewood de Venezuela in Guatire, Miranda state, Industrias MADEPREN C.A. in Portuguesa state, MADEMACA in Upata, Bolivar state, and Panel Carabobo C.A. near Valencia in Carabobo state.

Finewood de Venezuela was visited by the FPL personnel in March 1988. The mill, with modern capital equipment, was producing plywood and veneer overlayed blockboard and particleboard. Species used for face veneers included *Swietenia, Pterocarpus, Platymiscium,* and *Copaifera.* Core and crossbands were *Platymiscium, Brosimum alicastrum* group, *Hura crepitans,* and *Ceiba.* The FPL team also visited the MADEMACA mill in Upata (Fig. 36). This mill is producing both veneer and plywood. Veneer being produced was primarily for core plies. The face veneers were mostly imported from Brazil. The imported species were *Swietenia* and *Ocotea (rubra?).* Some *Spondias mombin* was used for face veneers also. Species peeled for core plies were *Spondias mombin, Ceiba pentandra, Ceiba sumauma,* and *Samanea.* Spondias was being used for all plywood backs. The MADEMACA was in the process of installing a new COE lathe with power back-up roll at the time of visit.

Argentina

In Argentina, a substantial amount of plywood is manufactured, mostly in the northeastern part of the



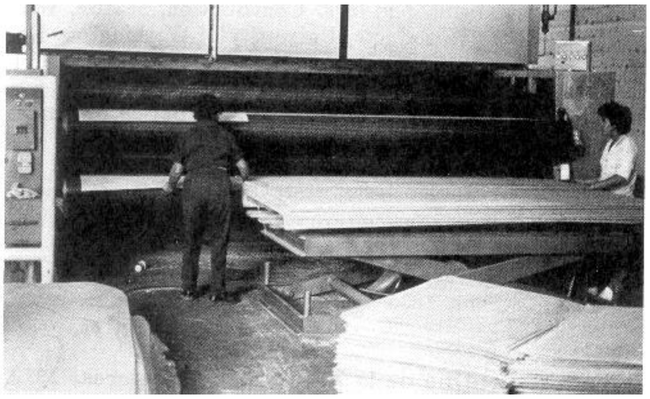


Figure 36-Rotary veneer mill, Upata, Venezuela (top). Veneer drier at plywood mill in Upata. Venezuela (bottom). (M90 0168, M90 0106)

country; however, details on the industry were very scarce. Information on the expansion of the Cellulosa Argentina pulp mill, in Garahaupe, to include a sawmill, plymill, and particleboard plant was found in World Wood (Anon. 1978e). The plymill began production at 600 m^3 per month, with the capability of doubling the production. The species being used were laurel negro, laurel amarillo, rabo amarillo, anchico colorado, grapia, cancharana, guayea, and alecrin. The mill, as described, was a high-technology mill. Tinto (1988) notes that in 1984, 23 plywood plants in Argentina, were producing 45,321 m^3 of plywood principally from *Cedrela, Balfourodendron, Ocotea, Nectandra, Araucaria, Populus, Melia,* and *Pinus.* He also notes that of the 23 plants, only 6 operate with excellent technology.

Costa Rica

Of the Central American countries, Costa Rica is the only one with a substantial plywood production, producing 33,000 m^3 in 1984 (Table 11). Blackman (1980b) discusses the use of lathe cores and veneer waste from Plywood Costaricense to manufacture particleboard.

Chile and Surinam are the final Latin American countries with even a moderate production of plywood, producing 20,000 m^3 in 1984.

Chile

Six veneer and plywood plants are in Chile, including Industria Foliadora de Maderas S.A. (INFODEMA), EMASIL, Industria de Terciados S.A., Laminadora S.A., Forestal Don Santiago, Industrias Forestales Curacautin (FOCURA), and Sociedad Agricola y Forestal Colcura (INFOR-CORFO 1987).

The author visited two veneer mills in Chile in 1987. One of the mills, Sociedad Agricola y Forestal Colcura, near Lota, was producing sliced veneer from plantation-grown Eucalyptus globulus. This mill, using modern Italian equipment, was doing very well with product recovery and quality. Most of the product was going into paneling and furniture.

The second mill, INFODEMA, in Valdivia, was producing veneer and plywood from native hardwood species, and plantation-grown *Eucalyptus globulus,* and *Pinus radiata.* The native species list included Alerce *Fitzroya cupressoides,* Lingue *Persea lingue,* Manio *Podocarpus saligna, P. nubigena,* Olivillo *Aextoccicum punctatum,* Roble *Nothofagus obliqua,* and Tepa *Laurelia philippiana.*

Production of veneer was both by slicing and peeling. Slicers were German-made of the horizontal type, and producing at 3, 6, and 16 m/min. Lathes were German and Italian. Product mix included fine veneers, interior grade plywood for cabinet and furniture use, and pine core blockboard glued with PVA. Most of the production was destined for export to Australia, Panama, Tahaiti, and the United States. A small amount of Structural Grade 4-mm plywood was being made, using pine core and olivillo faces, glued with phenolformaldehyde. Plywood production in the Valdivia mill was reported to be 1,500 m^3 per month.

Surinam

A large sawmill, veneer, and plywood mill complex is located at Paramaribo in Surinam. The company, Bruynzeel-Suriname Houtmaatschappij B.V., is a subsidiary of Bruynzeel Co. of Holland.

Countries producing less than 20,000 m^3 of plywood are Cuba, Guatemala, Honduras, Nicaragua, Panama, Bolivia, Paraguay, and Uruguay.

In 1971, Panama Plywood Industries of Tocumen was producing 35,000 ft^2 of plywood, on a 1/4-in. basis, daily. All of the production was for the local market. Their product was unique in that much of the production was treated with preservatives. The principal species used were cativo *(Prioria copaifera)* and vaco *(Magnolia sororum)* (Anon. 1971c).

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Wood Preservation

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Protection

This discussion of protection research covers conventional and nonconventional wood preservation, chemical sapstain control, and natural durability of wood.

Wood preservation is essentially the incorporation of chemicals in timber to prevent or retard the attack of certain wood-deteriorating agents. Wood preservation, as we know it today, is aimed primarily at the protection of wood against biological attack, including fungi, insects, and marine borers. Wood deterioration may also occur due to physical attack, mechanical attack, and chemical attack. Although the discussions in this section are limited to biological attack, chemical treatment for fire retardants, and stabilization of wood, other treatments are possible.

Conventional wood preservation includes pressure and nonpressure treatment systems. The pressure systems involve an air tight vessel and a relatively well-defined treatment schedule involving pressure and/or vacuum. Conventional nonpressure treatment systems are dip treatments, hot and cold bath thermal treatments, and brush treatments. Only the more promising nonconventional wood preservative systems are mentioned: double diffusion, cold-soaking, press-cap, single diffusion systems, and groundline preservative bandage treatments of utility poles.

Sapstain control systems are basically chemical treatments for green lumber to prevent surface growth of sapstain fungi and molds that grow on wet wood. The treatments keep the wood bright and free of discoloration. The application of wood finishes containing preservative chemicals is similar in its purpose; that is, the preservative chemicals maintain the inherent beauty of the wood surface.

Natural durability or natural decay resistance found in some species of wood is dependent on the extractives found in the heartwood of that species (Asenjo and others 1958; Carter and others 1975, 1983; Reis 1972; Silva and Assumpcao 1970). These extractives can make the wood resistant to fungal and insect attack. Examples of this type of resistance are found in greenheart, curupay, louro, cedro, and lignum vitae (Chudnoff 1984). The natural decay resistance of some species is variable and, in some cases, is nearly nonexistent (e.g., mahot, copaiba, pau marfim, virola, balsa) (Chudnoff 1984). Therefore, when the untreated woods are used, it is best to restrict the application to aboveground and to low-decay hazard areas.

History

In most of Latin America, prior to the arrival of Europeans, the use of wood in situations where decay might occur was met by the use of naturally decay-resistant species. In some cases, the aboriginals simply replaced the structures or items with new materials on a regularly recurring basis. In the Amazon region, anthropologists found that highly decay- and insect-resistant poles were used for housing and other structures. In other regions of Latin America, resistant species were used for structural components of stone and masonry structures (e.g., lintels). Many of the Mayan and Aztec structures contained wood elements that have long since disappeared due to decay; hence, the species of wood that was used is not known.

In the era since Columbus, the use of wood in decay and insect prone situations had not increased very much until recent times. A limited amount of chemically treated wood is now used. It is, however, expected that the use of treated wood will grow in the future, as will the use of more of the naturally decay- and insect-resistant woods.

State of the Knowledge

Brazil, Argentina, and Chile have published most of the Latin American literature on wood preservation. Extensive unpublished information in many of the research organizations of the various countries can be found. Our literature search has uncovered over 200 publications from Brazil, alone, on the broad subject of wood preservation.

Examples of some of the papers follow:

ANDEAN PACT (JUNAC 1988)

ARGENTINA (Ramirez and Barieri 1981; Ramirez and Felix 1982; Tinto 1967)

BRAZIL (Cardosa 1953; Freitas 1970; Galvao 1969; IBDF-IPT-ABPM 1971; Lima 1941; Pereira 1936; Raimbault and Carlos 1983; Realino and others 1978; Serpa 1978; Stillner 1965, 1969)

CHILE (Juacida and Peredo 1985; Navarrete-A. and others 1986; Peredo 1978; Uribe-C. 1985, 1986

COLOMBIA (Mena 1972; Romero 1971)

PERU (Gonzalez and Bueno 1967)

VENEZUELA (Arroyo-P. 1985; Conejos 1969; LABONAC 1974)

Natural Durability

Most of the published literature is on the subject of natural durability. This is not particularly surprising when one considers the variety of hardwoods available and the potential for finding species with natural durability to fungi, termites, and marine borers. The nature of the investigations vary from studies on extraction of chemicals and identification of active compounds that make certain species naturally durable (Silva and Assumpcao 1970) to simple methods of field evaluation to establish natural durability (Realino and Bueno 1979).

Cavalcante and others (1982a) published field and laboratory test results on 20 Brazilian hardwoods for natural durability. The Forest Products Laboratory, Instituto Brasiliero de Desenvolvimento Florestal (LPF-IBDF) in Brasilia, Brazil, established field stake tests of 150 Amazonian woods, in 1984, to evaluate the natural durability of these woods. Along with these conventional tests for natural durability, there have been a number of investigations, using extracts from selected hardwoods, to evaluate the effectiveness of the extracts against fungi and termite attack (Carter and others 1975; Carter and others 1983; Deon 1984; Eslyn and others 1981; Jones and others 1983). Beginning as early as 1948, studies were being conducted in Mexico on natural durability (Garcia-C. 1948); other studies have examined many species from Mexico (Gomez-N. and others 1978; Herrera-R. and others 1980; Paz-Perez Olvera and Salinas-Q. 1977). Greenwood and Tainter (1980) investigated 16 native species from Paraguay for decay resistance using the laboratory soil block test method. They found 13 of the 16 species to be highly resistant, and two species were found to be classified as resistant. In Venezuela, Mayorca (1969, 1972) evaluated more than 115 species of woods from the Guayana region for their natural durability.

Table 12 provides an example of some of the research that has been done over the years in the field of natural durability. Note that various countries and research organizations are involved.

Preservative Treatments

The need for chemical preservatives and wood treatment processes is very important, as is evidenced by the volume of published information on the subject. A limited search of the literature produced nearly 60 publications, with 24 of these originating in four Central and South American countries.

Preservative treatments run the gamut from dip treatment for stain in lumber (Juacida and Peredo 1985) to pressure preservation of post, poles, pilings, and sleepers (Fig. 37) (Karstedt and Gloger 1978; Navarette and others 1986; Peredo 1978; Raimbault and Carlos 1983; Serpa 1978; Stillner 1965). Baechler and others (1962) show results of the nonpressure double diffusion treatment on several woods from Puerto Rico. Uribe-C. (1985) and Karsted and Gloger (1978) discuss the use of treated members in the construction of homes, and Ramirez and Barieri (1981) and Ramirez and Felix (1982) discuss the treatment of timbers with fire retardants. All these papers describe both the treatment and the results of treatment with preservatives. The IBDF-IPT-ABPM (Instituto Brasiliero de Desenvolvimento Florestal) (1971) gives information on the quality control of the preservatives used in treatment and on the final product.

Realino (1979) describes several methods for treating wood with preservatives. A manual on wood preservation in tropical climates by Deon (1990) provides knowledge on such things as protection of sawlogs; temporary protection of fresh sawn lumber and rotary cut veneer; natural durability of timber, preservatives and preservative treatment processes for sawn timber, poles, piles, posts, and plywood. The treatability of 16 Amazon timbers was evaluated by Slooten and others (1976); this report also includes physical and

Table 12-Species evaluation for natural durability of Latin American woods

Species	Natural resistance: High	Resistant	Moderate	Low	Source	Country
Quercus crassifolia	X				Herrera-Rodriguez and others 1976	Mexico
Quercus candicans						
Swartsia cubensis	X					
Calophyllum brasiliense	X					
Nothofagus obliqua	X				French and Tainter 1973	Chile
Fitzroya cupressoides	X					
Quaraiba quianensis		X			Mayorca 1978	Venezuela
Hura crepitans		X				
Eschweilera spp.		X			Mayorca 1972	Venezuela
Peltogyne spp.		X				
Pirahnea longepedunculata	X				Guayana	
Platymiscium pinnatum		X				
Tabebuia serratifolia		X				
Tetrgastris mucronata		X				
Centrolobium paraense	X					
Cordia alliodora	X					
Lecythis davisii	X					
Manilkara bidentata	X					
Bombacopsis quinata	X				Silverborg and others 1970	Venezuela
Centrolobium paraense	X					
Clarisia rademosa	X					
Enterolobium schomburgkii	X					
Hymenaea courbaril	X					
Platymiscium pinnatum		X				
Swietenia macrophylla		X				
Tabebuia serratifolia		X				
Nothofagus dombeyi				X	Juacida and Peek 1982	Chile
Laurefia philippiana				X		
Eucryphia cordifolia				X		
Aextoxicon punctatum				X		
Dalbergia retusa	X				Bultman and Southwell 1976	Panama
Guajacum officinale	X					
Ocotea rodiei	X					
Vouacapoua americana	X					
Eperua falcata	X				Clark 1969	B. Guiana
Lophira alata	X					S. Africa
Eucalyptus marginata	X					B. Guiana
Gilbertiodendron preussii		X				S. Africa
Tetraberlinia tubmaniana		X				S. Africa
Metrosideros colina			X			Hawaii
Parinari excelsa			X			S. Africa
Tarrietia utilis			X			S. Africa
Eucalyptus robusta			X			Hawaii
Eucalyptus saligna			X			Hawaii
Terminalia amasonia	X				Scheffer and Duncan 1947	Costa Rica
Tabebuia chrysantha	X					Panama
Vitex gigantea	X					Ecuador
Minquartia guianensis	X					
Persea spp.	X					

Table 12-Species evaluation for natural durability of Latin American woods-con.

Species	Natural resistance: High	Resistant	Moderate	Low	Source	Country
Cryptocarya spp.	X					
Chlorophora tinctoria	X					
Cordia alliodora	X					
Libidibia corymbosa	X					
Myroxylon balsamum	X					
Erythroxylon glaucum	X					
Quercus copeyensis	X					
Clarisia racemosa	X					
Dipteryx alata	X				Highley and Scheffer 1970	Peru
Diplotropis martinsii	X					
Ziziphus cinnamonurn	X					
Aspidosperma macrocarpon	X					
Caryocar coccineum	X					
Hymenaea oblongifolia		X				
Terminalia amazonia		X				
Enterolobium maximum[a]	XT				Dolores and Santos 1982	Brazil
Symphonia globulifera	XT					
Bowdichia nitida	XT					
Laetia procera	XT					
Dipteryx odorata	XT					
Clarisia racemosa	XT					
Goupia glabra	XT					
Dinizia excelsa	XT					
Garapa quianensis	XT					
Celophyllum brasiliense	XT				Carter and Camargo 1983	Brazil
Carapa guianensis		XT				
Cedrela odorata		XT				
Diplotropis		XT				
Mezilaurus itauba		XT				
Ocotea aymbarum		XT				
Platymiscium ulei		XT				
Sweetia nitens		XT				
Micrandra siphonioides	XT					
Dalbergia retusa	XM				Southwell and Bultman 1971	Panama
Ocotea rodiaei		XM				
Tectona grandis		XM				
Eschweilera luschnathii	XM				Serpa and Karstedt 1978	Chile
Manilkara longifolia		XM				
Goupia glabra		XM				
Eucalyptus globulus		XM			Stuardo and Saelzer 1972	Chile
Nothofagus obliqua		XM				
Aextoxicon punctatum		XM				

[a]T and M refer to durability to termites and marine borers.

Table 13-Treated wood production in Brazil[a]

	Production volume ($\times 10^6$ ft^3)				
Commodity	1977	1978	1979	1980	1981
Poles	2.6	3.9	4.1	4.5	5.5
Sleepers	–	9.9	8.2	7.1	8.2
Posts	–	0.2	0.2	0.7	0.8
Crossarms	–	–	–	0.3	0.4

Cavalcante and others 1982b.

mechanical properties and drying behaviors of the species tested. The Forest Products Laboratory of IBDF in Brasilia has studies underway to evaluate treatment methods for 150 Amazonian woods and to establish field stake tests of these woods in 1984. In 1985, the LPF-IBDF also established field tests to evaluate the effectiveness of soil insecticides for subterranean termite control by the concrete-slab and ground-board methods (Alves 1988). A nontraditional treatment was tested in Mexico, examining the effects of gamma radiation on the resistance to fungal attack (Salinas-Q. and others 1971).

The wood preservation practices in Brazil are quite advanced, and several papers from Brazil describe new uses for treated wood as well as conventional uses of railroad ties and utility poles. A technical bulletin series has been published by Montana Quimica S.A., describing treatment methods for various applications (Montana, [n.d.]). Cavalcante and others (1982b) produced some wood preserving statistics for Brazil, which are presented in Table 13. A more complete compilation of the literature on wood preservation and natural durability can be found in FPL 1990.

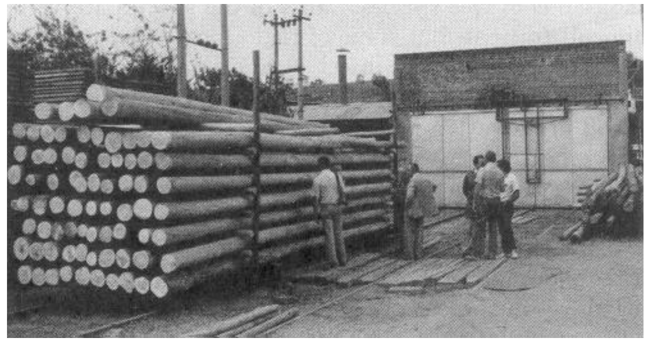
Expanded information on the durability and treatability of the hardwood resource is a basic need. Compiling that information is made difficult by the hundreds of species available, especially the lesser known species. Because most of the tropical hardwoods forests are in mixed stands with up to 400 or more species per hectare, efficient utilization is very difficult without information on the natural durability or treatability.

State of the Art

Even though the use of wood, including treated wood, is minimal in most parts of Latin America, some production facilities are state of the art, for the world. Brazil, for example, has nearly 50 wood preservation plants, including both pressure and nonpressure treating facilities.

Brazil

According to reports by Cavalcante (1985) and Cheynery (1987), the production of treated wood in Brazil, by product, is as follows:



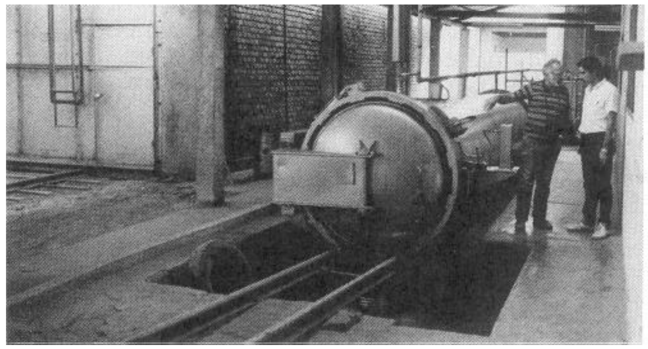


Figure 37-Eucalyptus poles prepared for kiln drying before preservative treatment, Quito, Ecuador (top). Preservative treating cyclinder at wood preservation plant in Quito, Ecuador (bottom). (M90 0130, M90 0154)

Product	Cavalcante Units	Cavalcante Volume (m^3)	Cheynery (m^3)
Crossarms	309,655	8,870	4,439
Fence posts	639,212	9,607	25,368
Sleepers	2,698,430	40,952	216,340
Other treated commodities	–	24,557	Poles 83,200

Several of these plants are under the auspices of Montana Quimica, S.A., Sao Paulo, Brazil (ex OSMOSE PENTOX DO BRASIL, Preservacao de Madeiras S.A.). In correspondence with personnel of the company, they note that 26 private pressure treating plants are in operation, 13 are being built and 4 are being modernized by Montana.

The preservative treating industry in northern Brazil is very different from that in the southern areas of the country. The northern part includes the Amazon basin and the states of Amazonas, Para, Rondonia, Acre, Mato Grosso, Goias, Piaui, Maranhao, Ceara, Rio Grande do Norte, Paraiba, Pernambuco, Sergipe, Alagoas, and Bahia. Northern Brazil is one of the largest natural tropical forest areas in the world, with thousands of tree species. Most of the species are very difficult to treat, but some of them have natural resistance to decay and/or insect attack.

Wood preservation in this area is in a very early stage. Just a few preservation plants exist in the north, and they are owned by railroad companies, primarily treating crossties for their own use.

The following are some of the many problems restricting the development of the treating industry in the north: population density is low; consumer centers are far away; transportation is poor and expensive (few roads); rainfall is great (5 to 6 m/year); climate is hot and humid; maintenance of equipment is difficult because of climate and distance to supplies; limited numbers of a given species in the forest; and the high cost of logging. Because of the attendant problems and risks, the wood treating industry has not developed in the north.

Southern Brazil is the most developed area in the country. Although the natural forests are no longer available for exploitation, plantations of pine and eucalyptus provide an industrial base. About 5×10^6 ha of plantations are available. It is in this southern region where the preservative treating industry exists. Industrial plants include 29 privately owned impregnation plants, treating mostly eucalyptus posts and poles; 13 plants are owned by government railroad companies, treating crossties; 3 plants are owned by government utilities producing eucalyptus poles; 1 plant is owned by a government bank producing eucalyptus poles for commercial sale; and 2 plants are owned by the Instituto Florestal, a government company, treating pine lumber for housing.

The number of producers of preservative in Brazil to supply the industry include: 3 producers of creosote; 1 producer of chromated copper arsenate (CCA); 2 producers of chromated copper borate (CCB); and 8 producers of chemical formulations for general treatment.

The Brazilian Wood Preservers Association (ABPM) has been established and standards have been created to govern product quality. The standards include the following:

NBR-8456: Preserved eucalyptus poles for electric energy distribution. Specification. (Postes de eucalipto preservados para redes de distibuicao de energia eletrica. Especificacao).

NBR-8456: Preserved eucalyptus poles for electric energy distribution. Specification. (Postes de eucalipto preservados para redes de distibuicao de energia eletrica. Especificacao).

NBR-6232: Penetration and retention of preservatives in wood poles-analysis methods. (Penetracao e retencao de preservativos em postes de madeira).

NBR-6236: Timbers for reels for wires, cordages, and cables. (Madeiras para carreteis para fio, cordoalhas e cabos).

ABNT EB474: Pressure treated fence posts. (Mouroes de madeira preservados para cercas).

Note: In cases where standards do not exist, the ABPM has adopted American Wood Preservers Association (AWPA) Standards.

Chile

Next to Brazil, Chile has the largest wood preservation industry in Latin America, with 30 treating plants in the country. All are pressure treating with waterborne CCA. The chemicals for the plants are from different sources including Osmose, Bayer, and Koppers. The major products are grapevine stakes, fence posts, distribution poles, and construction lumber (which is increasing rapidly). The production in 1986 consisted of 65,700 m^3 of which 39 percent was for lumber, 6 percent construction materials, and 54 percent posts and poles (Chile Forestal 1988).

Mexico

According to information from Zavala-Z. (1988), 12 preservation plants use creosote and pentachlorophenol and eight use waterborne salts. These plants have an installed production capacity of 1.25×10^6 m^3 but are producing only 36 percent of capacity. The products include posts, poles, piling, and railroad ties.

Argentina

Tinto (1988) reports that Argentina has 17 wood preservation plants:

Using CCA salts	5
Using pentachlorophenol	1
Using creosote	11
Total	17
Treating posts and poles	11
Treating railroad ties	2
Treating sawn wood	4
Total	17

In 1984, the production of treated wood products was as follows: 1,223,000 railroad ties of Aspidosperma, 44,000 fence posts, and 342,000 poles. The principal species treated are Eucalyptus, Aspidosperma, and Pinus. Two companies manufacture creosote, three manufacture pentachlorophenol, and two manufacture CCA salts in Argentina.

Ecuador

In the Quito area of Ecuador, at least two wood preservation companies are producing treated posts, poles, ties, and timbers from a wide variety of species. Poles are primarily eucalyptus and pine (AIMA 1985). The production of these companies was about 4,500 m^3 per annum in 1985 (Anon. about 1985).

Other Countries

Colombia has 10 treating plants. Peru has 5 treating plants. Venezuela has two or three treating plants. The Central American countries generally have one or two plants per country. A few treating facilities are found in the Caribbean countries.

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Reconstituted Board Products

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History

The history of reconstituted board products in Latin America covers only about 35 years. The history of reconsitituted board research from its inception covers only a few decades more than that in Latin America. Moslemi (1974) states that the first industrial particleboards were probably made in 1941 in Bremen, Germany. Earlier attempts in the 1920s failed for lack of a suitable adhesive. In the 1930s, synthetic thermosetting resins were developed to make the process viable. Investigations into the process of making reconstituted boards began in the late 1800s, and the first U.S. patent on the process was granted in 1905.

The first manufacturing facility in Latin America was a fiberboard plant that was established in 1949 in Argentina. The plant originally used a nonwoody resource but shortly changed to using eucalyptus fiber. The earliest particleboard mills were established in the mid-1950s. The FAO (1970) notes that five particleboard plants were operating in 1957, two in Brazil, two in Colombia, and one in Chile. In the years since these first manufacturing facilities were started, the industry has grown quite rapidly. However, even with the rapid growth, Latin America is lagging behind other areas of the world in reconstituted board production.

Between 1957 and 1968, the fiberboard industry grew from 68,000 t of production to 222,000 t. The particleboard industry grew from 8000 t in 1957 to 159,000 t in 1968 (FAO 1970). The FAO figures of the growth of the industry from 1961 to 1984 are found in Tables 14 and 15. In 1961, Latin American fiberboard production was 82,000 m^3, by 1984, it had grown to 1,188,000 m^3 The largest portion of the growth was in Brazil. The Brazilian fiberboard industry increased by 82.5 times between 1961 and 1984. In the particleboard industry, similar increases occurred. In Latin America, the growth was from 203,000 m^3 in 1961 to l,001,00 m^3 in 1984. Again, Brazil was the growth leader, increasing production by 620 percent between 1961 and 1984.

As with plywood, much of the information and technology for the fiberboard and particleboard industries in Latin America has come from Europe and North America. The history of these reconstituted board industries is really being written now. Most of the information on the use of native trees for the furnish in these products has been conducted in Latin American laboratories in recent years.

State of the Knowledge

Because the equipment and processing technology has come from outside Latin America, most of the Latin American research effort has focused on the raw material with which the boards must be made locally. The following several studies have evaluated local timbers for use in fiber or particleboards:

Argentina-Species possible for particleboard manufacture in Argentina (Garcia 1961)

Brazil-Particleboard from a mixture of Amazonian species (Nakamura and Sobral 1982)

Colombia-Hardboards from tropical woods (Myers 1978, 1979)

Costa Rica-Properties of experimental particleboard from three Costa Rican hardwoods (Cruz 1980).1 Suitability of some Latin American species for exterior particleboard (Schmidt-Hellerau 1977)

Chile-Particleboards of a mixture of species (Poblete 1986)

Nicaragua-Suitability of some Latin American species for exterior particleboard (Schmidt-Hellerau 1977)

Paraguay-Suitability of some Paraguayan species for particleboards (Carre and Fraipont 1969)

Venezuela-Determination of the coefficient of suitability of woods for wood cement panels (Vilela and Pasquier 1968)

Another area of research has been that of processing options and techniques with the local woods.

A considerable amount of attention has been paid to the working properties of *Pinus radiata* in Chile. The research covers a number of topics:

Moisture content of chips (Albin-A. and Jaramillo 1980)

Fabrication of panels in a single step (Devlieger and others 1986)

Using industrial waste in panels (ITPF 1986)

Using forest biomass in particleboard (Peredo and Poblete 1986a,b)

Table 14-Production of particleboard by Latin American countries 1961-1984[a]

Country	Production ($\times 10^3$ m^3)																			
	1961-1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
Bahamas																				
Belize																				
Costa Rica												6	24	28	31	32	23	11	11	11
Cuba	6	15	15	17	5	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
El Salvador																				
Guadeloupe																				
Guatemala	3	4	4	4	4	4	10	10	13	14	16	4	6	3	4	3	3	4	4	4
Haiti																				
Honduras																				
Jamaica								13	11	11	9	11	4	4	4	4	4	4	4	4
Martinique																				
Mexico	13	31	32	50	65	56	56	60	72	94	125	99	155	162	194	316	339	412	335	379
Nicaragua																				
Panama	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Trinidad																				
Total (Central America and Caribbean)	22	50	50	71	74	64	70	89	102	125	156	126	195	203	239	361	375	437	360	404

Table 14-Production of particleboard by Latin American countries 1961-1984[a]–con.

Country	Production (× 10^3 m^3)																			
	1961-1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
Argentina	25	55	64	91	105	117	135	166	172	200	209	225	176	185	248	268	217	215	241	241
Bolivia																				
Brazil	8	19	42	42	81	112	162	265	313	360	407	461	541	541	550	660	660	660	660	660
Chile	8	22	18	21	21	22	31	30	31	26	16	29	32	42	46	43	72	37	72	114
Colombia	11	10	10	10	9	9	10	10	11	12	12	17	20	20	30	31	42	50	50	50
Ecuador													8	14	19	26	28	49	30	32
Fr. Guiana																				
Guyana																				
Paraguay				1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2
Peru	2	11	8	8	6	7	7	8	8	8	8	5	1							
Surinam	20	24	20	10	20	17	10	11	14	13	13	13	8	7	6	6	6	6	6	6
Uruguay	2	2	1	2	2	2	2	2	6	7	6	7	6	6	7	7	6	4	5	5
Venezuela	6	10	15	17	20	24	27	29	30	30	35	35	35	35	35	65	66	60	78	78
Total (South America	82	152	178	201	265	311	385	521	586	657	707	793	829	852	943	1108	1099	1083	1144	1188
Total (Latin America)	104	202	228	272	339	375	455	610	688	782	863	919	1024	1055	1182	1469	1474	1520	1504	1592

[a]FAO 1978, 1986.

Table 15-Production of fiberboard by Latin American countries 1961-1984[a]

Country	Production ($\times 10^3$ m^3)																			
	1961-1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
Cuba	40	51	62	66	54	66	66	66										44	48	48
Mexico	17	17	18	22	22	22	23	23	25	18	14	25	30	26	26	26	26	26	67	65
Total (Central America and Caribbean)	57	68	80	88	76	88	89	89	25	18	14	25	30	26	26	26	26	70	115	113
Argentina	15	22	20	21	22	24	35	52	56	55	51	51	52	68	59	90	86	80	95	95
Brazil	117	148	149	192	209	269	323	368	351	394	504	631	710	765	724	780	780	602	727	
Chile	11	14	13	21	19	20	20	19	20	28	14	22	28	33	44	45	44	44	42	40
Colombia	2	12	13	12	12	12	12	12	12	11	15	13	13	13	17	19	17	18	19	19
Uruguay	1	3	4	4	4	4	3	4	4	4	3	3	3	3	3	3	4	3	3	3
Venezuela		1	1	1	1	2	2	2	2	4	6	8	10	12	16	16	16	4	4	4
Total (South America)	146	200	200	251	267	331	395	457	445	496	593	728	816	894	863	952	947	751	890	888
Total (Latin America)	203	268	280	339	343	419	484	546	470	514	607	753	846	920	889	978	973	821	1005	1001

[a]FAO 1978,1986.

Using sawdust in particleboard (Poblete 1979)

Influence of particle size on board properties (Poblete 1985a)

Movement of formaldehyde during pressing (Poblete 1985b)

Chemical changes during manufacturing (Poblete and Roffael 1985a,b)

Properties of boards protected against termites (Vidal and others 1981)

Changes in particles during pressing (Roffael and others 1985)

Other work done in Chile includes the study of mixed species: content of acid extractives and their changes in particles of different species (Roffael and Poblete 1985) and mechanical properties of boards produced with a mixture of species (Poblete 1986).

Research done in other countries on particleboard manufacture includes a study of the use of different resins in making particleboards from poplar and willow in Argentina (Nico 1957), and from Germany, a study on the suitability of Latin American timbers for exterior particleboard (Schmidt-Hellerau 1977).

Another board product that is rapidly gaining acceptance and is being investigated more and more is wood-cement board (Fig. 38). This product has been around in the form of wood wool-cement board for a long time. Only in recent years has a cement-particleboard come into being. The big difference between the products is the greater strength of the cement-particleboard. The FAO had the Bison Company of Germany prepare a report on the status of cement-bonded particleboard. This report covers, in detail, the mechanics of manufacture and the economic considerations of production of the product (Bison 1976).

Hallak (1972) researched the use of several mineral binders for manufacturing composite products, using sawdust as the wood fraction. He used cement, acrylic, and acrylic-cement binders in his experiments. The boards were aimed at the housing market.

State of the Art

As mentioned in the History section of this chapter, the reconstituted board industry in Latin America is fairly recent, beginning in 1949 with fiberboard in Argentina and in the mid-1950s with particleboard in Brazil, Chile, and Colombia. Since these early dates, the industry has expanded greatly, but as noted by FAO (1970), Latin America still only accounted for about 3 percent of the world production in 1968.

Virtually all the Latin American fiberboard, particleboard, and cementboard plants are designed by Europeans or North Americans and furnished with equipment from these same regions.

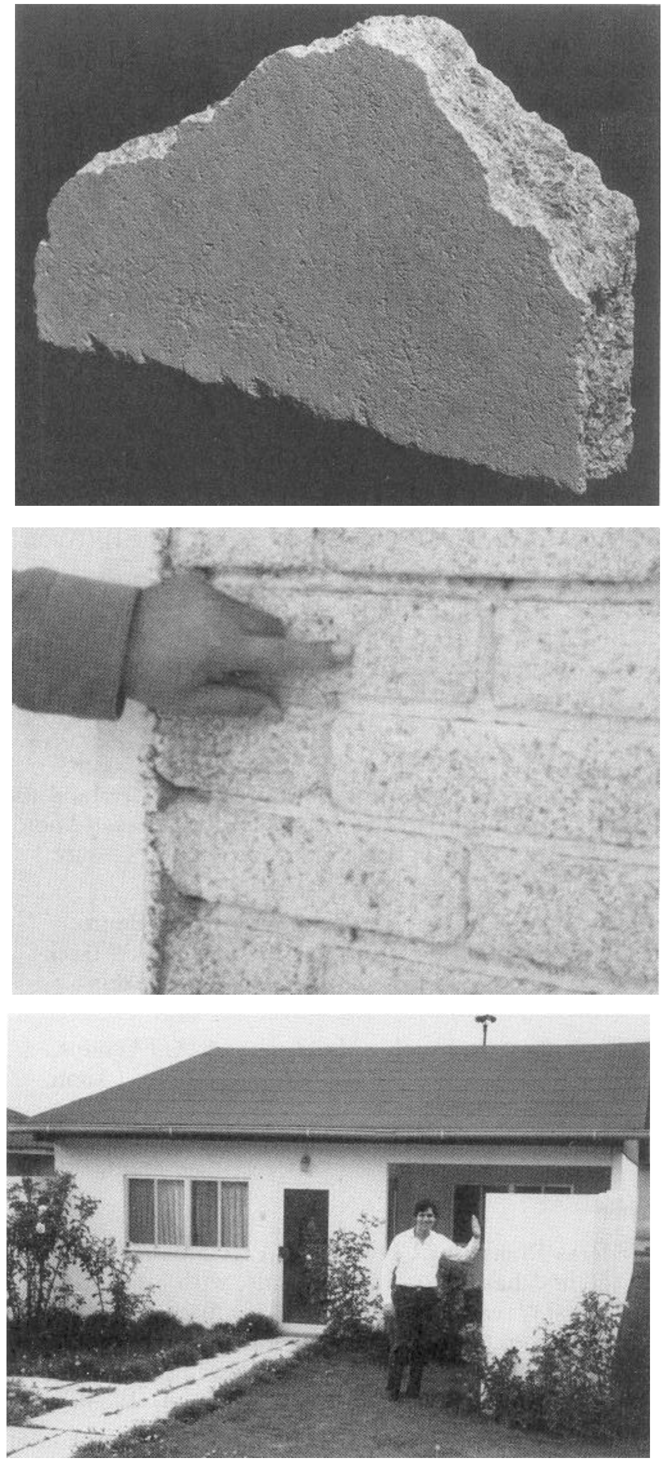

Figure 38-Segment of wood-cement panel manufactured in Mexico (top). Wood-cement bricks at the Forestry School in El Salto, Durango, Mexico (middle). House constructed on cement-board panels, Grupo Guadiana, Durango, Mexico (bottom). (M90 0107, M90 0131, M90 0155)

Beginning in the 1970s, World Wood, and in the 1980s, *Wood Based* Panels International reported on many of the reconstituted board mills in Latin America. The following notes some of the mills that have been described in the journals.

Argentina

Seven particleboard plants, one high-density fiberboard plant (1.00 g/cm^3), and one medium-density fiberboard plant are producing in Argentina according to Tinto (1988).

Tableros Guillerma S.A. (Villa Guillermo, Santa Fe, Argentina) MDF plant using mixed hardwoods (Anon. 1981b).

Brazil

Duratex Paula Sousa Plant (Botucatu, Brazil) producing door skins with Motala press. Mason (1975) and Anon (1983b) buys two particleboard companies, Madeplan (Gravati, Rio Grande do Sul, Brazil) and Alplan (Itapetininga, Sao Paulo, Brazil) (Anon. 1984b).

Eucatex S.A. (Salto, SP, Brazil) makes largest hardboard panel in world (2.44 × 6.1 m) with formers from Edge Wallboard Co., United States Voith of Brazil, and Washington Iron Works press (Mason 1976a).

Minasplac S.A. (Uberaba, MG, Brazil) high-quality particleboard for furniture, Fahrni of Switzerland using Novopan process and Siempelkamp press (Anon. 1977a) provides particleboard for a high pressure laminate company (Anon. 1986).

Freundenberg Industrias Madeireiras S.A. (Bauru, Brazil) using pine with lines by Bisonwerke, Hackhoto chipper, and Bison and Pallmann flakers (Anon. 1977b).

Freundenberg Industrias Madeireiras S.A. (Agudos, Brazil) begun in 1970, using pine residues (Anon. 1983c).

Industrias Madeirit S.A. (Barueri, Sao Paulo, Brazil).

Chile

Maderas Prensadas Cholguan S.A. (Chillan, Chile) the first hardboard mill in Chile, with a capacity of 52,000 t/year in 1988 (Han 1988), used Voith equipment from Germany (Mason 1976b with Motala press (Blackman 1979b; Anon. 1983a), further expansion of production capability (Anon. 1984a).

Maderas y Paneles (MAPAL) S.A. (Concepcion, Chile) particleboard with Bison equipment. (Anon. 1981a).

Masisa Madera Sinteticos S.A. (MASISA) (Valdivia, Chile) making furniture grade board (Anon. 1977d) was producing 30,000 m^3 year in 1988, (MASISA) (Chiguayante, Chile) was producing 60,000 m^3/year in 1988.

Industrias Forestales Curacautin (FOCURA) (Curacautin, Chile) is producing panels by the extrusion process (INFOR-CORFO 1987).

Manufacturera de Fibro Paneles Chile S.A. (MDF CHILE), a joint venture between Maderas Prensadas Cholguan S.A. and Carter-Holt-Harvey Ltd. of New Zealand, started operation in 1988 producing 103,000 m^3/year of MDF, using Sunds Defibrator technology and a Washington Ironworks press. Most of the product will be exported.

Figure 39-House built of particleboard panels and structural members, Quito, Ecuador (top). Particleboard panels manufactured in Ecuador (bottom). (M90 0108, M90 0132)

Colombia

Pizano S.A., Barranquilla, Colombia with Bison former and Siempelkamp press (Davis 1973b). Valdes-S. (1983) said that two particleboard plants existed in 1981, with an installed capacity of 49,000 m^3 and operating at about 89 percent, producing 44,000 m^3. There was also one fiberboard plant with a capacity of 15,000 m^3 and a production of 12,750 m^3 or 85 percent.

Ecuador

Novopan (Quito, Ecuador), Fahrini designed and equipped (Blackman 1979a) (Fig. 39).

Aglomerados Cotopaxi S.A. (ACOSA) (Latacunga, Ecuador), Siempelkamp equipped, began production in 1977 (Han 1988).

Empresa Durini Industria de Madera C.A. (EDIMCA) (Quito, Ecuador), founded in 1940.

Mexico

Novopan de Mexico (Oaxaca, Mexico) with particleboard line by Jacob Lehner A.G., Switzerland (Davis 1973a; Anon. 1978a,b)

Maderas Conglomeradas (San Juan, Ixhuatepec, Mexico) thinboard with Bison-Mende equipment (Anon. 1975), expanded production for doors and manufacturing own resin (Blackman 1980).

Duraply de Parral S.A. (Parral, Mexico) pine furnish to the largest particleboard press in Latin America (1977), with line by Bison (Anon. 1977c) installs continuous press from Bison (Anon. 1985).

Paneles Ponderosa S.A. (Chihuahua, Mexico) largest particleboard plant in Mexico (1979), with Carl Schenk A.G. equipment (Blackman 1979a).

Anafata, Duraply (Mexico City, Mexico), particleboard replaces plywood due to short veneer log supply, Bison-Mende equipped (Anon. 1980).

Costa Rica

Plywood Costarricense at San Jose is producing particleboard from a mixture of logging residue, veneer cores, and veneer waste, using several species.

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Part III

End Use

Engineered Uses

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For purposes of this discussion, the term "engineered use" is defined as any application where a structural member is selected on the basis of its physical and mechanical properties to resist anticipated loads. The more refined the knowledge of material properties and loads, the more efficient the design. Examples of engineered uses for wood extend from the intuitively selected moment or impact resisting tool handle to the highly engineered structural members used in timber bridges.

In South and Central America, the engineered uses of wood tend to fall more on the intuitive end of the scale than on the highly engineered end (Falconer 1971; Hallett 1984; Keenan and Tejada 1984). This is primarily the result of tradition, limited technology transfer, and governmental policy rather than a lack of knowledge or ability. Historical perceptions have resulted in barriers that cannot be removed simply by technological solution. These barriers include established policy by governing bodies, financial institutions, and insurance underwriters as well as public acceptance. In this section, we discuss the following as a possible approach to gaining greater acceptance of wood as an engineering material:

1. Historical perceptions that led to these barriers.
2. Technological advancements that challenge the relevance of current apprehensions about wood use.
3. State of the art in engineered uses of tropical species.

History

Latin American attitudes toward the use of wood as an engineering material reflect the traditions of Spanish and Portuguese emigrants as well as the major native Indian cultures. These people had a long-standing tradition of building with stone, brick, and adobe. This tradition, possibly the result of material availability and durability, led to a rapid acceptance of concrete and a negative attitude toward wood. Concrete is now the preferred structural material in Latin America, and wood if desired, is very expensive.

The Spanish and Portuguese colonists, who settled in the area in the later part of the 15th century, had a tradition of limited use of wood in structures. Their preference was for stone, clay, brick, and mortar for floors and walls. They did show a preference for wood rafter roof systems, however. In Spain and Portugal, the timber resource was not nearly as accessible as the stone and clay resource. Thus, building trades developed around masonry rather than carpentry.

The more advanced Indian cultures of South and Central America also built primarily with stone and adobe. The three major Indian cultures, Incas, Aztecs, and Mayans each developed distinctive building styles using these materials. Studies of Mayan architecture indicate some use of the dense tropical species for lintels over door and window openings and, in some areas, small round timber roof rafters. Some evidence of wooden technique was represented in their stonework, suggesting that at some prehistoric time they had developed skills in wood construction, but these skills were lost, possibly due to problems with harvesting, transportation, and durability.

The only examples of traditional wood-framed structures in these areas were those built by the scattered primitive, seminomadic tribes living close to the forest resource (Crane 1949; Keenan and Tejada 1984). For their lifesytle, wood was the best choice from the standpoint of cost and ease of construction. These structures, designed on the basis of generations of trial and error, were often built using small-diameter trees for corner poles and a floor platform located well above the ground. Palm fronds were used for the roof. These structures were designed to give protection from the sun and rain and to give good ventilation. They were easily repaired and not intended to last for long periods.

Despite its limited demand, wood is more expensive than other construction materials in many of the heavily populated coastal areas of South and Central America. As a result of the traditionally negative view of wood structures, craft workers and engineers have little incentive to develop expertise in design and construction with wood and thus little incentive for efficient timber management, harvesting (Hallett 1984; Keenan and Tejada 1984), or lumber production. In many areas, most notably the Carribean and Central America, past abuses, such as slash and burn land clearing for cattle grazing and indiscriminate cutting for fire wood, have limited the timber resource to either protected or inaccessible areas. Poor roads and mountainous terrain result in high transportation costs for wood coming from jungle areas. A scarcity of sawmills and dry kilns limits the quantity and quality of wood construction materials. Finally, little effort has been made to develop any universally accepted design standards or structural grading rules for tropically grown species. Thus, a quality home built of native timber would require rare design and construction expertise to use an abundant resource that would have to be specially harvested and processed.

The traditional preference for masonry structures has led to the strong acceptance of concrete. It is easier to work than stone, gives the same sense of mass, strength, and durability and can be made from raw materials that can be found in most countries of South and Central America. The process for making cement, patented in 1824, requires only limestone and clay and a kiln capable of heating the proper mixture of the two to roughly 2,200°F. Builders in the Latin American regions are obviously very experienced in the use of reinforced concrete. The relatively low cost, proven performance, and availability of experienced craft workers make it is easy to understand the preference for concrete over wood.

Wood-using industries place little emphasis on the need for structural grading and knowledge of the mechanical properties of wood in an engineering sense. Furniture markets focus on a few species identified for their workability and dimensional stability, and their designs do not challenge the strength limits of the wood. Handles for impact and moment resisting tools are often imported because the engineering properties of local woods are not known or understood. Buildings constructed of wood are often built cheaply with little concern for the risk of failure. This attitude not only creates little demand for good engineering design standards for wood, it also strengthens the negative perception of wood as a structural material.

Latin America has a long-standing tradition of nonwood structures, baaed largely on the cost of wood relative to other building materials. Such costs include transportation, maintenance, and loss caused by decay, insects, and fire. Although technological advances have reduced these costs to the point that they should be comparable to those of other materials, similar advances have not been made in the commodity markets and building trades to support more extensive use of wood.

State of the Knowledge

In comparison to the state of the art of the engineered uses of wood, the state of the knowledge appears to be fairly advanced. Required knowledge for the engineered use of wood includes an awareness of mechanical and physical properties, material variability, mechanical connections, and environmental effects. Although the extent of this knowledge seems to vary from one country to the next, they all exhibit a large gap between what is known and what is practiced (Hallett 1980). This situation is not unique to Latin America but appears to be true for many developing countries (Berhane 1986).

Of the countries visited by the FPL team, Brazil appeared to have the most advanced state of knowledge about engineered uses of wood. This knowledge is well summarized in a six-volume set of texts, entitled Brazilian Experience in Wood and Wood Structures, published by the University of Sao Paulo (1983), school of engineering in Sao Carlos. The six volumes discuss the properties of wood and special considerations for its use in a number of structural applications, including bridges, trusses, housing, and agricultural buildings. These volumes provide construction and design details as well as discussion of methods used for full structural testing.

Brazilian and Chilean researchers have published numerous articles and books dealing with a wide range of topics related to engineered use of wood. Topics covered include structural design with wood (Fox and Cortes 1984; Hellmeister 1984; Pfeil 1980), lumber grading (IBDF 1975), structural composites (NBS 1974; Nnabuife 1984), self-help housing (IPT 1984, 1985; Perez, 1985), and reliability based design methodologies (Freitas 1978).

The Latin American wood research community is well equipped to promote wood as an engineeering material. Many of the scientists involved with wood research have received training in countries noted for engineered use of wood. Test facilities have the equipment needed to determine material properties and to test the performance of wood structural components and systems. Limiting factors, however, appear to be technology transfer and research funding. A wealth of information and ideas for wood use is available in English language journals but somewhat limited in the Spanish and Portuguese literature. This information is limited for technicians, builders, or the general consumers who do not read English. In addition, the predominant use of masonry and steel restricts the demand from the private sector for basic engineering research on wood. Without providing ready access to information on the advantages of wood as a structural material and government support for basic research, it is difficult to realize the full potential of the available research facilities.

Mechanical Properties

There appears to be a fairly large data base of physical and mechanical properties for wood from Latin American species. Many research facilities scattered throughout Latin America have collected information on the properties of the timber species growing in their area (Arroyo-P. 1971, 1985; Barghoorn and others 1967; Karsulovic-C. and Navarrette-M. 1977; Martinez 1977; Mora 1974; Perez-G. 1982, 1983a,b; Perez-G. and others 1971a,b, 1973). A few encyclopedias of properties and applications for many species have been published (Carabiss-J. 1978; Chudnoff 1984; Echenique-Manrique

1972; Keenan and Tejada 1984; Longwood 1962; Vilela 1969). The works by Chudnoff and Longwood, however, did not place much emphasis on the derivation of strength distributions or the methods used to compile the data. In compiling data, for purposes of analyzing strength and stiffness distributions and interactions, it is important to assure that all values represent the same conditions of moisture content, member size, and load rate. Information should also be given to permit adjustments for sample size (within- and between-tree variations). The report by Vilela was done over 8 years and provides a good record of controls, sample size, test methods, and data analysis for 137 species. The study by Keenan summarizes the results of five separate studies conducted in the five Andean Pact countries; Venezuela, Colombia, Ecuador, Peru, and Bolivia. His report gives only the mean values for strength and stiffness of 104 species; however, the statistical details are reported in five reports (one for each country) published by the Junta del Acuerdo de Cartagena (JUNAC). An in-depth study of all available data for purposes of characterizing the distributions and interactions of physical and mechanical properties would be of value to the wood industry throughout the world and to the development of engineered uses of wood for Latin America.

Allowable Stresses

The lack of any universally recognized standard for the assignment of allowable stresses is a major obstacle to the acceptance of wood as an engineering material in Latin America. Most of the research to evaluate strength and stiffness properties of tropical woods follows the recommendations of the American Standards for Testing and Materials (ASTM). However, no universal grading standards are recognized, and each country maintains a file of strength and stiffness properties derived without regard for research done in other countries.

Brazil has a design standard for wood structures and grading rules for sawn hardwoods. The design standard ABNT NB11-51, published in 1951 (ABNT 1951), lists average axial and bending strength and stiffness values for green and dry material of 34 different species. This standard recommends use of design stresses derived as a fraction of the published average small clear, green, strength for a given species (15 percent for bending and tension, 10 percent for horizontal shear, 20 percent for compression parallel, 6 percent for compression perpendicular). Grading rules for tropical hardwoods, published by the Brazilian Institute for Forestry Development (IBDF 1983) could serve as a model for the development of a universal tropical woods grading standard. A number of texts are published on the design of wood structures in Brazil that reference these Brazilian standards (de Freitas 1978; Hallett 1980; Hellmeister 1984; Pfeil 1980; University Sao Paulo 1983).

Researchers at the Instituto Tecnologico de Costa Rica have also done considerable work in the area of allowable stresses, lumber grading, and load duration effects (Hoyle 1979; ITCR 1980; Serrano-M. 1981). Their work includes the publication of grading rules and design values for more commonly used species. These design values were derived following the recommendations of ASTM standards, D 143, D 2555, and D 245 (ASTM 1983, 1981a, 1981b). This procedure references a 5-percent exclusion strength value as the basis for an allowable stress, and the derivation of a design stress is much more rigorous than that presented in the ABNT standard.

Engineered Uses

Knowledge of the design of structural components such as glulam beams, trusses, and I-beams is available to Latin American researchers, but little incentive is provided for them to pursue research in these areas because of very limited markets and research funding.

A potential wood-based structural component that is receiving quite a bit of attention by researchers, however, is wood-cement composite panels (Nnabuife 1984; Stillinger and Wentworth 1977). These panels hold good potential for acceptance due to their cement finish. Several laboratories in Latin America have done or are doing work to reduce negative effects of naturally occurring sugars on the cement curing and cement-wood bonding properties (Ahn 1980; Weatherwax 1964). Nnabuife (1984) effectively summarizes the problems and solutions found for improving the performance of cement panels made using tropical species. The resulting panel products appear to be dimensionally stable and resistant to decay and termites. Thus, this product holds great potential for the use of waste products from tropical forests.

Other structural wood commodities that are receiving some attention include treated timbers for use as poles, piles, and railroad ties (Mendes 1977; Quintana and others 1978).

Housing

A tremendous demand for low-income housing (Fig. 40) has prompted interest on the part of some government agencies and researchers to promote the use of wood-frame construction. In a society raised with masonry structures, the massive appearance and perceived indestructible nature of concrete, stone, and brick provide the basis for judging the true value of a home. The fact that wood structures cost less to build than do masonry structures, in areas with the facilities and resources to produce both, only serves to reinforce the belief that wood structures are inferior. Government backing for programs to provide low-interest financing for wood houses designed with emphasis on comfort and durability may help to change this attitude in time and to promote the structural use of wood.

A wide range of low-cost housing demonstration programs have been conducted in Latin America. Some

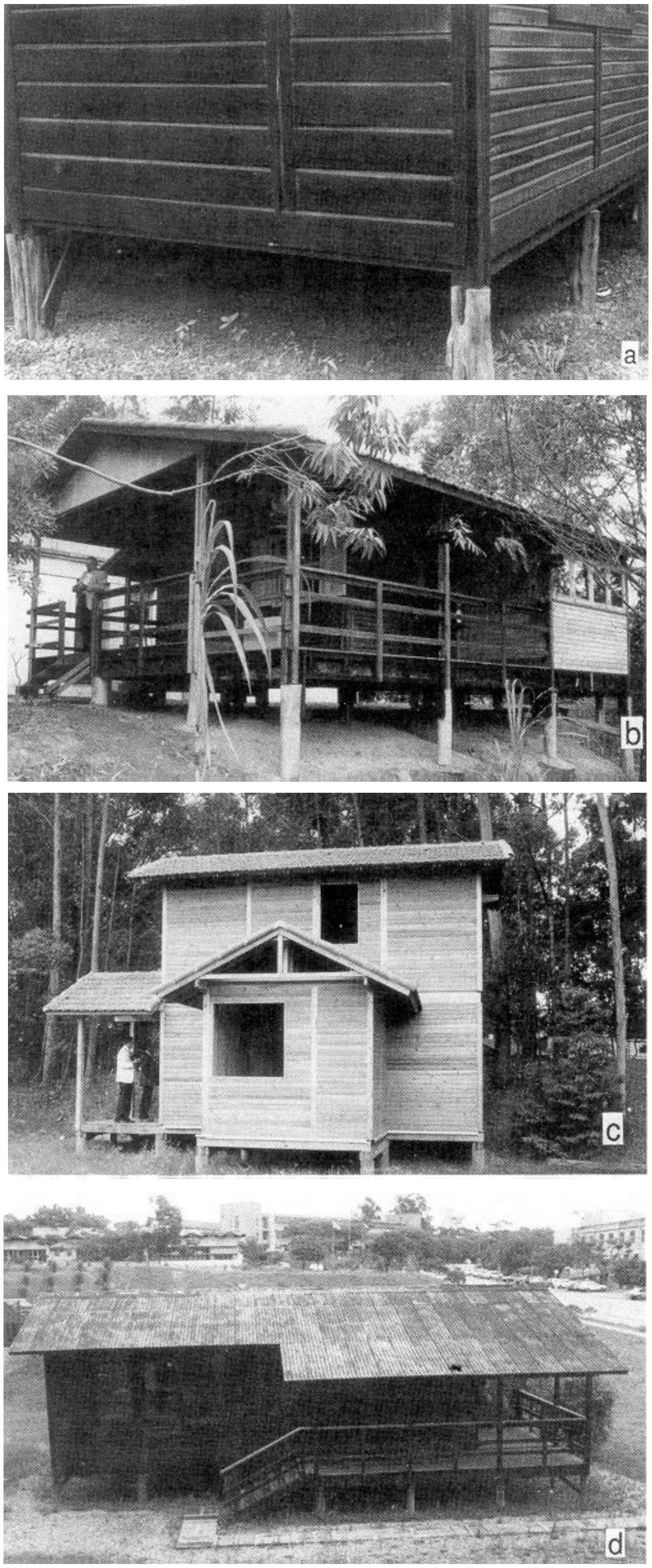

Figure 40-Low-cost house designed by IPT (Instituto Pesquisas de Tecnologicas) Sao Paulo, Brazil. This house is constructed of insect- and decay-resistant Amazonian woods (a). Preservative-treated wood house (b); preservative-treated pine house (c); all native durable wood house (d)–all designed at IPT, Sao Paulo, Brazil. (M90 0156, M90 0109, M90 0133, M90 0157)

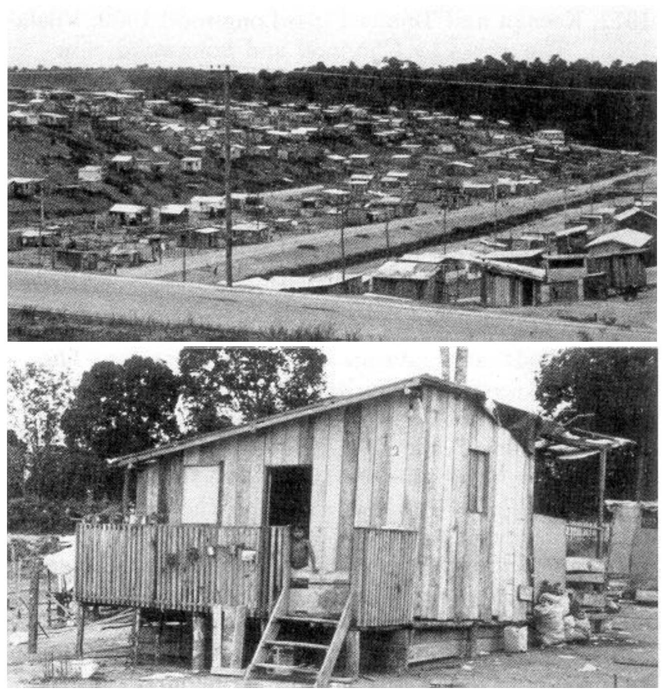

Figure 41-Low-cost housing development (top) and low-cost housing unit (bottom), Manaus, Brazil. (M90 0110, M90 0134)

projects, such as those conducted in Brazil (IPT 1982, 1984) are oriented toward the owner builder and emphasize (1) low-cost panelized construction methods, (2) design details to minimize problems associated with termites and decay, and (3) use of locally available species.

Other programs generated, using funding from foreign aid programs (Brealey 1975; Edwards 1983; HHFA 1959; Waggaman 1967), place emphasis on housing designs that can be mass produced at low cost to house the homeless (Fig. 41). More recent projects funded by the American Plywood Association (APA) and the Southern Forest Products Association (Anon. 1986a,b, 1989) place major emphasis on durability by promoting the use of treated wood framing and sheathing products from the United States.

State of the Art

The state of the art in the engineered use of native species in Latin America is quite limited by comparison to that in Europe and the United States. Although the wood furniture market appears to be healthy and growing, other engineered uses are barely visible. There is little, if any, market for engineered wood components such as trusses, glulam, and wood I-beams. Round timbers are occasionally used in rural and coastal areas for distribution lines, but concrete poles and steel distribution towers dominate in heavily populated urban areas. Wood rafters and joists are common in masonry structures, but wood-framing members and sheathing are not generally accepted for structures; thus, they are not readily accessible as a commodity item for those who would use them.

Allowable Stresses

Although people involved with wood research throughout Latin America are familiar with ASTM standards, a number of other standards are also being used, such as COPANT (Commission Panamaericana de Normas Tecnicas; British Standards Institution), CSA (Canadian Standards Association), ICONTEC (Instituto Colombiano de Normss Tecnicas), and ABNT (Asociacion Brasileiro do Normas Tecnicas).

Wood design in Brazil would be more likely to follow the ABNT design procedure. A number of structural design manuals published in Brazil (de Freitas 1978; Hellmeister 1984) describe the derivation of allowable stresses for structures on the basis of the stresses published in the ABNT standard (3-1,2). These methods could also be applied to any of the other 200 to 300 tropical species, identified as acceptable for use in construction throughout Latin America, provided the methods of measuring material strength values are compatible. The problem is that not all researchers follow the same test procedures or test material from a significant number of sources to give a good representation of the strength and variability in a given species.

When wood is used in engineered applications, structural members are selected in one of three ways:

1. Trial and error. In each country, certain species are commonly available. Experienced builders have developed their own repertoire of species and sizes to be used in given applications. Some of these are handed down from a past generation, some are extrapolations of past practice. This is especially common in the furniture industry.

2. Comparison to U.S. standards. In some instances, allowable stresses are derived by comparing the tropical species to some common U.S. species. By evaluating specific gravity, stiffness, and perhaps bending strength of a few samples, allowable stresses are obtained by using published values for a U.S. species with similar properties.

3. Tests of strength and stiffness. These tests may or may not follow some recognized standard, such as those published by the American Society for Testing and Materials (4-1,2) or the Associacao Brasilerira de Normas Tecnicas (4-3). If done by an established testing laboratory, these tests usually follow a recognized standard procedure. If done by an individual, samples are likely to be small and from a narrow range of growing conditions. Vital information such as sample size, moisture content at time of test, test procedure followed, and variability of the test results are rarely published. This makes it impossible to place any degree of confidence on the derived values.

Engineered Uses

The greatest engineered use of tropical wood in Latin America is furniture. Furniture designs have evolved by trial and error or by copying popular styles. The concerns of the furniture industry are concentrated more in the areas of drying, adhesives, and finishes rather than mechanical properties. The markets for furniture, furniture grade hardwoods, veneers, plywood, and composite sheathing products have been strong enough that efforts to improve design efficiency have been minimal. Most furniture manufactured in Latin America is made from solid wood. However, a number of state-of-the-art plywood mills manufacture furniture-grade plywood, primarily for the export markets.

Plywood made using waterproof adhesives is gradually gaining greater acceptance in place of solid wood for concrete forms, but the limited supply prohibits its use as structural sheathing. As the number of producers of exterior-grade plywood increases, its use may also expand to other areas of construction.

For the most part, wood is used only when it is shown to have a distinct advantage over concrete and steel. Distribution poles are made of concrete except in the remote areas where transportation and handling costs give wood the advantage and along the coast where wood is more resistant to the salt air. Wood use as piling is also limited to remote areas for reasons of accessibility, and to marine applications where it is preferred for docking structures.

A major deterrent to the use of wood in engineered applications is the lack of grading, design, and construction standards. In the United States, these standards developed along with the wood industry, which evolved along with the steel and concrete industries. In Latin America, the steel and concrete industries dominate all construction markets. If wood is to catch up, the standards must be developed ahead of the market. As a result of the lack of universally accepted standards, relatively few visible examples of well-designed wood structures exist.

Housing

The state of the art in the use of wood for housing has been limited by a number of factors. Major problems, which must be confronted, include the market influence of competing materials, negative policies of financial and insurance institutions, and visibility of substandard wood housing for the poor.

The traditional preference for concrete and steel provides a negative incentive for the creation of wood commodity markets. Preference for masonry has resulted in advancements in the state of the art of concrete building construction, which may make it difficult for wood housing to compete for price even if it would gain acceptance by the general public. The materials and experienced labor needed to build reinforced concrete structures are readily available at a relatively low cost.

In Guatemala, for example, the cost of concrete houses in 1986 ranged from US$5 to US$6 per square foot. The limited supply of structural wood products and experienced labor make it difficult to construct comparable wood houses in that price range. Although wood is commonly used for roof rafters, its future use as a competitive structural material is strongly dependent upon public acceptance to provide economic incentives.

Government insurance and financial institutions also pose a major barrier to the acceptance of wood-frame structures, in many areas, by refusing to insure or finance them. As a result, for those who might be interested in building with wood, financing costs may be prohibitive. The primary concern is loss due to fire. Although little evidence supports the claim that wood structures are more prone to fire, the wood structure is more likely to be a total loss. There may also be greater danger to other buildings in densely populated areas.

Adding to the disadvantage of a lack of good examples of well-designed wood structures is the widespread use of wood in subsistence housing. In many areas of Latin America, a large portion of the population have barely enough income for food and clothing. These people often take over an area and build shelters from whatever materials they can get. In many cases, shelters are built of wood scraps. To many potential home buyers in these areas, this very visible subsistence housing is their example of wood-frame construction.

Latin America is not without examples of engineered wood structures. This is especially true in areas settled by emigrants from northern Europe. There are examples of wood trusses, wood columns and beams, and board sheathing used in housing and commercial buildings. 'Busses are normally fabricated on site using rough sawn boards, connected using nailed lap joints. In some cases, plywood gussets are used, but in most cases, the truss chords consist of two parallel boards nailed on either side of the board web members. Most wood beam applications require the use of splice joints to attain over 14ft spans due to limits on log lengths that can be transported. In those areas where wood is accepted as a structural material, potential markets exist for items such as visually graded lumber, structural plywood, wood siding, trusses, and I-beams.

The tremendous demand for housing in Latin America (a deficit of millions of housing units per year) indicates a vast potential for the development of an industry to use wood as an engineering material. Such an industry would enable these countries to utilize their timber resource more efficiently and to provide needed housing, as well as jobs, for their poor. Before these potentials can be realized, however, attitudes must be changed, and some incentives must be provided to promote the efficient use of the timber resource.

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Furniture Manufacture

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Wood furniture was in common use when Columbus first arrived in the Western Hemisphere. Since then, the industry of Latin America has produced some very good and some very crude furniture. Even today, it is easy to find the extremes in quality of furniture. It is also easy to find great differences in the technology of furniture manufacture.

State of the Knowledge

Although furniture manufacture is an active business in all of Latin America, little published literature is available on the furniture industry. Exceptions are from Brazil and Chile. In Brazil, a number of journals deal with furniture design and manufacture; for example, Revista da Madeira, Revista Design Decoracao, Revista Moveleiro, and Movel Press. In addition to these, Fundacao de Ensino, Tecnologia e Pequisa (FETEP) of Sao Bento do Sul, SC, Brazil, has published more than 40 basic texts for furniture quality control (Souza 1988). A paper on the industry in the Biobio region of Chile is also available (Ilabaca-U. and Fuentealba-H. 1985). Most of the literature contains references to furniture but not much on the design or manufacture of it.

Many of the documents listed in the sections on anatomy and properties note what a species is used for or whether it is suitable for furniture. Other documents in this vein include IBDF [n.d.]), which gives basic information on Brazilian woods for a furniture fair, and IBDF (1981), which lists 164 Brazilian species, their coded properties, and uses, including furniture manufacture. In a study of Brazilian mahogany, Brazier and Lavers (1977) give advice on the use of two species in the manufacture of furniture. Other documents (Becerra-M. 1977; Herrera 1981) note properties (including machining) and uses of oaks from Mexico and list furniture as a potential use. Further work in Mexico evaluates workability for furniture for numerous species, both temperate and tropical (Martinez-C. and Moreno-Z. 1984; Vazquez-R. 1983; Zavala-Z. 1976). Also available from Mexico is a promotional study on 43 tropical woods (Torelli 1982). A discussion of the species *Catalpa longissima* from the Dominican Republic (Basilis 1978) lists high-quality furniture as a use of the now scarce species. From Paraguay (Evans and Rombold 1984), comes a study on agroforestry promoting *Melia azedarach* for furniture use when harvested at age 12 to 15 years. From Argentina (Moure 1978), a booklet on the properties of quebracho colorado *(Schinopsis lorentzii)* and quebracho blanco *(Aspiclosperma spp.)*, suggesting their use in furniture.

In a combination of plantation management, general wood technology research, and research on furniture, the Instituto Pesquisas Tecnologicas (IPT), in Sao Paulo, Brazil, is working with clonal eucalyptus. The IPT has developed clones of eucalyptus with specific colors and working properties, which they are incorporating into furniture. The idea is to show that 5- to 6-year-old trees can be processed efficiently into quality furniture for higher value.

If further work is being done on wooden furniture design or manufacture, it was not found in our literature search or from our contacts in Latin America.

State of the Art

The one item that characterizes much of the Latin American furniture industry is a lack of understanding of the basics of wood performance in different climates. Considerable amounts of furniture are manufactured for export to countries in Europe and North America where the winter condition in heated homes is very dry. Often, the beautiful furniture fails under the low ambient equilibrium moisture content (EMC). This has especially been the case with furniture manufactured in the Caribbean Islands and Central America, but it is true of manufactured furniture from other countries too.

We visited several Central American furniture plants that were exporting to Europe and North America. None of the plants had humidity control in the manufacturing or the storage facilities. The EMC conditions in the plants would be over 12 percent, whereas the conditions in the heated homes of the higher latitudes may be from 1 to 5 percent.

Each month in his Wood and Wood Products column, "Consult Jerry Metz," Metz gives the same advice on humidity control and moisture content. For example, a typical response on humidity control (Metz 1987): "A. [answer]:-Storage and manufacturing areas must be within the 65°F to 78°F range and the humidity not under 30 percent or over 45 percent. This is the broad base required. If you are not (and I gather you are not)

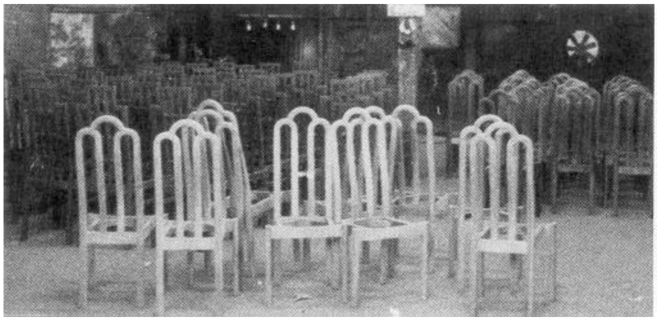

Figure 42-Chairs at furniture factory in Guatemala City, Guatemala. (M90 0158)

within all of these ‘rules’ you are subject to trouble.” Or, a question and answer on moisture content. “Q:– Also, what spec (specification) do I require for moisture content of hardwoods?-Thank you for your help. Mr.R.” “A.–The moisture content for hardwoods is 6-1/2 to 7 percent and that means right on it, as far as the specs go.”

Karstedt and Simioni (1979), commenting on the furniture industry in Brazil, note that the quality of furniture must be improved to compete effectively in world markets. Our limited observations in several furniture plants in South and Central America would confirm this statement of Karstedt and Simioni. The lack of humidity control in manufacturing and storage are the most critical items. Also, the lack of dust control not only makes finishing a difficult problem but also creates fire and health hazards in the factories.

Other observations in the plants we visited were that the quality of craftsmanship was very high and the design and structure of the furniture was good (Fig. 42). These comments are on furniture plants using high-level technology and craftsmanship.

Many cottage industry furniture manufacturers have low levels of craftsmanship and virtually no technology. In many countries, these furniture manufacturers can be seen selling their wares on the streets. Most often, the furniture is made of low-density, easily worked wood. For example, we saw many vendors selling pine furniture on the streets of Guatemala and Mexico. The furniture is fitted and worked, largely by hand, with crude tools.. This low-cost furniture is primarily used within the individual countries; however, some is shipped to the United States and perhaps other countries for specialty markets.

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Miscellaneous Products

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Reports in the area of miscellaneous products are quite limited. Because of the small number of reports and the small amount of information available on the state of the art, all sections will be combined in the following discussions.

Pallets and Containers

Little information was found on the manufacture or use of pallets. Tinto (1988) notes that the Instituto Argentino de Racionalizacion de Materiales (IRAM) has developed several standards relative to pallets. He also says that the common pallet woods used in Argentina are Aspidosperma, Populus, and Eucalyptus.

A few documents on the manufacture of containers were found. These include discussions on standardization and grading rules in Brazil (Anon. 1971a), suitability of species from Venezuela for packing cases (Anon. 1971b), manufacture of veneer and lumber boxes in Panama (Anon. 1971c), manufacture of boxes in Chile (Blackman 1981), treatment of boxes with fungicides in Mexico (Lamas-R. and others 1982), and a survey of the wire-bound packing crate industry in Mexico (Compean-G. and others 1984; Enriquez-Q. 1980). Although not mentioned in the literature, a sizeable crate and box industry exists throughout other parts of Latin America. This is noted in the markets of the United States, especially for the shipment of fruits.

An example of the box industry was observed in Mexico. by the author. Over 200 box factories are located in the city of El Salto in the state of Durango. These are essentially all family owned facilities, employing up to 5 or 6 persons. Some of the factories use waste pine wood from a local sawmill and some use pine bolt wood. The boxes are a standard fruit crate size (approximately 30 by 45 by 38 cm) (Fig. 43) and are rigid in construction. The production of most of the factories is low and slow because of the hand labor. In El Salto, a very advanced, high-production factory produces wire-bound folding crates. All of the boxes and crates produced in El Salto are used in the fruit industry. Another similar factory was visited in the state of Veracruz, again using pine wood.

Other Products

This discussion covers all other minor products for which literature was found. Bueno-Z. (1975) discusses an evaluation of 161 Peruvian woods for pencil making. He notes that only three species were suitable without modification: *Ceibs* spp., *Cedrela odorata,* and *Virola spp.* If waxed, six other species would be suitable: *Chorisia integifolia, Guazuma ulmifolia, Nectandra spp., Spondias mombin, Sterculia spp.,* and *Trichilia spp*.

In San Carlos, SP, Brazil, the author saw a large factory that is using pine to manufacture pencils. The resource for manufacture is from plantations.

Souza (1983) describes evaluations of 100 Amazonian woods for potential use in musical instruments. He notes the selection of 20 species with suitable properties for use in musical instruments, both stringed and woodwinds.

Sternadt (1983) provides an insight into the trade in small wood items manufactured in Brazil during 1973 to 1983. He notes 40 types of products and the importance of the items to the economy of Brazil. The types of items vary from art objects to mouldings, from toys to hairbrushes.

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Figure 43-Drying box shook at El Salto, Durango, Mexico (a). Assembling boxes at La Selva Ejido, Veracruz. Mexico (b,c). Cutting corner pieces for boxes at box factory in La Selva Ejdo, Veracruz, Mexico (d). (M90 0135, M90 0111, M90 0159, M90 0176)

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Part IV

Areas for New Initiatives and Programs

Research

The following research suggestions are in no way exhaustive, but rather just suggestive of areas of potential work. Each individual country or region will develop its own needs for research. The suggestions put forth are deemed by the authors and reviewers to be of the greatest importance.

Anatomical and Physical Properties

As mentioned in Part I, Wood Resources chapter, anatomy and physical property research on species already studied need not be repeated. However, the diversity of the moist tropical forests may call for continued evaluations. This is especially true for the physically smaller and currently unused species that have not received evaluation and for the new discoveries that periodically occur.

- Wood anatomists and technologists should keep in touch with government and private forest surveys or botanical expeditions to obtain samples of new or unevaluated species for testing. For preferred species of a wide geographical range, anatomical and physical property data, on a regional basis, should be assembled for possible use in genetic control of properties in planting stock.

Mechanical Properties

Although numerous evaluations of mechanical properties have been made, they have not all been made to the same standards. Several different standards of testing have been applied, including ABNT (Associacao Brasileira de Normas Tecnicas): AFNOR (Association Francaise de Normalisation); ASTM (American Society for Testing Materials); CITEMA (Centro de Investigacion Tecnologica de la Madera y Afines); COPANT (Comite Panamericano de Normas Tecnicas); INCONTEC (Instituto Colombiano de Normas Tecnicas); INN (Instituto Nacional de Normalization); and IRAM (Instituto Argentino de Racionalizacion de Materiales). The mix of testing standards does not permit the cross comparisons that are desirable from site to site or region to region.

- A network of laboratories should be developed to evaluate species for mechanical properties, using standard testing methods. The methods to be used should be jointly established by the Latin American community to best serve the local needs for use of the timbers in question, as well as for broader world markets (see Veneer and Plywood, this section).
- Mentor laboratories should be designated to coordinate research and train researchers (see Training chapter).

Chemical Properties

Because of the great diversity of species, especially in the tropical wet forests, there will be a continuing need to examine the chemical properties of newly discovered species. Also, there is the continuing need to find new chemical feedstocks to replace those now derived from petroleum. Many of the new materials may be found in the forest resources of Latin America.

- We recommend that laboratories throughout Latin America continue determining conventional chemical properties of new woods and examine in more detail the chemical properties of known woods.

Pulping

Even though the pulping industry is very much state of the art in Latin America, definite needs exist for the immediate future of the timber and water resources of the region. Current technology is still highly polluting in nature and can only be kept clean by expensive technological measures. One of the hopes for clean pulping is biological pulping.

- Vigorous effort is recommended to find organisms that will permit efficient biological pulping of the indigenous woods of Latin America. This effort should be coordinated among the major pulp producing nations to provide diversity of ideas and sources of fungi. Based on the current degradation of the major waterways and oceanic waters of Latin America, we suggest that the World Bank be approached for funding of this endeavor through its environmental concerns branch.
- Continuous efforts should be made to find nonpolluting methods of bleaching pulp.

Sawing

Most of the work still needing to be done in the realm of sawing tropical woods is in the area of sawing very dense woods, woods with high silica content, and species with high growth stress problems. However, potential problems also exist in the area of juvenile core wood for both hardwoods and conifers with the increasing establishment of plantations.

- We recommend that an international team study the problem of growth stress. The studies should be in a logical and progressive manner, from the formation of stresses to the variation of stresses in time and geography, to the alleviation of negative aspects in sawing, and to the establishment of physiological or genetic control over stress formation.
- An international effort should be made to develop and test new saw blade materials and cutting methods for sawing high-density and siliceous woods.
- Research should be conducted on methods of sawing juvenile material to achieve high yields.

Drying

Our conclusions and recommendations on drying research needs agree with those stated in the 1986 report of the International Union of Forestry Research Organizations (IUFRO), "Improved Utilization of Timber Resources in South America: A Programme for Action."[2] We found, from our visits and review of the literature, that several government and university laboratories have or are currently running screening tests to determine general drying characteristics of the more common woods of their areas. The screening subjects wood to three kiln-drying regimes: mild, moderate, and severe, and then categorizes the degrade for each drying regime.

- For those species that are currently in demand but have only basic drying information available, more refined kiln schedules should be developed to optimize drying times, decrease drying defects, and make more efficient use of equipment and energy.
- Many species or species groups are found in several countries. There is, then, no need for each country to conduct research on all species. A reasonable level of sharing and/or coordinating of the generation and dispersion of technical knowledge is needed between research institutions and countries. Based on our observations and the literature, this is not currently being done at what we consider a satisfactory level. However, some repetition of experiments may be necessary or desirable to verify whether the same species, grown under extremely different conditions, responds as reported by others.
- We recommend drying schedules be developed for kiln loads consisting of mixed species to provide adequate volumes for economical and quality kiln drying.
- Research related to solar drying systems should be intensified, particularly the development of low-capacity driers for small enterprizes (e.g., in the furniture sector).

[2] See Reference in Introduction.

- Research results should be shared widely to reduce the need for duplication of effort, but research should be repeated where extremely different growing conditions exist for the same species.
- Research should be conducted on all species for which there is no drying information and which have commercial possibility, to establish the drying potential by the three-step screening method.
- Research should be conducted on species that have been screened for drying and have imminent commercial use, to establish schedules for minimizing drying times and energy use, while maximizing product quality.

Veneer and Plywood

As noted in a previous section, the veneer and plywood industry is at a fairly high level of technology. On a maintenance level of research, new species should be evaluated for peeling, slicing, gluing, and pressing. A further need is for the development of structural products and standards.

- We recommend that Latin American standards be developed for structural plywood using input from the standardized mechanical properties testing noted earlier. A networking system should be used to establish the standards.
- Continuing research should be conducted on new species, as they become available, to determine peeling and slicing properties, drying features, and ability to glue.
- Species mixes of lesser known species of similar characteristics and properties should be tested for plywood manufacture.

Wood Preservation

One way to conserve the natural forests of Latin America is the more total use of logged areas, providing the logging is done in small and controlled cuts. However, to make such operations economical, all the timber cut must be used. Many trees in the diversified wet forests of Latin America are small in diameter but tall and straight. These timbers are ideal for uses where preservative treatments are necessary, such as sleepers, poles, posts, and piling. Most of the species, because of their small size, possible high density, or other properties, have not been researched for products. Many of these trees may have natural durability that has not been evaluated.

- We recommend that a concerted effort be made to evaluate the lesser know small-diameter and high-density species for use in preservative treatment applications.
- A concerted effort should be made to evaluate the natural durability of the lesser known small-diameter and high-density species in well-planned and well-maintained stake cemeteries.
- Extractives from naturally durable woods should be evaluated for prevention of fungal and insect

attack, artificial synthesis, and fixation in non-durable woods, to replace currently used toxic chemicals.

Reconstituted Board

The reconstituted board industry in Latin America, like the plywood and paper industries, is at a high level of technology. There is, however, an area of structural products that is not as highly developed. Research into the manufacture of structural composite boards from Latin American woods needs to be conducted. We observed a pilot home constructed entirely of composite components. The need for better product manufacture and better design was quite obvious.

- We recommend that research be conducted at numerous laboratories on the manufacture of structural composite boards from indigenous woods for each laboratory's specific area. Design, as well as manufacturing technology, should be an integral part of the research.

Standards for Latin America should be developed for structural composite board products, using the previously discussed networking system.

Engineered Uses of Wood

The major deterrants to the acceptance of wood for structural use in Latin American countries appear to be cultural in nature. Some acceptance problems require more than public education, however. The most prevalent of these have to do with the wide variety of species available in the tropics. A coordinated effort is needed to develop a means of classification that addresses the most valuable attributes of a species.

Researchers throughout Latin America should be encouraged to develop a standard classification scheme that could be used to classify wood as to its best end use. Use categories would include, for example, furniture, structural products, chemical production, pulp, and fuel. Each category would have its own set of material requirements, with pulp and fuel at the bottom, to gather all material not acceptable for other uses. Furniture woods should resist dimensional change and splitting due to moisture change, be easily worked, and have attractive character. Structural woods should have a density range from 0.30 to 0.65 g/cm^3, be easily sawed with little or no inherent growth stresses, and have acceptable strength and stiffness properties. It may be possible to develop specifications for wood in general with no need for species identification. Special consideration may be needed, however, for species with inherent resistance to decay or fire. Valuable extractive content of fruit, leaves, or wood would determine a species use for production of chemicals.

Within each classification, grading methods are needed to place some value on the wood. In the structural classification, for instance, machine stress rating methods could be employed to place lumber or poles into specific strength and stiffness categories. Coordinated efforts among countries, involving standard test and analysis methods applied to different species, would facilitate this task and give added value to the end result.

Technology Transfer

In many cases, it is difficult to separate technology transfer and training. For discussions here, we will consider technology transfer to be the practical exchange of information, at the operator level, for immediate application. Some instructor training may be included in the technology transfer effort. Training, as discussed here, will apply to those who will receive academic instruction and will instruct others or will be conducting research.

General Needs

One of the glaring deficiencies in Latin America is the lack of extension or technology transfer systems. Without a system of exchange of information on a relatively free basis, it is difficult to move an industry or a discipline ahead. The academic and research organizations that develop data, techniques, and systems to improve wood use need to have an outlet that is more applicable to industry than just publishing the information. This need for technology transfer was quite obvious to the members of our team in the Latin American countries that we visited. In every conversation with government officials, university, industrial, and association personnel, we were told of the need for assistance in sawing, drying, wood preservation, and other areas of the wood industry.

- An effort should be made by the United Nations Development Program/Food and Agriculture Organization (UNDP/FAO) to assist in the development of a charter forest products extension service in a selected Latin American country. This extension service should be an exemplary group that would serve as a training source for other countries in developing their own forest products extension services. Assistance of the countries that now have functioning and successful extension services should be obtained to help in the development of the exemplary extension service in this selected country.

Pulping

The state of the art in the pulping industry in Latin America is at a very high level and the known technology transfer needs are just to keep up with new developments as they become available.

Sawmilling

The technology transfer needs in Latin America for sawmilling are great and cover the entire area of sawmilling. Updates on techniques from sawing patterns to plant layout are needed.

- A program should be developed to provide intercountry assistance in the upgrading of sawmills throughout Latin America by means of a sawmill improvement team. This program could be sponsored by an international funding organization and be made available to any mill requesting the assistance of the team. Initially the team would be made up of representatives of countries where such programs now exist. The initial team would train indigenous teams to do the work beyond the first stage. The goal would be to establish in each country a sawmill improvement team to be operated and maintained by the individual countries.
- Regional sawdoctoring clinics should be established for the training of millwrights and sawfilers where national programs are not available.

An example of such a clinic is that at Escuela Nacional de Ciencias Forestales (ESNACIFOR), Siguatepeque, Honduras. This school invites Latin American participation in its clinics and has used German instructors, in addition to their own. The courses include sawfiling, mill alinement, saw tensioning, and other items of saw operation and maintenance. Other centers of sawmill training that might be potential locations for clinics are Centro de Pesquisas em Productos Florestais (CPPF) Manaus, Brazil; Laboratorio de Productos Forestales, Universidad Nacional, Medellin, Colombia; Corporacion de Desarollo para el Sector Forestal y Maderero del Ecuador (CORMADEIXA) Technical Center, Quito, Ecuador; Instituto Nacional de Administracion Forestal, El Salto, Durango, Mexico; and Laboratorio Nacional de Productos Forestales, Merida, Venezuela.

Drying

The great need in the area of wood drying is to train mill managers and their kiln operators to understand the reasons for drying and the methods to accomplish proper drying. This type of training needs to be repeated frequently to keep up with the turnover of personnel that generally takes place in mills. The key areas of instruction are (1) a general understanding of wood moisture and its effects on wood product quality, (2) an understanding that all species and products are not dried the same way, and (3) an understanding of the proper methods for drying wood in kilns.

- Regional schools, industrial associations, individual industries, governmental agencies, and universities develop and conduct kiln drying short courses, in a manner similar to the saw doctoring short courses. Patterns for such courses are available from several U.S. sources; such as, University of Minnesota, St. Paul, Minnesota; Oregon State University, Corvallis, Oregon; and Michigan State University, East Lansing, Michigan.

Veneering and Plywood

The greatest apparent need in the area of veneer and plywood is that of structural plywood. Most of the product now being manufactured in Latin America is appearance plywood for furniture and paneling. There are great possibilities for structural plywood in Latin America for construction use.

- Structural plywood technology should be transferred to the industry in Latin America. However, because of needs for markets prior to manufacture, this transfer would have to be coordinated with the development of wooden housing and light construction.

Preservation

The need for transfer of wood preservation technology is very evident in nearly all Latin American countries. The need for technology transfer in the developed countries also exists because of the constant change due to environmental considerations. In Latin America, both the basics of chemicals and treatment processes and the knowledge about their environmental effects need to be transfered to processors and users.

- Wood preservation experts in Latin American countries should conduct seminars on preservative treatment problems as they relate to preservative chemicals, processes, and environmental concerns. These seminars should be held in key locations on a periodic basis.
- The wood preservation industry and scientists working in the preservation discipline should conduct sessions for key governmental persons, to transfer information on the benefits of treated wood and the hazards of uncontrolled use of dangerous and toxic chemicals. This effort would be aimed at controlling the treating industries while promoting their commodities.
- The great diversity of the forest resource in Latin America requires transfer of research information on the treatment and ultimate use of the timbers. Research has investigated many species, yet most of the treating industry in Latin America uses only a few species.
- Research institutions with experience in treating the diverse and little-used species should conduct informational sessions for the wood preservation industry to advance the use of high-density and little-used species.
- More preservative treatments and field testing should be conducted in all countries. This effort should be coordinated so as to reduce unnecessary duplications.
- One problem that stifles the acceptance of new products is the lack of uniformity in the product. The same is true of preservative-treated wood products. Without an industrial or national standard, producers are not held accountable. However, with strict guidelines, consumers can feel confident of the quality of product that they purchase.
- The wood preservation industries in the individual countries should develop product standards and appropriate identification of approved products. Further, we recommend that the industry promote the standards concept to the public in the form of informational brochures and advertising.
- In each country, wood treaters should form wood preservers associations to promote and control the industry, with participation of representatives of government bodies, research institutions, and users of treated wood.

Wood Engineering

Researchers in Latin America appear to be well trained and competent, but isolated. Although they are working on projects to promote the use of wood, a lack of information sharing and coordination among the various countries is resulting in unnecessary repetition and various approaches to the evaluation of design properties.

- Latin American efforts to promote more efficient use of their timber resource would be enhanced by the creation of a professional society devoted to tropical timber engineering. A professional society would serve to coordinate research around common goals. Such an organization would provide an outlet for publication of results in Spanish and Portuguese, an opportunity for professionals to meet and exchange ideas, and an emphasis on the importance of the standardized approach to research and product development.
- A networking system of institutions and individuals involved in wood engineering and structural design needs to be formed to exchange ideas and technology in Latin America. Establishment of the system should be coordinated through IUFRO with the financial assistance of UNDP/FAO, the World Bank, or the Interamerican Bank. The network would be the parent organization of a Latin American professional society.

Other Wood Technology

In the entire area of secondary processing and woodcraft production, Latin America needs basic information on the behavior of wood in both processing and end use. The need is especially great in the tropical regions. Many secondary industries, such as furniture and wooden art objects, are operated by people unaware of the properties of wood or of its reaction in different climates.

- Regional seminars on basic wood technology should be established to inform those involved in wood products manufacture about the performance of wood and how to use it most efficiently and effectively in both domestic and export markets. A proposed USDA Forest Service and Agency for International Development (AID) program includes such a seminar for the Caribbean Islands. The seminar could serve as a model for other regions in Latin America.

Training

General training of Latin Americans, in wood technology and related disciplines, is proceeding on a regular schedule in Latin American universities and in universities of other countries. This general academic training and development should continue, so as to provide a good base of knowledgeable researchers and instructors for Latin America. For some product and processing areas, however, specific training needs need to be met. Specific training needs were not identified in several of the product or processing areas.

Wood Anatomy

One rapidly growing area in wood identification is in computer-assisted identification, Inputs of Latin American woods to the data base of the existing computer systems are needed. Also, making the computer systems available to the Latin American community is vital in updating their programs in wood identification for academic and industrial purposes.

- Wood identification experts from Latin America, who do not have experience with computer-assisted identification, need to seek training in Germany, Japan, or the United States to develop expertise in the use of these systems. Such training would include the operation of the systems including the formats for information entering the systems.

Sawmilling

To a large extent, the technology transfer centers that are teaching saw doctoring, saw maintenance, and saw operation depend on European expertise? In-country instructors are needed to sustain these operations.

- Latin American instructors need to be trained to conduct the necessary technology transfer sessions in sawing and saw maintenance. Such training sessions might be carried out at ESNACIFOR in Honduras, at any of several regional locations in South America, or in Canada, Europe, or the United States.

Drying

The needs for technology transfer of available drying information is the greatest need in drying. But, to accomplish this technology transfer, trained instructors will be needed.

- In each country, instructors should be trained to conduct drying short courses for kiln operators and mill managers. Such training is available in many Latin American schools and in Canada, Europe, and the United States.

Wood Preservation

When dealing with chemical preservatives, it is important to have extensive knowledge as to how various chemicals affect the environment. Knowledge of the effects of various chemicals on the environment is at its highest level in the developed countries of Europe and North America.

- Key individuals in the governments of Latin America should receive training in the area of environmental effects of chemicals, especially those used in the wood preservation industry. This training should be received in one of the countries that has an advanced level of expertise in this area.

Engineered Wood Use

Training does not appear to be a major problem for the scientific staff of the major research centers. People who deal with the large mix of tropical species, however, should have a strong background in statistics and nondestructive testing methods.

- Much of the written material on the engineered use of wood is found in English publications. Technician training in reading the English language would benefit efforts to promote wood use in Latin America.

Appendix

Common and Scientific Names of Species Referenced in the Text

Page

The following species list is organized by common names that are used in the text. An * preceding an entry indicates that only the common name of the species is mentioned in the text. In most of these cases, based on our experience and knowledge of the literature, we have supplied the corresponding scientific name. For entries without a preceding symbol, both the common name and the corresponding scientific name are used in the text.

An exotic species list follows the primary list.

Alphabetical by Common Name

Common name	Scientific name
* Alecrin	*Holocalyx balansae*
Alerce	*Fitzroya cupressoides*
* Almacigo	*Bursera simaruba*
Amburana	*Amburana cearensis*
* Anchico colorado	*Piptadenia rigida*
Angelique	*Dicorynia guianensis*
* Anime	*Protium* spp.
* Arapira	—
Araracanga	*Aspidosperma* spp. *(Araracanga group)*
Assacu	*Hura crepitans*
Balsa	*Ochroma pyramidale* (syn. *O. lagopus)*
* Balsamo	*Myroxy1on balsamum*
Baromalli	*Catostemma* spp.
Basralocus	*Dicorynia guianensis*
Brazil-nut	*Bertholletia excelsa*
* Cabreuva	*Myocarpus frondosus, M. fastigiatus*
* Cancharana	*Cabralea* spp.
* Canelo	*Drimys winteri*
* Caramuri	*Humiria* spp.
* Casuarina	*Casuarina* spp.
* Cativo	*Prioria copaifera*
* Cauchorana	*Perebea calophylla* (syn. *Olmedia calophylla)*
* Gaucho vermelho	—
Cedro	*Cedrela* spp.
Cedro	*Cedrela odorata, Cedrela* spp.
Cedro vermelho	*Cedrela* spp.
Ceiba	*Ceiba* spp.
Ceiba amarilla	*Hura crepitans*
Ceiba amarilla	*Ceiba* spp.
Ceiba bruja	*Ceiba* spp.
* Chalviande	*Osteophloeum platyspermum*
* Coca	*Lecythis* spp.
* Coeur dehors	*Diptotropis purpurea*
Coigue	*Nothofagus dombeyi*
Copaia	*Jacaranda copaia*

Alphabetical by Common Name

Common name	Scientific name
* Copal	*Protium* spp.
* Courbaril	*Hymanaea courbaril*
Crabwood	*Carapa guianensis*
* Croton	*Croton* spp.
* Cuangare	*Dialyauthera* spp.
Curupay	*Anadenanthera macrocarpa*
Degame	*Calycophyllum candidissimum*
Determa	*Ocotea rubra*
Encino	*Quercus* spp.
* Freijo	*Cordia* spp. (Alliodora group)
* Gambombo	—
Goncalo alves	*Astronium graveolens*
* Grapia	*Apuleia leiocarpa*
* Greenheart	*Ocotea rodiaei*
* Grignon franc	*Nectandra* spp.
* Guaba	*Inga* spp.
* Guayea	*Guarea* spp.
Haiari	*Alexa imperatricis*
Hill pine	*Podocarpus palatorei*
Honduras *rosewood*	*Dalbergia stevensonii*
Imbuia	*Phoebe porosa*
Ipe	*Tabebuia* spp. (Lapacho group)
Jacareuba	*Calophyllum brasiliense*
Jarana	*Holopyxidium jarana*
* Jatahy	*Dialium guianense*
Jatoba	*Hymenaea* spp.
Jatoba	*Hymanaea stilbocarpa*
* Jatoby	*Erisma* spp.
* Jobo	*Spondias mombin*
* L'amarante	*Peltogyne* spp.
Lapacho	*Tabebuia* spp. (Lapacho group)
* Laurel	*Cordia alliodora, C.* spp.
* Laurel amarillo	*Ocotea* spp.
* Laurel negro	—
Lignumvitae	*Guaiacum* spp.
Lingue	*Persea lingue, Persea* spp.
Long John	*Triplaris* spp.
* Louro	*Aniba* spp.
* Lupuna	—
* Macacauba	*Platymiscium* spp.
Mahogany	*Swietenia* spp.
* Mahot	*Couratari* spp.
* Mangrove	—
Manio	*Podocarpus saligna, P. nubigena*
Manio	*Saxegothaea conspicua*
* Marfil	—
* Mascarey	*Hyeronima chocoensis*
Mexican fir	*Abies religiosa*
Mierenhout	*Triplaris* spp.
Misiones pine	*Araucaria angustifolia*
Mora	*Mora excelsa*
* Muiracatiara	*Astronium lecointei*
* Muiratinga	*Perebea calophylla* (syn. *Olmedia Calophyella)*
Neuquen pine	*Araucaria araucana*
Oak	*Quercus* spp.
Olivillo	*Aextoccicum punctatum*
Orey	*Campnosperma panamensis*

Alphabetical by Common Name

Common name	Scientific name
Parana pine	*Araucaria angustifolia*
* Paricarana (high density)	*Bowdichia* spp.
* Paricarana (low density)	*Pityrocarpa pteroclada*
* Pau marfim	*Balfourodendron riedelianum*
* Pau mulato	*Capriona uberiana*
* Peroba	*Paratecoma peroba*
Pochote	*Bombacopsis quinata*
Quaruba	*Vochysia* spp.
Quebracho	*Schinopsis Jorentzii, S. quebracho-colorado, S. balansae*
Quebracho blanco	*Aspidosperma* spp.
* Rabo amarillo	*Lonchocarpus albiflorus*
Roble	*Catalpa longissima*
Roble	*Nothofagus obliqua*
* Saint-Martin rouge	*Andira inermis, A. coriacea, A. surinamensis*
Sajo	*Campnosperma panamensis*
* Saman	*Samanea saman* (syn. *Pithecellobium saman)*
* Sande	*Brosimum* spp. (Utile group)
Sangre	*Pterocarpus* spp.
* Sangre de gallina	—
Santa Maria	*Calophylum brasiliense*
Spanish-cedar	*Cedrela odorata, Cedrela* spp.
* Sucupira	*Diptotropis purpurea*
* Sumauma vemelha	*Ceiba pentandra*
* Tangare	*Carapa guianensis*
Tepa	*Laurelia philippiana*
Tinguaciba de restingua	*Fagara arenaria*
* Ulmo	*Eucryphia cordifolia*
Verawood	*Bulnisia arborea, B.retama*
Virola	*Virola surinamensis, V. multinervia*
Virola	*Dialyanthera* spp.
* Wacapou	*Vouacapoua americana*
Wallaba	*Eperua falcata, E.* spp.
* Wapa	*Eugenia* spp.
West Indian mahogany	*Swietenia mahagoni*
Yagrumo hembra	*Cecropia peltata*
Yemeri	*Vochysia* spp.
	Exotic Species
Douglas-fir	*Pseudotsuga menziesii*
Gmelina	*Gmelina arborea*
Insignis pine	*Pinus radiata*
Loblolly pine	*Pinus taeda*
Melia	*Melia azedarach, M. azedarach* var. *gigantii*
Pino oregon	*Pseudotsuga menziesii*
Radiata pine	*Pinus radiata*
Slash pine	*Pinus elliottii*
Teak	*Tectona grandis*
Weeping willow	*Salix babylonica*
Willow-poplar	*Salix alba* var. *calva*

The following species list is organized by scientific names. A + preceding an entry indicates that only the scientific name of the species is mentioned in the text. An * preceding an entry indicates that only the common name is used in the text. For entries without a preceding symbol, both the common and scientific names are used in the text.

For most scientific names, we have listed additional common names that are not used in this text but are sometimes used in describing these species.

An exotic species list follows the primary list.

Alphabetical by Scientific Name

Scientific name	Common name
Abies religiosa	Mexican fir, abeto, acxoyatl, pino
Aextoccicum punctatum	olivillo
Alexa imperatricis	haiari
Amburana cearensis	amburana
Anadenanthera macrocarpa	curupay
* *Andira inermis, A. coriacea, A. surinamensis*	Saint-Martin rouge, cabbage bark
+ *Aniba calelilla*	—
+ *Aniba firmula*	—
+ *Aniba gigantifolia*	—
+ *Aniba guianensis*	—
* *Apuleia leiocarpa*	grapia
Araucaria angustifolia	parana pine, Misiones pine
Araucaria araucana	neuquen pine, hoop pine
+ *Aspidosperma discolor*	—
Aspidosperma spp.	quebracho blanco
Aspidosperma spp. (Aracanga group)	araracanga
+ *Aspidosperma* spp. (Peroba group)	—
Astronium graveolens	goncalo alves
* *Astronium lecointei*	muiracatiara
+ *Austrocedrus chilensis*	cipres de la cordillera
* *Balfourodendron riedelianum*	pau marfim
Bertholletia excelsa	brazil nut tree
Bombacopsis quinata	pochote
+ *Bombacopsis sessilis*	—
* *Bowdichia* spp.	paricarana (high density)
+ *Brosimum rubescens, B.* spp., (Alicastrum group)	muiratinga, capomo, ojoche, cacique
* *Brosimum* spp. (Utile group)	sande
Bulnesia arborea	verawood, vera
+ *Bulnesia retama*	—
* *Bursera simaruba*	almacigo
+ *Bursera simaruba*	gumbo-limbo
* *Cabralea* spp.	cancharana
Calophyllum brasiliense	jacareuba, jacaruba, Santa Maria
Calycophyllum candidissium	degame
Campnosperma panamensis	sajo, orey
* *Capriona uberiana*	pau mulato
Carapa guianensis	crabwood, tangare
* *Casuarina* spp.	casuarina
Catostemma spp.	baromalli
Catalps longissima	roble, bois chene, yokewood
Cecropia peltata	yagrumo hembra
Cedrela odorata	Spanish-cedar, cedro
Cedrela spp.	cedro, cedro vermelho

Alphabetical by Scientific Name

Scientific name	Common name
+ *Ceiba pentandra*	sumauma
* *Ceiba pentandra*	sumauma vemelha
Ceiba spp.	ceiba, ceiba amarilla, ceiba bruja
+ *Cephalanthus spathelliferus*	—
+ *Chorisia integifolia, C.* spp.	samohu, paineira
+ *Commiphora guidotti*	—
Cordia alliodora, C. spp.	laurel, laurel macho
* *Cordia* spp. (Alliodora group)	freijo
Couratari panamensis	congolo-garapelo
* *Croton* spp.	croton
+ *Cupressus sempervirens, C.* spp.	cipres
+ *Dalbergia nigra*	Brazilian rosewood
Dalbergia stevensonii	Honduras rosewood
+ *Dendropanax arboreus*	—
* *Dialium guianense*	jatahy
* *Dialyanthera* spp.	cuangare
Dialyanthera spp.	virola
Dicorynia guianensis	basralocus, angelique
+ *Dicymbe altsoni*	—
* *Diplotropis purpurea*	sucupira, coeur dehors
* *Drimys winteri*	canelo, casca de anta
+ *Endlicheria* spp.	—
Eperua falcata, E. spp.	wallaba
* *Erisma* spp.	jatoby
* *Eucryphia cordifolia*	ulmo
* *Eugenia* spp.	wapa
Fagara arenaria	tinguaciba de restingua
Fitzroya cupressoides	alerce,lahuan
Guaiacum spp.	lignumvitae
* *Guarea* spp.	guayea (guarea?)
+ *Guazuma ulmifolia*	guacimo, guacimo blanco, guacimo hembra
+ *Helietta longifoliata*	—
Hevea brasiliensis	rubbertree
* *Hibiscus* spp.	mahot, maho
* *Holocalyx balansa*	alecrin, alecrim
Holopyxidium jarana	jarana
+ *Hovenia dulcis*	—
* *Humiria* spp.	caramuri, caramuru
Hura crepitans	assacu, hura, possumwood, ceiba amarilla
* *Hyeronima chocoensis*	mascarey
* *Hymanaea courbaril*	courbaril, jatahy
Hymenaea stilbocarpa	jatoba
* *Inga* spp.	guaba, guama, guamo
Jacaranda copaia	copaia
+ *Joannesia princeps*	—
Laurelia philippiana	tepa
* *Lecythis* spp.	coca, sapucaia, monkey pot
+ *Leonia cymosa*	—
+ *Leonia glycycarpa*	tamara, trapiarana
+ *Licaria puchury-major, L.* spp.	kaneelhart
* *Lonchocarpus albifforus*	rabo amarillo
+ *Machaerium incorruptible, M.* spp.	caviuna
Mora excelsa	mora
* *Myocarpus frondosus, M. fastigiatus*	cabreuva, cabreuba

Alphabetical by Scientific Name

	Scientific name	Common name
*	*Myroxylon balsamum*	balsamo
	Nectadra spp.	grignon franc, determa
	Nothofagus dombeyi	coigue
	Nothofagus obliqua	roble
	Ochroma pyramidale (syn. *O. lagopus)*	balsa
+	*Ocotea porosa, O.* spp.	—
+	*Ocotea pretiosa*	canella sassafraz
*	*Ocotea rodiaei*	greenheart, demerara
	Ocotea rubra	determa
*	*Ocotea* spp.	laurel amarillo
*	*Osteopbloeum platyspermum*	Chalviande
+	*Pandaca [Tabernaemontana] retusa*	palo vivora, leiteira
*	*Paratecoma peroba*	peroba, peroba de campos
*	*Peltogyne* spp.	L'amarante
*	*Perebea calopbylla* (syn. *Olmedia calophylla)*	cauchorana, muiratinga
	Persea lingue, P. spp.	lingue
	Phoebe porosa	imbuia
+	*Pinus caribaea, P.caribaea* var. *caribaea, P. caribaea* var. *hondurensis*	Caribbean pine
+	*Pinus muricata*	Bishop pine
+	*Pinus oocarpa*	ocote pine, pino
+	*Pinus patula*	patula pine, pino
+	*Pinus strobus* var. *chiapensis*	chiapis white pine
+	*Pinus tecunumanii*	—
+	*Pinus tropicalis*	—
*	*Piptadenia rigida*	anchico colorado
*	*Pityrocarpa pteroclada*	paricarana (low density)
*	*Platymiscium* spp.	macacauba, macawood, trebol
+	*Podocarpus lambertii*	—
+	*Podocarpus nubigena*	—
	Podocarpus nubigena	manio
	Podocarpus palatorei	hill pine
	Podocarpus saligna	manio, podocarp
*	*Prioria copaifera*	cativo
*	*Protium* spp.	anime, kurokai, copal
	Pterocarpus spp.	sangre
	Quercus spp.	encino, roble, oak
+	*Salix humboldtiana*	sauce colorado
+	*Salix X argentinensis*	—
	Samanea saman (syn. *Pithecellobium saman)*	saman
	Saxegothaea conspicua	Manio
	Schinopsis lorentzii, S. quebracho-colorado, S. balansae	quebracho
+	*Schizolobium amazonicum*	pashaco
+	*Sclerolobium* spp.	—
	Spondias mombin	jobo
+	*Sterculia* spp.	sterculia
	Swietenia mahagoni	West, Indian mahogany, caoba
*	*Swietenia* spp.	Mahogany, caoba
	Tabebuia spp. (Lapacho group)	ipe, lapacho
+	*Tachigalia* spp.	—
+	*Torresia [Torresea] acreana*	torresia

Alphabetical by Scientific Name

Scientific name	Common name
+ *Tovomita choisyana*	bosmangro, boesi-mangro
+ *Tovomita macrophylla*	—
+ *Trichilia* spp.	cedro manteco
Triplaris spp.	long john, mierenhout
+ *Urbanella* spp.	—
Virola spp.	Virola, banak, baboen
Virola surinamensis, V. multinervia	Virola, banak
Vochysia spp.	yemeri, quaruba
Vouacapoua americana	wacapou
Exotic Species	
+ *Acacia melanoxylon*	austraban blackwood
+ *Anthocephalus chinensis*	cadam, kadam
+ *Eucalyptus alba*	eucalipto, eucalyptus
+ *Eucalyptus camaldulensis*	eucalipto
+ *Eucalyptus citriodora*	eucalipto
+ *Eucalyptus deglupta*	eucalipto, deglupta
+ *Eucalyptus globulus*	eucalipto, blue gum
+ *Eucalyptus grandis*	eucalipto
+ *Eucalyptus nitens*	eucalipto
+ *Eucalyptus paniculata*	eucalipto
+ *Eucalyptus punctata*	eucalipto
+ *Eucalyptus robusta*	eucalipto
+ *Eucalyptus rostrata*	eucalipto
+ *Eucalyptus saligna*	eucalipto
+ *Eucalyptus tereticornis*	eucalipto
+ *Eucalyptus urophylla*	eucalipto
+ *Eucalyptus viminalis*	eucalipto
Gmelina arborea	gmelina
Melia azedarach, M. azedarach var. *gigantii*	melia, persian lilac
Pinus elliottii	slash pine
Pinus radiata	insignis pine, radiata pine
Pinus taeda	loblolly pine
+ *Populus angulata*	—
+ *Populus nigra* var. *italica*	lombardi poplar
Pseudotsuga menziesii	pino oregon, Douglas-fir
Salix alba var. *calva*	willow-poplar
Salix babylonica	weeping willow
+ *Salix nigra*	black willow
Tectona grandis	teak