

Articles that follow in this section describe the current situation in wood use over a wide range of applications and employing much modern science and technology. New technologies have been developed to use the wood resource prudently to meet an increasing variety of consumer needs and provide dependable long-term service.

See also: **Solid Wood Products:** Construction; Logs, Poles, Piles, Sleepers (Crossties); Glued Structural Members; Lumber Production, Properties and Uses; Structural Use of Wood; Wood-based Composites and Panel Products. **Wood Formation and Properties:** Chemical Properties of Wood; Mechanical Properties of Wood; Physical Properties of Wood. **Wood Use and Trade:** Environmental Benefits of Wood as a Building Material.

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International Trade in Wood Products

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Global Forest Resources

The *Forest Resources Assessment* (2000 Summary Report) of the Food and Agricultural Organization (FAO) of the United Nations indicates that the

world's forests total 3.867 billion ha in 2000, or 29% of the world's land area. Of this, 47% are tropical forests, 9% subtropical, 11% temperate, and 33% boreal. Over the past half century the area of temperate and boreal forest has remained relatively stable, even modestly expanding in recent decades, while net deforestation occurred at a rate of 9 million ha annually during the 1990s, almost entirely in the tropical and subtropical forests.

Production and Consumption

The world requires approximately 1.5 billion m³ of harvested wood annually to produce the manufactured wood and paper products it consumes. The developed countries account for over 70% of industrial roundwood (log) production and nearly 75% of the wood and paper production consumed. The global value of primary forest products (wood, pulp, and paper) in 1999 are estimated by the FAO at approximately US\$750 billion, with about US\$350 billion for pulp, paper, and paperboard products and \$400 billion for solid wood products. Developed countries of the Organization for Economic Co-operation and Development (OECD) account for over 80% of this production. Tropical solid wood products, coming primarily from the developing world, are estimated at about US\$28 billion. Total international trade in forest products was estimated at about US\$135 billion in 1996 or roughly 18% of the total value of production.

The United States and Canada account for approximately 35% of global demand for wood and paper products and the European countries of the OECD account for about 25%. All developed countries account for about 75% of world consumption, while 25% is consumed by developing countries.

Table 1 presents the volume of timber harvest by major regions in a recent year while **Table 2** provides information on the value of exports, imports, and net forest product trade in a similar year. The high-harvest countries are almost all major forest-product exporters, although some, most notably the United States, are net importers due to very high demand levels. Thus, while we focus on the value of net forest products exports, this figure is also a good proxy for harvest levels.

Why Trade?

In general, forest products trade flows from countries with abundant forest resources to countries with more modest forest resources. However, raw forest resources are often transported to an intervening regional location for initial or subsequent processing.

Trade occurs because some raw materials or products are less expensive in one region than in another, even when considering transport costs. This may be because the raw material is cheaper or because the processing is less expensive. It may also reflect differences in regional demand due to population and income differences. If the costs are sufficiently higher in one region so that the wood and transport costs can be covered, well functioning wood markets would be expected to promote wood trade from low-cost to high-cost regions, if trade barriers do not offset the inherent cost advantages.

Table 1 World industrial roundwood production (volume), 1997

Country	Volume (m ³)	Percent total
USA	416 092	27.32
Canada	185 859	12.21
Europe, excluding Nordic	218 526	14.35
Nordic	111 844	7.34
Brazil	84 661	5.56
Russian Federation	63 190	4.15
Japan	21 545	1.42
Indonesia and Malaysia	83 077	5.46
China and India	133 748	8.78
Other	204 216	13.41
World	1 522 758	100.00

Source: FAO (1997) *Forest Products Yearbook*. Rome: Food and Agriculture Organization of the United Nations.

Trade occurs at various stages of the production process. Roundwood is usually the raw material in the production process. Processed wood, e.g., sawn-wood, wood panels and pulp, is typically an intermediate input in production that is used in the production of other products such as furniture, construction, and paper products. The basis of trade is found in differences in the location of the raw material (roundwood) from the locations of processing and the locations of final product markets. Often, but not always, the first stage of processing is done near the location of the raw wood, while subsequent processing is commonly done in another location, often near the final market. However, there are major trade flows of raw logs, which may involve processing in locations far from the origins of the raw wood.

Wood-producing countries may trade raw logs, process the logs to wood products and paper, or both. This is seen in the flows of sawlogs from North America to Asia for processing to lumber for Asian markets and pulpwood imported from South America into the United States for processing to pulp and paper. Trade constitutes about 7% of world consumption of logs (roundwood), 30% of wood products, and 29% of paper products. Major forest products exporters include Canada, the United States, Russia, Finland, Sweden, New Zealand, Chile, Indonesia, Malaysia, and Brazil.

Table 2 Major global exporters and importers of forest products (value), 1996

Country	Exports (US\$ × 10 ³)	Imports (US\$ × 10 ³)	Net (US\$ × 10 ³)
Canada	25 333 157	2 622 203	22 710 954
Sweden	10 996 199	1 323 936	9 672 263
Finland	10 301 017	699 632	9 601 385
Indonesia	5 206 522	865 424	4 341 098
Malaysia	4 161 279	881 539	3 279 740
Austria	4 149 678	1 988 878	2 160 800
Brazil	3 233 476	1 154 971	2 078 505
Russian Federation	2 995 568	115 030	2 880 538
Norway	2 059 960	1 402 551	657 409
Switzerland	1 797 767	2 501 957	- 704 190
France	4 193 914	5 356 351	- 1 162 437
Belgium and Luxembourg	2 180 694	3 544 574	- 1 363 880
Hong Kong	1 872 717	3 488 083	- 1 615 366
Spain	1 523 810	3 552 249	- 2 028 439
Netherlands	2 406 430	4 489 773	- 2 083 343
China (and Taiwan)	1 490 413	3 858 254	- 2 367 841
Germany	9 438 751	11 926 822	- 2 488 071
Korea	1 258 793	4 425 527	- 3 166 734
Italy	2 486 782	6 148 593	- 3 661 811
USA	16 939 897	22 558 536	- 5 618 639
United Kingdom	1 957 907	8 476 689	- 6 518 782
Japan	1 781 177	18 890 397	- 17 109 220
World	134 656 439	138 652 187	- 3 995 748

Source: FAO (1996) *Forest Products Yearbook*. Rome: Food and Agriculture Organization of the United Nations.

Traded Products

Forest products trade runs the spectrum from raw wood materials, such as logs and wood chips, to highly processed products such as furniture and fine papers. Within the wood products sector some countries specialize in the production of the raw wood, others specialize in various facets of the processing, while still others produce both raw wood and processed value added. Thus, the value of wood products appears to be only a crude proxy of the amount of raw wood harvested, both domestic and imported. Nevertheless, since there are often advantages in processing located near the source of the raw material, most of the countries with large dollar values of production and exports also have large volumes of forest resources.

Sawnwood, wood milled in a sawmill and commonly referred to as lumber, is the most prevalent produce produced in the solidwood side of the forest industry and the most intensively traded globally. Sawnwood is typically used for structural purposes in construction, as well as in furniture, flooring, and woodwork. Wood panels, such as plywood, are the second most traded wood product. Plywood is manufactured from wood veneer sheets that are glued and pressed. The United States is the largest producer of conifer plywood while Indonesia is the world's largest producer of nonconifer plywood, using tropical hardwoods in its construction. Europe is a major producer and consumer of plywood, most of it being produced from hardwoods. In addition, panels, such as particleboard and oriented strandboard, made from wood fibers that are compacted and glued, are increasing in use for a variety of purposes.

Global and Regional Production and Trade Flows

As noted, international trade in forest products was estimated at about US\$135 billion in 1996. Traditionally, most of the trade occurs in the northern hemisphere between industrial countries. About 75% of industrial wood comes from temperate forests. Tropical timbers are produced and consumed largely in the tropical world, with modest international exports to the temperate developed countries from Africa and South America. The Asia-Pacific region is the only really large regional exporter of tropical wood, with large volumes of wood exports flowing from Malaysia and Indonesia, largely to the Asian countries, including Japan and China, and also to the United States and Europe. Smaller tropical wood flows originate in South America and Africa.

Industrial wood is produced throughout the northern hemisphere. In the Soviet era Russia was a major producer of industrial wood, primarily for its own consumption. Today Russia continues to be an exporter of industrial wood to parts of Europe, e.g., pulpwood to Finland, and to Asia, e.g., logs to Japan. Also, wood flows from Russia to the former centrally planned economies of Europe have decreased as these countries have been using more of their domestic wood resources directly and also exporting some of their raw wood to other European countries.

North America continues to be the world's major producer and exporter of industrial wood, producing over one-third of the world's production. This overall situation has not changed substantially from that of the 1970s. The United States continues to be the world's major wood producer and also its number one consumer market for industrial wood and wood products. Within the United States wood is produced in the South, which is the dominant producing region, as well as the West, the Lake States and the Northeast. In general, North American markets draw upon regional wood resources with supplies provided from these various wood-producing regions within the United States supplemented by huge exports from Canada. Canada, with its vast wood resources and its relatively small population, is the world leader in wood products exports with the major portion of these filling the gap between production and consumption in the United States. While log exports from Canada are generally restricted, for many years over 30% of the United States consumption of softwood lumber has been imported from Canada, as well as large amounts of other wood products. The volumes of wood products imported from outside North America are relatively small, but have been growing in recent years.

Europe is a huge wood market. Most of the total wood consumed in Europe is produced within Europe, including the Nordic countries. The Nordic countries of Europe also have historically provided large volumes of wood products to continental countries. Sweden and Finland are large producers and exporters of forest products, with most of the exports going to other countries within Europe, in the form of pulp and paper and some wood products. In recent years the Nordic raw wood supply is being supplemented by imports of raw wood from Russia and Estonia. As elsewhere, in recent years the amount of processing in the Nordic countries has increased and more processed products, including large volumes of paper, are exported. In addition to imports from Nordic countries, there is a great deal of forest-products trading within the broad European

setting, with France, Germany, Austria, and Poland being the primary wood-producing continental countries. Western and central Europe also import large volumes of wood products from eastern Europe and Russia and North and South America, with more modest volumes from Africa and Asia. Overall, however, Europe is a wood-deficit region with the wood deficits provided from a variety of suppliers throughout the world including, importantly, North America and Russia.

Asia is the most rapidly growing of the major global wood markets and Japan has been the dominant consuming country in Asia and indeed, Japan is the world's largest net importer of forest products and has the world's largest wood deficit (Table 2). Japan draws the vast majority of its wood resources and products from a host of producing countries in the Pacific Basin. In the post-World War II period the Pacific Basin has been a vast arena of wood products trade with Japan as the hub of a huge trade inflow. Traditionally, Japan has imported large volumes of logs, which were subsequently processed to meet Japanese unique sizes and standards. Log flows into Japan have come from many sources, both tropical and temperate and include log exports from Malaysia, Indonesia, Russia, and the United States. In recent years the log flows have declined and have been replaced by wood product imports. For example, logs from Indonesia have declined, being replaced by processed wood like plywood and lumber, and log flows from North America have also declined in recent years, having been replaced by North American lumber and by increased log flows from New Zealand and Australia.

In recent decades other Asian countries have been or are becoming major wood importers, including Korea and Taiwan. China particularly has become an important importer for forest products, with its imports largely being unprocessed wood. Other countries in Asia, such as India, consume substantial volumes of wood products. However, South Asian wood consumption is mostly produced domestically.

Finally, Africa and Asia tend to supply largely tropical wood, while South America supplies growing volumes of wood pulp, primarily to Europe but increasingly to other regions too, produced by plantations, and also some tropical woods.

Traditionally, most of the raw wood used by the world global forest industry has been obtained by harvesting natural forests. Thus, the wood is obtained through an essentially foraging operation with the location of the forest resource determined by natural processes. Forest raw material trade thus began in the natural forest and made its way to the final market with various processing activities along

the way. In this situation the productive advantage goes to forests with large volumes of healthy desired species. In recent years, however, the source of raw wood production has been undergoing substantial changes. Wood fiber from natural forests is being replaced by wood fiber from planted forests. In some cases these forests simply replaced earlier natural forests on the same sites, as in much of Europe. Increasingly, however, planted forests are being established on sites not recently in forest, as in planted forests established on lands on which agriculture has been abandoned, e.g., in the South of the United States. However, in other areas forest plantations are being established on lands that may never have been forested, as in grasslands of parts of Latin America or regions of Australia not previously forested.

Sources of Changing Trade Patterns

The advent of planted forests has resulted in important new supplies of industrial wood that are reflected in new patterns of wood products trading. Countries such as New Zealand, Chile, and Australia have, in recent decades, become important exporters of wood products, particularly to the growing markets of Asia. Brazil, too, has become an important producer of forest products and the nature of its product mix has changed. In the case of Brazil, its tropical hardwood exports, drawn from its vast Amazonian forests, are now dwarfed by the export of wood pulp, which uses plantation forests as its raw material.

Another factor influencing the pattern of forest products trade is growing environmental concerns. The establishment of protected forests, free from commercial timber harvests, together with the institution of new forest practices requirements, is influencing harvest levels and harvesting costs and thereby influencing wood trade flows. The dramatic reduction in timber harvests from US National Forests undoubtedly has resulted in increased lumber imports from Canada as well as increased production from the US South. Higher costs of harvesting in the coastal forest of British Columbia, due to a more stringent forest practices code enacted in the 1990s, likely is an important contributor to reduced wood trade flows from coastal British Columbia to Japan.

Trade Barriers

Trade barriers are often inserted to reduce or preclude trade. Trade barriers can consist of prohibitions of exports or imports of certain products, e.g., log export prohibitions; import taxes (tariffs), which

place a tax on the imported product; export taxes, which place a tax on the product when it is exported; and quantitative restrictions, which place limits on the amount of a product that can be imported (or exported). Trade barriers have the effect of reducing the volume of imports (or exports) and thus influencing supply or prices within a country.

Quantitative restrictions in trade are common with forest products. **Table 3** provides an estimate of wood products' import tariff averages in selected countries. Note that this average does not include consideration of trade prohibitions and quotas. Trade barriers are usually introduced to achieve certain policy or political objectives and typically are designed to protect a product, industry, or other group. A restriction of lumber imports, for example, increases the price of lumber in the importing country thereby benefiting domestic producers of lumber (both firms and perhaps lumber workers). The common rationale for an export restriction, as on logs, is that the raw material be processed within the country where the log is found, thereby generating increased employment and value added. An export restriction, for example logs, has the effect of making log prices lower in the exporting country and encouraging domestic wood processing. Canada has used this rationale for decades to support a policy decision to insure that logs would be available for domestic processors at low prices. The United States restricted the export of logs from national forests in the West to insure an adequate log supply to western mills. Some countries place restrictions on processed imports for a similar reason. Japan placed an import tariff on certain types of processed wood in order to protect the domestic processing industry.

In general, forest product tariffs tend to be low. An analysis carried out in 1999 estimated that the effects of the Uruguay Round of the General Agreement on Tariffs and Trade (GATT) reduced tariffs of 33% on most forest products and increased total forest products world trade by US\$460–593 million. This is an increase of only a very small fraction of global trade in forest products. Modest levels of change in trade suggest only modest levels of change in production. In the specific markets analyzed in this study, which included products with relatively modest amounts of processing valued added (logs, sawnwood, veneer, particleboard, fiberboard, plywood, wood pulp, and newsprint), trade increases constituted an increase of 1.6–2.0%. The largest trade increase was 5% for plywood, a product where tariffs have tended to be relatively high, in the 10–15% range. The lowest trade effect was a 1% export increase for wood pulp, a product which in most countries has little or no tariff. This study also found that the trade effects of tariff reductions would generally increase the exports of developed countries while reducing exports of developing countries.

Trade Liberalization

Trade liberalization has generally been regarded as a socially desirable activity in that production efficiency is increased thereby lowering costs and providing benefits to consumers. The last several decades have seen a series of trade negotiations to rationalize the global trading system with the general objective of liberalizing trade, e.g., reducing tariffs and other restrictions. An extension and further reduction of the scheduled tariff reductions associated with the Uruguay Round was proposed to the World Trade Organization (WTO), the international organization charged with overseeing the international trade process. The 1999 proposal would have accelerated scheduled tariff reductions on both solid wood products and on pulp and paper. Concerns have been raised, however, that trade liberalization could have an adverse influence on the environment.

In forestry, for example, the conflict between freer trade and concerns regarding the implications of freer trade on forest sustainability were raised in response to the proposal to accelerate the Uruguay Round agreement to decrease tariffs on forest products. This proposal, which was raised at the G7 meeting of finance ministers in Seattle in late 1999, was met with street protests that derailed the effort. The concerns raised suggested that tariff reduction would increase timber harvests thereby accelerating pressures on forests to increase the rates of harvesting. This was viewed as undermining forest

Table 3 Average of forest products tariffs in selected countries

<i>Country</i>	<i>Tariff % (Most Favored Nation average)</i>
Australia	2.88
Canada	3.88
Chile	11
China	20.86
Taiwan	3.22
Hong Kong and China	0
Indonesia	9.7
Japan	1.14
Korea	4.98
Malaysia	12.26
Mexico	11.32
New Zealand	6.06
Singapore	0
Thailand	20.04
USA	1.4
European Union	5.26

Source: FAOSTAT website (1998).

sustainability and promoting deforestation. One can view this concern as a variant of the 'race to the bottom,' often cited by environmentalists, whereby countries with lax environmental standards have a cost advantage in production and trade. Here, freer trade is viewed as imparting an additional competitive advantage to countries with lax logging standards thereby leading to excessive rates of logging and the associated forest damage and destruction.

Another 1999 study estimated the trade effects on global harvests and deforestation and found them to be very modest. It was estimated that the effects generate an increase in harvest of 6–10 million $\text{m}^3 \text{year}^{-1}$ or about a 0.4–0.7% increase in the global industrial wood harvest. Further, it was suggested that the effects would be confined largely to the northern hemisphere countries which are likely to be able to facilitate additional harvests with minimal effects on the forest environment. This is due to the modest nature of the impact, new laws on forest practices, new forest set-asides, and movement toward improved practices designed to achieve multifaceted sustainable forestry. Nevertheless, the negotiations held by WTO countries in Seattle in 1999 did not result in an acceleration of wood products tariff reductions.

Trade and Forest Environmental Issues

The years since the 1992 United Nations Conference on the Environment and Development (UNCED) Earth Summit in Rio have seen significant changes in our perceptions of forest issues. Although Rio was not primarily about forests, a number of important international forest initiatives, many involving trade, emerged from Rio. In the dialogue leading up to UNCED in 1992, concerns had been expressed about forest sustainability, the loss of biodiversity, and the overall rate of deforestation, especially in the tropics.

A total of 178 governments were represented at UNCED, and a contentious debate revolved around forest issues. UNCED ultimately produced four documents related in whole or in part to forests:

- *Agenda 21*, a global environmental action plan
- a framework convention on global climate change
- a convention on biological diversity
- a *Statement of Principles on Forests*.

The *Statement of Principles on Forests* reflects a global consensus on a set of nonbinding principles of management, conservation, and sustainable development of all types of forests. One of the major outcomes of the Earth Summit was the industrial world's nonbinding agreement that sustainable for-

estry should be practiced by all countries, both tropical and temperate. The discussion and documents coming out of the Earth Summit also broached some specific management issues, such as the issue of forest certification and ecolabeling. For example, *Agenda 21* encourages

expansion of environmental labeling and other environmentally related product information programs designed to assist consumers to make informed choices.

In response to international and domestic concerns, many major wood-producing countries have made changes to their domestic laws and policies concerning forests. These include changes to improve water quality, protect biological diversity, and implement less intensive silvicultural treatments. Some of these policies are regulatory in nature while others rely on taxation or other incentives. In many temperate forested countries significant revisions have been made in the legal and institutional framework dealing with forest matters.

Additionally, perhaps the most impressive changes have been the activities leading to the certification of forest practices and the movement to use certified wood in ecolabeled products. Over the past decade a number of forest certifying organizations have emerged. There are currently a number of alternative approaches to auditing and certification of forestry management under consideration and there are a host of different organizations that can act to set standards, oversee monitoring, undertake auditing and award certification of forest management. These approaches were led by the World Wildlife Fund (WWF) Forest Stewardship Council (FSC), which has initiated an aggressive forest certification campaign over the past decade.

In addition to the FSC, there have been a number of other similar efforts. In some countries and regions the forest industry has taken the initiative to create organizations similar to but strongly competitive with the FSC, sometimes in cooperation with governments. These include country and regional organizations such as the Sustainable Forestry Initiative (SFI) of the American Forest and Paper Association, a forest industry associated in the United States; the Canadian Standards Association in Canada, and, more recently, the Pan European Forest Council (PEFC) in much of Europe. Additionally, there are local and regional certification systems such as the Nordic Forest Certification System and the Finnish Forest Certification System (FFCS).

Changes in domestic forest practices regulation and the introduction of the certification to forest management are designed to address concerns of poor logging

practices and excessive harvest rates, while promoting forest sustainability. However, changes in domestic forest policies and movement toward certification can have differential impacts on the underlying production cost structure of various countries thereby influencing the comparative production and trading capacities and costs. Thus, trading patterns would be expected to respond to these changes and countries are seen to strive to modify rules and practices so as to advantage their forestry production sector in relation to its competitors.

See also: **Mensuration:** Yield Tables, Forecasting, Modeling and Simulation. **Papermaking:** World Paper Industry Overview. **Resource Assessment:** Regional and Global Forest Resource Assessments. **Tree Breeding, Principles:** Economic Returns from Tree Breeding.

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Environmental Benefits of Wood as a Building Material

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Introduction

The management of forests to obtain wood for use in the production of houses and a host of manufactured products is often criticized based on environmental concerns. Such concerns have led some to conclude that periodic harvesting of forests and the use of wood should be minimized, or even halted altogether. However, careful consideration of global environmental concerns in the context of the realities of today's world leads to a much different conclusion: to protect the environment, forests and the wood they produce should be utilized to the maximum extent possible within sustainable limits.

It is essential that forests be managed in a manner that sustains a myriad of forest values over the long term. At the same time, it is vitally important that forests be managed in such a way as to minimize impacts on the global ecosystem, of which forests are one part. Thus, there are a number of things to consider when contemplating the proper role of forests. One of these is the fact that growing populations worldwide consume vast quantities of raw materials, including wood. Another is that wood is the only widely available industrial raw material that is renewable. Yet another, and very important consideration, is that the environmental impacts associated with the manufacture and use of wood products are less, and in many cases substantially less, than those associated with the manufacture and use of products made of non-wood materials.

Assessing Environmental Impacts of Industrial Activity

An effective means of assessing the relative environmental impacts of a product is to examine them over the life cycle of the product from raw materials extraction, through processing and conversion, and ultimate use. Examination of energy use is particularly revealing, since a number of serious environmental problems are related to consumption of energy including acid deposition, oil spills, air pollution (SO₂, NO_x), and increasing concentrations of atmospheric carbon dioxide.

Research involving systematic examination of the environmental impacts of a product over its life is