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**General Technical
Report RM-199**

An Analysis of the Timber Situation in the United States: 1989–2040

A Technical Document Supporting the 1989 USDA Forest Service RPA Assessment

Preface

The Forest and Rangeland Renewable Resources Planning Act of 1974 (RPA), P.L. 93-378, 88 Stat. 475, as amended, directed the Secretary of Agriculture to prepare a Renewable Resources Assessment by December 31, 1975, with an update in 1979 and each 10th year thereafter. This Asessment is to include "an analysis of present and anticipated uses, demand for, and supply of the renewable resources of forest, range, and other associated lands with consideration of the international resource situation, and an emphasis of pertinent supply, demand and price relationship trends" (Sec. 3.(a)).

The 1989 RPA Assessment is the third prepared in response to the RPA legislation. It is composed of 12 documents, including this one. The summary Assessment document presents an overview of analyses of the present situation and the outlook for the land base, outdoor recreation and wilderness, wildlife and fish, forest-range grazing, minerals, timber, and water. Complete analyses for each of these resources are contained in seven supporting technical documents. There are also technical documents presenting information on interactions among the various resources, the basic assumptions for the Assessment, a description of Forest Service programs, and the evolving use and management of the Nation's forests, grasslands, croplands, and related resources.

The Forest Service has been carrying out resource analyses in the United States for over a century. Congressional interest was first expressed in the Appropriations Act of August 15, 1876, which provided $2,000 for the employment of an expert to study and report on forest conditions. Between that time and 1974, Forest Service analysts prepared a number of assessments of the timber resource situation intermittently in response to emerging issues and perceived needs for better resource information. The 1974 RPA legislation established a periodic reporting requirement and broadened the resource coverage from timber to all renewable resources from forest and rangelands.

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The authors of Chapter 1, **Overview**, were David R. Darr and Richard W. Haynes.

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Chapter 3, **Domestic Timber Resources**, was authored by Daniel D. Oswald. The information on Forest Statistics was compiled by Karen Waddell and Daniel D. Oswald. They were assisted by the following members of the Forest Inventory and Analysis Research Work Units at Forest Experiment Stations: Theodore Setzer, Vernon J. LaBau, Gary Carroll, Bruce Hiserote, Thomas Farrenkopf, Sharon Woudenberg, Robert Nevel, David Dickson, Thomas Frieswyk, James Blyth, William B. Smith, John Tansey, Larry Royer, Robert Cathey, Carl Bylin, William McWilliams, and Dennis May. The following provided the same coordination and data submission assistance from Timber Management Staffs at the Regional Offices of the Forest Service: James Laux, Moxon Hart, Daniel Greene, Mel Mehl, Pat D. Jackson, Henry Cheatham, Allen Toby, Ralph Warbington, Carl Bronson, John Teply, Marianne Sheets, Karl Stoneking, Ray Ellis, Richard Hesse, and George Rogers.

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Donald F. Flora and David Brooks were the authors of Chapter 5, **International Trade in Forest Products**.

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Appendix A, **A Glossary of Forest Inventory Terms Used in the Assessment**, was prepared by Douglas Powell.

Appendix B, **Conversion Factors for Forestry and the Timber Products Industry**, was prepared by Kristine C. Jackson.

Appendix C, **Previous Assessments Bibliography**, was prepared by Kristine C. Jackson.

The planning and general direction of the study and much of the final drafting were provided by Richard W. Haynes, assisted by Judy L. Mikowski.

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An Analysis of the Timber Situation in the United States: 1989–2040

Richard W. Haynes, Coordinator

CHAPTER 1. OVERVIEW

The Forest and Rangeland Renewable Resources Planning Act (RPA) of 1974 as amended by the National Forest Management Act of 1976 directs the Secretary of Agriculture to prepare a Renewable Resource Assessment. The purpose of this Assessment is to analyze the timber resource situation in order to provide indications of the future cost and availability of timber products to meet the Nation's demands. The analysis also identifies developing resource situations that may be judged desirable to change and it identifies developing opportunities that may stimulate both private and public investments. The study is primarily concerned with prospective trends in demands and supplies of timber and the determinants of these trends, the implications of these trends, the land and timber resource base, and the opportunities to manage and use this resource base to meet private and public sector goals.

The map shown on the back cover shows the regional detail used in this Assessment. Much of the information presented in this Assessment will be for the Assessment regions (North, South, Rocky Mountains, and Pacific Coast). Some of the projections and industry descriptions will be provided in subregion detail (Northeast, North Central, Southeast, South Central, Great Plains, Rockies, Pacific Southwest, Douglas-fir or Pacific Northwest-West, and Pine or Pacific Northwest-East subregions). The Assessment regions correspond to U.S. Forest Service Regions in the East and aggregations of U.S. Forest Regions in the West. All dollar values are given in constant 1982 dollars, unless otherwise noted.

Analysis of the demand/supply situation for timber has a history dating back to 1876 (see appendix c). The structure, methodology, and much of the historical base developed in earlier assessments, and particularly those immediately preceding, have been carried forward with modifications and refinements.

TRENDS IN PRODUCT CONSUMPTION

Trends in consumption of timber products reflect the interactions of variables that determine demands and supplies. Increases in U.S. population, income, and economic activity have been strong forces in the growth of demand for timber products. The availability of supplies of roundwood and timber products also influenced the amount of timber products consumed. For example, the development of the softwood plywood industry in the South had a dramatic effect on the availability of wood for use in home construction. Increased imports of softwood lumber from Canada in the 1970s and 1980s have retarded the rates of price increases of softwood lumber, leading to increased consumption. Between 1950 and 1988, these trends in demand and supply determinants led to a nearly 50% increase in softwood lumber consumption. The volume of paper and board consumption nearly tripled, and for softwood plywood, consumption increased more than 7 times.

In total, the consumption of industrial roundwood rose from about 10 billion cubic feet in 1950 to nearly 17 billion cubic feet in 1988. Industrial roundwood does not include fuelwood. The oil price shocks of the 1970s caused a resurgence in the use of wood for fuel after decades of decline. The softening in the real price of petroleum-based energy in the 1980s, however, has led to reduced consumption of fuelwood. While the net effect was an increase in fuelwood consumption, much of this wood originates on land other than timberland and thus its effect on the consumption of industrial roundwood is lessened.

Future consumption of timber products is assumed to be the end result of interactions of determinants of demands and supplies, as it has been in the past. The projections of increased population and economic activity on the demand side and management of the timber resource on the supply side lead to a continuation in the growth of consumption of most timber products. Consumption of lumber, structural panels, pulp, and fuelwood are expected to grow through the coming decades as follows:

Product	1986	2040
Lumber (billion board feet)	56.8	69.4
Structural panels (billion square feet 3/8-inch basis)	24.9	39.8
Paper and board (million tons)	81.7	173.0
Fuelwood (roundwood, billion cubic feet)	3.1	5.4

In the latter part of the projection period, consumption of fuelwood is projected to decline somewhat because the cost of petroleum-based energy is assumed to level off after rising through 2020. These projections have in them explicit assumptions about technology. For example, softwood lumber recovery is assumed to increase 19% in the South by the end of the projection period.

When all products are converted to roundwood equivalent and added together, the results show that consumption rises from 20.5 billion cubic feet in 1986 to 28.6 billion cubic feet in 2040. For softwoods, the increase is from 14.3 billion cubic feet in 1986 to 17.5 billion cubic feet in 2040 and for hardwoods, from 6.2

billion cubic feet to 11.1 billion cubic feet. The faster rate of growth in consumption of hardwoods largely reflects increased use of hardwood roundwood for pulpwood and OSB/waferboard.

Much of the projected increase is in consumption of pulp products. Consequently, pulpwood accounts for about 38% of roundwood consumption in 2040 compared with 28% in 1986.

TRADE

Part of the projected increases in consumption will be based on imports. Between 1950 and 1987, the roundwood equivalent of the imports of timber products, mainly softwood lumber, wood pulp, newsprint, and hardwood plywood and veneer—increased from 1.5 to 1.9 billion cubic feet. Much of the increase was based on development of the Canadian softwood resource, especially interior British Columbia. Increases in softwood lumber imports from Canada in the 1980s led to a trade dispute between the two countries that was settled by a Memorandum of Understanding on softwood lumber trade. This trade was also at issue earlier in this century. For the purposes of projections, however, it is assumed that trade between the two countries will be based on the inherent competitiveness of the forest products industries in the two countries, rather than trade constraints.

In the absence of a national assessment of the timber supply/demand outlook in Canada, there has developed a difference of opinion about the potential for increased output of forest products in that country. One view is that the industry has exceeded the sustainable harvest level in some parts of the country and that for the Nation as a whole, the industry is near the sustainable harvest level. An opposing view is that Canada has large acreages of low quality, currently economically inaccessible timber that will come on to the market as timber prices rise. The exact volume of this timber is unknown but may be enough to increase the allowable cut by tens of millions of cubic meters. Also, there is potential for extending timber supplies through application of technology in processing.

Deforestation, global climate change and other issues have come to be associated with trade in tropical hardwood timber products. In addition, hardwood log export restrictions in Southeast Asia have shifted the origin of most U.S. imports of tropical hardwood veneer and plywood from South Korea and the Philippines to Indonesia. Tropical hardwood products will continue to be available on world markets in the foreseeable future, but the volumes, costs, and origins of these products are increasingly uncertain as projections go beyond the turn of the century.

About the turn of the century, New Zealand and Chile have the potential to be major sources of softwood fiber on world markets with Pacific Rim countries being the likely destination of any increased exports. In addition, Brazil and other countries have the potential to expand pulp shipments in world markets based on plantation forests. Depending on currency exchange rates, other countries such as Sweden can be competitive in the U.S. market for paper.

There is potential for expanded growth in world trade in timber products. For the purposes of this study, however, it is assumed that the United States will continue to rely on Canada for softwood product imports and Southeast Asia for hardwood product imports. In view of the uncertainties about future growth in supplies from these sources, imports are assumed to stay near current levels of about 4 billion cubic feet, roundwood equivalent.

Exports of timber products, chiefly pulpwood-based products and softwood logs and lumber, increased from 140 million cubic feet in 1950 to 2,655 million cubic feet in 1987. Since 1985, the U.S. dollar has been weak as compared with the Japanese yen and other currencies. This, in combination with export promotion programs of U.S. industry and the Foreign Agricultural Service have led to expanded exports of solid-wood products in the late 1980s. It is uncertain as to whether this momentum can be maintained if the U.S. dollar rises in relation to other currencies. In addition, the potential effects of New Zealand, Chile, and Brazil on world markets is uncertain. It is assumed that total U.S. exports measured in roundwood equivalent will increase from about 2 billion cubic feet currently to 2.5 billion cubic feet in 2040, and some change in product mix is assumed. For example, exports of softwood logs from Washington and Oregon are assumed to decline while exports of softwood lumber are assumed to increase. This reflects an expected decline in availability of high-quality, old-growth timber and further success of trade promotion efforts.

Current GATT negotiations, further integration of the European Economic Community in 1992, on-going negotiations with the Japanese, and the Free Trade Agreement with Canada could all have significant effects on U.S. trade in timber products in the coming decade and beyond. Therefore, the pattern of U.S. imports and exports in timber products will be a major factor to be analyzed in the next update of this series of studies.

Given the above assumptions, annual net imports will decline from 2.5 to 1.5 billion cubic feet by 2040. Thus, most of the domestic U.S. consumption will continue to be based on the domestic resource.

CONSUMPTION FROM DOMESTIC FORESTS

After allowances for improvements in utilization, technology, and the international trade outlook, projected consumption of timber from domestic forests increases from 18 billion cubic feet in 1986 to 27.1 billion cubic feet in 2040. For softwoods, the increase is from 11.7 billion cubic feet to 15.8 billion cubic feet and for hardwoods, from 6.3 to 11.3 billion cubic feet.

The U.S. Timber Resource

The United States has a very large domestic timber resource. About 731 million acres—32% of the country's area—is forest land. Nearly two-thirds of this, or 483 million acres, is classified as timberland—defined as land capable of producing at least 20 cubic feet of industrial wood per acre per year and not reserved for uses that are not compatible with timber production.

Farmer and other private ownerships—a diverse group that includes people from a cross section of the population and firms other than those in the forest industries—contain 276 million acres, some 57% of the timberland. Another 71 million acres, 15% of the total, is owned by forest industries. The remaining area, some 136 million acres, or 28% of the total, is in public ownership. The largest part of this, 85 million acres, is in national forests.

Softwoods predominate in the Nation's timber inventory. In 1987, there was a total of 451 billion cubic feet of softwood growing stock including 2,032 billion board feet of sawtimber. The largest portion of the softwood timber inventory in 1987 was in national forests, including some 41% of all softwood growing stock and 47% of the softwood sawtimber. Most of the timber was in old-growth stands in the western United States. Some 30% of the softwood growing stock and 25% of the sawtimber was in farmer and other private ownerships. Most of this volume was in the East. Another 16% of the softwood growing stock and 15% of the softwood sawtimber volume was in forest industry ownership. Over half of this was in the West.

Hardwood growing stock inventory in 1977 totaled 305 billion cubic feet. About 70% of these inventories were on farmer and other private ownerships and 11% on forest industry ownerships. The bulk of the hardwood timber in these ownerships was in the East and about equally divided between the North and South.

Trends in Inventories, Net Annual Growth, and Harvests

By most measures, the domestic timber situation has been improving. For example, between 1952 and 1987, softwood growing stock inventories increased 5% and hardwoods, 69%. Softwood sawtimber inventories declined 2.8% and hardwood inventories increased 85%. The increase in inventories has been mainly on the young stands in the North, South, and western Washington and Oregon on the farmer and other private ownerships. Softwood growing stock inventories on national forests in the West declined between 1952 and 1977 because of the harvest of old-growth stands with high inventories per acre. Since 1977, large areas of timberland have been taken out of timber production and this is reflected in the drop of 25% in national forest inventories between 1977 and 1987 in Washington and Oregon. Softwood inventories on forest industry ownerships in Washington and California increased between 1977 and 1987, reflecting the growth of young timber on harvested acres. Inventories continued to decline in Oregon. Timber inventories in the Rocky Mountain region, where harvests are at a relatively low level, have changed little since 1952, with most of the volume in Idaho and Montana.

The increase in inventories reflects net annual timber growth/removal balances. Since 1952, net annual growth of softwoods in the eastern sections of the United States has been higher than removals which are defined as harvest of roundwood products plus logging residues and loss of timber inventory from changes in land use and clearing. In 1986, net annual growth of eastern softwood growing stock exceeded removals by 670 million cubic feet, or 10%. Most of the excess of net annual growth over removals was on the farmer and other private ownerships.

For the western United States, removals of softwood growing stock in 1986 exceeded net annual growth by 836 million cubic feet, or 17%. Most of the excess of removals over growth was on the forest industry and national forest ownerships in the Pacific Coast section. In the Rocky Mountain region, net annual growth was over two times removals in 1986.

Net annual growth of eastern hardwoods in 1986 substantially exceeded removals, particularly in the North. For the entire East, net annual growth of hardwood growing stock was 8.8 billion cubic feet, some 78% above removals. The greatest part of the surplus was in farmer and other private ownerships, although growth exceeded harvest on all ownerships.

Outlook for Roundwood Consumption by Region

The current growth/removal balances show that the hardwood forests and eastern softwood forests can now support additional timber harvests. These balances will, of course, change as growth and removals change over time. Given the demand and supply assumptions in this study, it is apparent that timber harvests will increase substantially during the coming decades.

There are important differences in the outlook among the major softwood timber producing regions. The projected softwood growing stock removals in the contiguous states of the Pacific Coast region decline from 4.1 billion cubic feet in 1986 to 3.6 billion board feet in 2000 and then increase to 3.8 billion cubic feet by 2040. The major cause of the decline in the Pacific Coast region is harvest of the remaining old-growth timber on forest industry lands. The old-growth inventory in this ownership class is being liquidated and harvests from second-growth stands cannot offset the decline in supplies from old-growth stands for several decades. The timber supply outlook on public lands in the West is uncertain; many issues that are currently being debated could have a downward influence on timber supplies from these lands.

The supply/demand outlook in the South is strongly influenced by projected increase in the area of pine plantations in this region of the country. Until these plantations begin to reach maturity, the growth/removal balance is near 1.0 and there are periods when the softwood inventory is drawn down to support existing harvest. Even with the plantations, removals exceed net annual growth in 2040. There are also increases in consumption in the North and Rocky Mountains, but on a much smaller scale.

Hardwood roundwood consumption is projected to increase significantly in both the North and South. By 2040, consumption in the North is almost two-thirds higher than in 1986. For the South, consumption in 2040 is 73% larger than in 1986. Hardwood inventories are drawn down significantly in the South, reflecting, in part, conversion of hardwood types to pine plantations.

OUTLOOK FOR PRICES

There are two types of prices that characterize forestry markets. First, there are roundwood prices in the various regional stumpage markets and second there are various product prices set largely in national markets. In addition to both stumpage and product markets there are differences in the short-term and long-term outlook for prices. There differences vary between the two markets.

Roundwood Prices

The projected increase in pine plantations in the South have a dramatic effect on the outlook for softwood stumpage prices. In both the South and Pacific Northwest, stumpage prices increase rapidly through 2020. When the pine plantations in the South come into production, these prices level off and actually decline by 2040. This is in contrast to past assessments where prices were projected to increase continually in the future. Even with the additional pine plantations, however, stumpage prices in the South and Pacific Northwest in 2040 are more than double the price in 1986. Annual rates of increase for the South for the period, 1986–2020, are 2.5% and for the period, 1986–2040, 1.5%. For the Pacific Northwest, the rates of increase are 2.8% through 2020 and 1.7% through 2040.

In general, the projections for hardwood—both roundwood and sawtimber—show a more favorable supply/demand outlook than is the case for softwoods. Advances in pulping technology, however, are blurring the distinction between hardwood and softwood fibers for some paper and paperboard products. There are beginning to appear local situations where softwood and hardwood pulpwood are the same price. Hardwood sawtimber prices vary between the highest quality with the export and other high-value end uses as outlets and lesser quality that may have the pallet industry or firewood markets as outlets. The upper end of the hardwood sawtimber market has become a search for individual trees and this will likely continue. There are huge volumes of hardwoods advancing in age in the North, however, and these volumes may affect the supply situation after the next several decades.

Current concerns over tropical deforestation may lead to increased demands for temperate hardwoods. If this occurs, there will be increased pressure on the price of high-quality hardwoods, but it may also increase foreign interest in application of technologies to make use of lesser quality sawtimber.

Product Prices

Because of market interactions, such as imports of pulp, newsprint, and softwood lumber from Canada, the prices of end products are expected to increase at a lesser rate than for roundwood. For example, between 1986 and 2040, softwood lumber and plywood prices increase at annual rates of 0.6% and 0.3%, respectively. The rate of increase through the projection period is more uniform than that for stumpage prices.

STUDY IMPLICATIONS

(1) The U.S. softwood sawtimber supply situation will be unprecedented through 2020.

Throughout its history, the United States has had available a reserve of undeveloped softwood sawtimber. The timber resource of first the Northeast, then the South, the Lake States, the U.S. West Coast, interior British Columbia, and then the South again all played important roles in the development of the Nation. For the next two decades, until the pine plantations in the South reach maturity, the United States will not have a reserve of softwood sawtimber available for harvest. There will be a period of two to three decades when the price of softwood sawtimber will increase significantly. This run-up in stumpage prices has many and far-reaching implications. It will:

- Offer opportunities for application of technologies to further develop the northern hardwood resource;
- Stimulate development of innovative ways to conserve on softwood sawtimber such as laminated beams and wood-saving engineering in construction designs;
- Stimulate substitution of glass, steel, and other construction materials for wood;
- Stimulate production of timber products from currently economically inaccessible timber stands in Canada and thereby lead to increased imports;
- Decrease the competitive advantage of U.S. timber products in world markets and thereby decrease U.S. exports;
- Provide further market incentives for tree planting on private lands;
- Force reconsideration of many issues related to management of timber on public lands, such as below-cost timber programs.

During the next two to three decades, much of the softwood roundwood used in the manufacture of lumber will come from trees that are young by historical standards—as young as 45 years in the Pacific Northwest and 25 years in the South. Technical issues such as the strength properties of juvenile wood may gain higher visibility as lumber from young trees makes up a higher proportion of the total lumber used in the United States.

In the short term there are few options for alleviating pressures on softwood sawtimber stumpage prices. Research on and application of improved utilization and use of abundant hardwoods appear to be promising responses to the declining availability of large-sized softwood sawtimber. The decade of the 1980s saw application of many technologies that are saving of softwood—OSB/waferboard, for example, and laminated beams. The use of manufactured components in housing can cut down on wood waste as compared with on-site assembly. It is reasonable to expect further application of softwood-saving technologies and allowances have been made for them in projections. Other potential responses to the short-term outlook such as increasing imports or decreasing exports would affect the situation, but do not appear viable in the current trade environment.

As discussed in the later section on assumptions used in the study, increased recycling may significantly affect the short-term supply/demand outlook.

(2) The Nation's forest industries will continue to be concentrated in the East.

In the mid-1980s, some 45% of the U.S. employment in primary and secondary wood processing was in the North and 35% in the South. In 2040, these two Eastern regions will continue to have about 80% of the total industry employment. New technologies being applied in primary processing such as in the softwood lumber segment of the industry have as a side effect lasting elimination of employment in the industry as capital is substituted for labor. In 2040, employment in the lumber and wood products portion of the industry will only be 72% of the employment in 1985, despite a 44% increase in lumber production and a 60% increase in production of structural panels.

(3) There are opportunities to increase timber supplies.

Available information shows that the potential exists for intensifying management and earning an economic return on some 66 million acres of timberland in the other private ownership category. With treatment of these acres, net annual timber growth could be increased by 3.5 billion cubic feet. Almost all of increase in growth would be softwood. About two-thirds of these opportunities involve some form of regeneration activity. Approximately three-fourths of the opportunities are in the South and one-fifth in the North.

There are also large acreages termed marginal crop and pastureland that may be suitable for tree planting. For example, there are 22 million acres in the South with this designation that would yield greater returns as pine plantations than in crop or pasture use.

The Assessment projection assumes that continuation of trends will lead to the implementation of some of these economic opportunities. For example, some 20% of opportunities on other private timberland in the South are assumed to be treated by 2040.

As the Nation enters the decade of the 1990s, concerns for the world environment have high visibility and are expressed in differing ways. For example, the potential effects of tree planting in aiding the environment are so appealing that the economics of tree planting are often second stage to the potential benefits to the global environment such as urban shading and carbon sequestration. This view is unprecedented in modern times. It may well have a major influence on the Nation's future timber supply/demand outlook, but the supply-enhancing aspect of this view may be a byproduct of other goals of tree planting.

Tree-planting initiatives such as the Conservation Reserve Program and America the Beautiful should increase the area of timberland in the short term. The long-term influence of these initiatives is uncertain at this time and their potential influence on long-term trends will be reviewed in the next update of the supply/demand situation and in subsequent Assessments.

(4) There are opportunities to extend timber supplies through improved utilization.

The Nation's timber industries have come far in the utilization of the timber resource in the past 50 years. For example, in the early 1950s, logging residue amounted to 13% of growing stock removals and in the late 1980s, it was 9.6%. There have been major advances in the manufacture of softwood plywood, fiber-based structural panels, and pulping technologies that have had major influences on the current supply/demand situation. Opportunities for further improvement of these technologies are considered in the study.

ASSUMPTIONS USED IN THE STUDY

All projections are the consequence of assumptions. In this study, these include assumptions about the basic determinants of timber demands such as growth in population, economic activity, and income; technological and institutional changes; energy costs; capital availability; prices of stumpage and timber products; and public and private investments in forest management, utilization, and research (USDA FS 1989a).

In making assumptions about these basic determinants, it is recognized that the long-run course of events may be different from what is assumed. However, expectations about the future of these determinants are often strongly influenced by past trends. These trends reflect the interactions of massive economic, social, and political forces which are not easily or quickly changed. Barring major catastrophes such as nuclear war, such trends are likely to continue over a considerable time. Thus, it is reasonably certain that the basic assumptions provide a sound basis for preparing an analysis for use in developing and guiding public and private responses to the projected timber resource situation. The following important assumptions were used to develop this Assessment.

Population

The population of the United States has grown by about 118 million people in the last five decades reaching 249 million in 1989. Projections of the U.S. Department of Commerce, Bureau of the Census, indicate that population is likely to continue to show substantial growth during the next 50 years. The median population projection with a high immigration assumption shows population rising by another 84 million to 333 million in 2040. In the later decades of the projection period, much of the growth in population is attributable to immigration.

Economic Activity

Economic activity as measured by the gross national product in constant 1982 dollars, increased more than 4 times in the last 5 decades, to $4 trillion. Projections prepared by Wharton Econometrics Associates show the gross national product continuing to rise and reaching $15.6 trillion in 2040—almost 4 times that of 1988.

Disposable personal income, i.e., the income available for spending by the Nation's population, is projected to grow from about $2.9 trillion in 1989 to $9.6 trillion ($1982) in 2040. Associated per capita disposable income rises to $28,790 in 2040, some 2.4 times the 1989 average. This growth means that the Nation is faced not only with the task of meeting the resource demands of an additional 84 million people, but the demands of 333 million people with much greater purchasing power than today's population.

Timber Growth

Assumptions about future growth of the timber inventory are key components of the analysis of timber supply. The basis for assumptions about growth on private lands is continuation of the growth indicated in the latest reinventory of permanent plots on these lands, as modified by management intensity assumptions. Growth for national forests and other public lands is the projected growth as reported by the agencies.

Management Intensity for Private Timberlands

Growth is determined, in part, by assumptions about management intensity. Advances in research have enabled a growing sophistication in the way that these assumptions are used in conjunction with models of forest growth. A key assumption of the study is that by the turn of the century, all of forest industry lands in the South and western Washington and Oregon will be managed intensively and that there will be a growing acreage of softwood plantations on nonindustrial private lands in the South. These pine plantations begin to affect the supply/demand outlook in significant ways about the decade of 2020. After 2020, the pine plantations begin to reach merchantable size and affect domestic prices, imports, and other indicators of the supply/demand situation.

The assumptions about future management intensity lead to higher timber supplies as compared with similar assumptions in previous RPA Assessments. The assumptions are so critical to the outlook that they will be reviewed in depth for an update of the supply/demand situation planned for 1993.

Timberland Area

Assumptions about future area of timberland also have an obvious effect on the timber supply/demand outlook. Trends for the past 40 years indicate a decline in timberland area for the Nation as a whole. This trend is expected to continue in the future and by 2040, there is projected to be a net loss of 21 million acres of timberland. There are some gains in timberland area as some land reverts from agriculture to timberland in the North. Urbanization and shifts from timberland to agricultural areas are expected to more than compensate for these gains, however.

Future Timber Harvest on National Forests

The National Forest Management Act of 1976 set in motion an unprecedented planning effort on the Nation's national forests that is near completion for the first round of planning. For the purposes of this study, it is assumed that harvests on national forests will be the volume shown in plans in effect or in draft stage as of 1987. In total, this assumption means that harvest on national forests will increase from 2.3 billion cubic feet in 1986 to 2.7 billion cubic feet in 2040.

There are a number of issues whose resolution may have a downward influence on national forest harvest levels. For example, the Threatened and Endangered Species Act of 1973 contains provisions for protection of habitat for species listed as threatened or endangered. The Forest Service has habitat management responsibility for approximately 31% of the Nation's threatened and endangered plant and animal species. The number of species listed is growing with implications for timber harvest in areas that contain the species' habitat. In general, the effect has been to reduce rather than to increase timber harvest where timber harvest has been affected. Nonetheless, the sum of forest plans is considered to be a reasonable estimate of future harvest levels. As plans are revised, any changes in future expectations will be considered in future Assessments of the timber supply/demand situation.

Changes in Processing Technology

The decade of the 1980s has been one of rapid changes in the application of technology in the U.S. timber industries and their utilization of timber resources. For example, OSB/waferboard has been accepted in the marketplace and advances in processing technology have increased the proportion of roundwood recovered as solid products. Also, application of technology has enabled the pulp industry to increase the proportion of hardwoods in the pulp mix. Explicit assumptions are made in this study about technology in the manufacture of both solid and fiber-based wood products. In general, the effect of technology is to extend timber supplies—satisfying the same demand with less wood and to use the fiber available as in the use of hardwoods in pulp manufacture. The cumulative effects of 50 years of technology development and application has significantly affected the U.S. timber industries and similar effects are expected in the future.

POTENTIAL SOURCES OF STRUCTURAL CHANGE IN THE OUTLOOK

Sources of change in the supply/demand situation are generally gradual and can take years or decades to shift long-term trends. For example, the pine plantations in the South in the Assessment projection are a source of structural change, but they take decades to reach maturity. Two potential sources of fairly rapid change in the U.S. timber industries are global change and recycling of paper and paperboard.

Global Change

Global change has developed into a phrase that signifies all the disruptions that may attend significant increases in global warming—not only changes in the growth and distribution of trees, but the massive socioeconomic dislocations that may be caused by global warming. The potential for global warming to occur and its aftermath are currently the subject of debate. If it occurs, there is potential for shifting of the supply/demand outlook with as yet undetermined implications. For the purposes of this study, it is assumed that changes in the global climate will not affect the overall supply/demand outlook.

Recycling

The study assumes that recycling of paper in the United States will increase from about 25% of consumption to 31% in 2040. An alternative future was analyzed that assumed 39% by 2040. The high recycling future has dramatic effects on the supply/demand outlook by lowering stumpage prices and the demand for wood in pulp manufacture. At the time of the writing of this summary chapter, the U.S. pulp and paper industry has announced as a goal 40% paper recovery and reuse by 1995. There are technical and market problems that must be overcome to achieve this goal. If achieved, it would have major influences on forestry in the United States and Canada. The 40% goal is established with the expectation of using existing technologies. New technologies developed through research may make a 50% goal achievable.

Summary

In summary, this study projects rising demands for timber products, as have previous assessments. The study, however, has identified three potential sources of structural change in the supply situation that could shift the outlook.

- Continuation of establishment of pine plantations in the South will affect the outlook and this is reflected in the Assessment projection. If these plantations are not established, the Nation faces prolonged increases in prices of timber products.
- Concerns over the global environment have stimulated interest in planting trees as a way to sequester carbon. Large tree planting programs in addition to the plantations in the Assessment projection could further affect the supply outlook after 2020. If global warming occurs, it could either increase tree growth or reduce it, depending on rainfall and other characteristics of the environment at that time.
- Increased recycling of paper and paperboard could shift the outlook during the next decade.

These sources of structural change are not reflected in historical data except for the establishment of pine plantations in the South. Global change and recycling of paper and paperboard are developing issues. They should be monitored closely for their potential effects on the outlook.

CHAPTER 2. RECENT TRENDS IN THE CONSUMPTION OF TIMBER PRODUCTS

This chapter presents estimates of timber products consumption in the United States over the past three and a half decades, and relates changes in consumption to economic, social, and institutional factors during the period. In this analysis, the following timber products are considered: (a) lumber; (b) structural panels—softwood plywood, oriented strand board, waferboard, and similar wood panel products used primarily for structural applications; (c) nonstructural panels—hardwood plywood, insulating board, hardboard, particleboard, medium-density fiberboard, and similar wood panel products used primarily for nonstructural applications; (d) pulpwood; (e) silvichemicals; (f) fuelwood; and (g) other miscellaneous industrial roundwood products such as poles and piling, posts, and mine timbers. Consumption of lumber is discussed in terms of the major markets for structural and nonstructural panels, i.e., new housing, residential upkeep and improvements, new nonresidential and railroad construction, manufacturing, packaging and shipping, and other uses. The pulpwood section contains a discussion of trends in the consumption and production of woodpulp, and of paper and board by type. A final section summarizes trends in consumption of the major roundwood products—saw logs, veneer logs, pulpwood, miscellaneous products, and fuelwood—by softwoods and hardwoods.

Total U.S. consumption of timber products has increased markedly over the past 35 years, rising from about 12 billion cubic feet in the early 1950s to almost 20 billion in 1986. Although total use has grown through most of the period, there have been short-term fluctuations and divergent trends in the relative importance of the various products and in the species mix of timber consumed. These fluctuations and trends are the result of changing market levels and changing product use within these markets.

TIMBER PRODUCTS CONSUMPTION IN NEW HOUSING

New housing has long been the largest single U.S. market for timber products. In 1986, more than a third of the lumber and structural panel products, and over a fourth of the nonstructural panel products were used for the construction of new housing units.

New Housing Unit Production

The volumes of timber products consumed in new residential construction are dependent on the numbers and types of housing units built, and the amounts and types of wood products used in each.

The average number of new housing units—conventional units and mobile homes—produced in the United States has been somewhat higher in the 1970s and 1980s than during the 1950s and 1960s (table 1). Despite this long-term trend, changes in such demand determinants as interest rates, household formations, vacancy and replacement rates, and conversion of existing structures to alternative uses, have caused annual production to vary substantially from the decade averages (fig. 1). For example, in 1972 total housing production reached nearly 3.0 million units, dropped to 1.4 million in 1975, and subsequently increased to more than 2.3 million in 1978. Total output again declined to a low of 1.3 million in 1982, recovered to more than 2.0 million in 1983 through 1986, and dropped to just under 1.9 million units in 1987.

Table 1.—Average annual production of new housing units in the United States, by type of unit, specified periods 1950–87.

Period	Total demand	Conventional units: Total	Conventional units: Single family	Conventional units: Multi-family	Mobile homes
			Thousand units		
1950–54	1,692	1,619	1,434	185	73
1955–59	1,569	1,455	1,260	194	115
1960–64	1,601	1,470	996	474	131
1965–69	1,695	1,415	860	554	281
1970–74	2,342	1,868	1,060	808	474
1975	1,384	1,171	896	275	213
1976	1,793	1,547	1,166	381	246
1977	2,279	2,002	1,452	550	277
1978	2,312	2,036	1,433	603	276
1979	2,037	1,760	1,194	566	277
1980	1,535	1,313	852	461	222
1981	1,341	1,100	705	395	241
1982	1,312	1,072	663	409	240
1983	2,008	1,712	1,068	644	296
1984	2,052	1,756	1,084	672	296
1985	2,029	1,745	1,072	673	284
1986	2,051	1,807	1,179	628	244
1987	1,853	1,620	1,146	474	233

Note: Data may not add to totals because of rounding.
Sources: 1950–58: USDC BC 1966b, 1959–87: USDC BC 1987c.

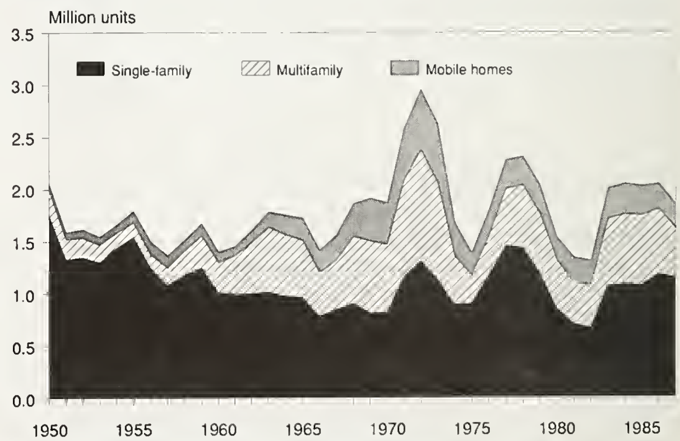


Figure 1.—New housing unit production, by type of unit, 1950–1987.

In addition to the total numbers of units produced, their type (single-family, multifamily, mobile home) also has been an important factor in determining the volumes of timber products used in new housing because of the large differences in the average amounts of timber products used in each.

Single-family houses are typically occupied by households whose heads are in the middle-age classes, while occupancy of units in multifamily buildings and mobile homes is highest among households headed by younger and older persons (USDA FS 1982). Since 1950, about 60% of all housing units produced (including mobile homes) have been of the single-family type (fig. 1). However, as a result of shifts in the age distribution of the population, and the associated changes in household types and income, there has been wide variation in their relative importance. For example, the proportion of single-family housing units—about 85% in the mid-1950s—dropped to less than 45% in the early 1970s. By 1976, however, single-family homes accounted for nearly two-thirds of all housing production. Subsequently, the proportion dropped to slightly more than 50% in 1982, before climbing to 57% in 1986, and 62% in 1987.

Through most of the 1950s, multifamily units accounted for nearly all of the remaining output. However, in the late 1950s the mobile home emerged as a significant source of new housing. Its share of the housing market grew to over 21% in 1973, before declining, with some fluctuation, to about 12% in 1986 and 13% in 1987.

Timber Products Use Per Housing Unit

In 1986, single-family houses used an average of about 12,975 board feet of lumber; 6,770 square feet, 3/8-inch basis, of structural panel products; and 2,755 square feet, 3/8-inch basis, of nonstructural panel products (table 2).

Table 2.—Timber products used per housing unit in the United States, by product and type of unit, specified years 1962–86.

Product and type of unit	1962	1970	1976	1986
Lumber	*Board feet*			
Single family	11,385	11,130	12,375	12,975
Multifamily	5,325	5,375	5,030	4,720
Mobile homes	1,525	1,905	2,655	4,340
Structural panels[1]	*Square feet (3/8-inch basis)*			
Single family	2,960	4,580	5,560	6,770
Multifamily	1,810	2,150	2,575	2,505
Mobile homes	855	1,135	1,225	1,610
Nonstructural panels[2]	*Square feet (3/8-inch basis)*			
Single family	1,805	2,535	2,855	2,755
Multifamily	1,205	1,175	920	850
Mobile homes	1,240	2,125	3,765	3,805

[1]*Softwood plywood, waferboard, oriented strand board, and composite board.*

[2]*Hardwood plywood, hardboard, insulating board, particleboard, and medium-density fiberboard.*

Note: Volumes include allowances for onsite and manufacturing waste.

Multifamily units averaged less than half as much lumber and structural panels, and a third as much nonstructural panels as single family units. Mobile homes used lesser amounts of lumber and plywood than multifamily units, but somewhat greater amounts of nonstructural panels than other types of units.

As shown in table 2 and figure 2, the types and amounts of timber products used per housing unit have changed over the past 25 years. In general, structural and nonstructural panel products use have increased significantly, while lumber use has grown much more slowly. These trends have resulted from changes in such factors

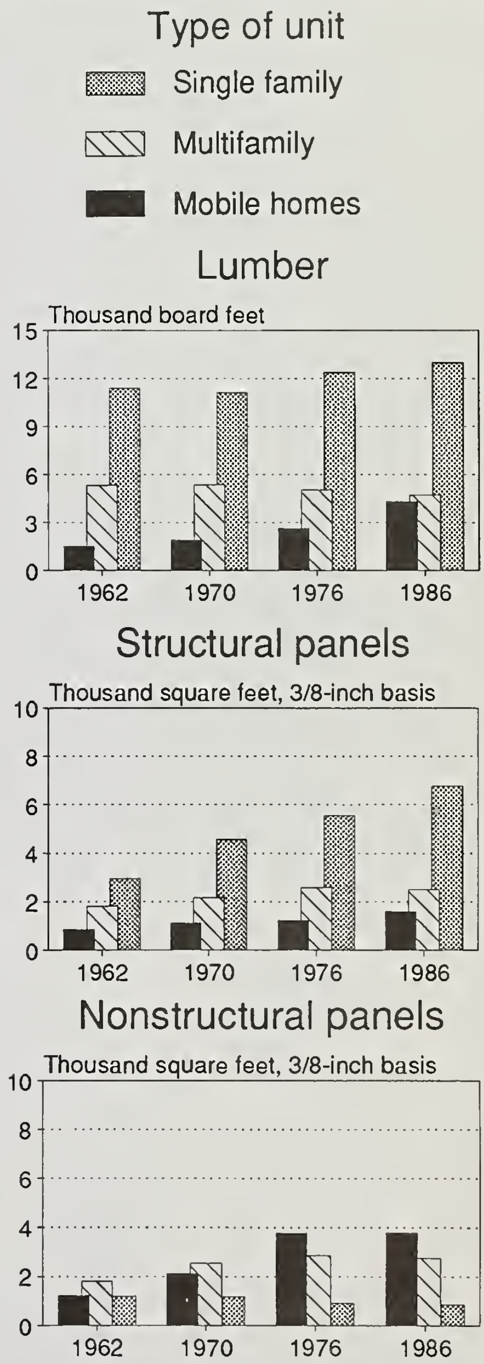


Figure 2.—Timber products use per unit in new residential construction.

as unit size, structural and architectural characteristics, and materials substitution.

Trends in Unit Size

The average size of new single-family housing units grew fairly steadily between the early 1950s and the 1970s, rising from less than 1,100 square feet of floor area in 1950–53 to 1,700 square feet in 1976, and 1,760 square feet in 1979 (Phelps 1988) (fig. 3). This growth, in part a reflection of rising real household income during the period, contributed to the increases in the use of structural and some nonstructural panel products per single-family unit, and partially offset a downward trend in lumber use per square foot of floor area (USDA FS 1982). Average single-family house size fell to 1,710 square feet in 1982 as housing production dropped to the lowest level since 1945, but subsequent increases in the 1980s raised the average to 1,825 square feet in 1986 and to 1,905 square feet in 1987 (USDC BC 1988a).

The size of units in multifamily structures also increased into the early 1970s, but has been somewhat lower since that time. For example, the average size of new multifamily units in 1986 was 911 square feet, 15% above the average in the early 1950s, but down 20% from the mid 1970s (Phelps 1988, USDC BC 1988a).

Mobile homes have shown the most dramatic increase in size in recent years. In the early 1960s, most were single units, 10 feet or less in width and typically 29 to 45 feet in length. By 1970, most units were 12 or more feet wide, and 50 or more feet long. In addition, a growing number were double-wide or expandable models. In 1976, nearly half were 14 feet wide, while double-wide mobile homes accounted for about a fourth of total shipments. This trend continued over the next 10 years, and by 1987 more than 37% of all mobile homes placed at building sites were double-wide units. As a result of these changes, average unit size has increased from about 620 square feet in the early 1960s, to 966 square feet in 1976, 1,110 square feet in 1986 and 1,140 square feet in 1987 (Phelps 1988, USDC BC 1988a).

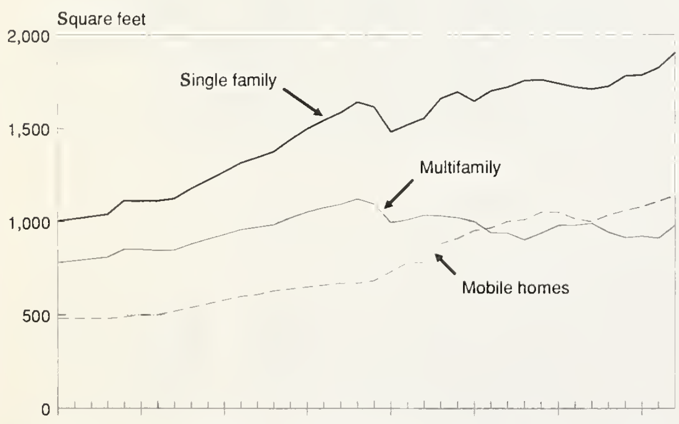


Figure 3.—New housing unit average floor area, by type of unit, 1950–1987.

Trends in Use Per Square Foot of Floor Area

In addition to changes in unit size, the amounts of timber products used per housing unit have been strongly affected by trends in the average use per square foot of floor area. As shown in the tabulation below, estimated lumber use per square foot of floor area in single-family units dropped from 8.5 board feet in 1962 to about 7.3 board feet in 1976, and to 7.1 board feet in 1986. Lumber use per square foot in multifamily units has shown the same general downward trend. On the other hand, structural panel use per square foot of floor area increased in both single-family and multifamily units. Over the past 35 years, mobile homes have been constructed increasingly like conventional single-family units. As a result, use of nearly all types of timber products per square foot of floor area has increased.

Floor area, and average timber products used per square foot of floor area in single-family houses

Year	Floor area	Lumber	Structural panels	Nonstructural panels
	Square feet	*Board feet*	*Square feet (3/8-inch basis)*	*Square feet (3/8-inch basis)*
1962	1,346	8.46	2.20	1.34
1970	1,482	7.51	3.09	1.71
1976	1,700	7.28	3.27	1.68
1986	1,825	7.11	3.71	1.51

These trends in timber products use per square foot of floor area have resulted, in part, from changes in the structural and architectural characteristics of the units built, and in materials substitution in the construction process. A discussion of each of these factors follows.

Structural and Architectural Characteristics

Shifts in structural and architectural characteristics of new units built since the early 1950s have had marked effects on timber products used per square foot of floor area. For example, growth in use per square foot has resulted from the rising proportion of new, single-family houses built with garages. About 50% of all houses built in 1950 had garages, compared to 79% in 1987—over four-fifths of which could accommodate two or more cars (USDC BC 1988a).

Increases in wood products use per square foot of floor area have also come from growth in the percentage of new single-family units using wood products as the principal exterior siding material, particularly during the 1970s and early 1980s. In 1986, 43% of new single-family houses used wood or wood products as the principal exterior wall material, up from 37% in 1976 (USDC BC 1977, 1988a). In addition, an increasing number of new houses are being built with wooden decks. This latter trend has been accelerating since the early 1980s.

One of the most important factors tending to reduce timber products use per square foot of floor area has been the substantial increase in the proportion of single-family units built on concrete slab foundations, a type of construction that markedly lowers average wood products use because of the elimination of the wood-joist floor system. Between 1956 and 1970, the proportion of single-family houses constructed with concrete slab floor systems rose from 16 to 36%, with a further climb to 45% in 1986 (USDL 1958, USDC BC 1988a).

Another change affecting timber products use has been the steady growth in the percentage of two-story houses built. In 1956, less than 10% of new, single-family houses had two stories; by 1986, 44% had two stories (USDL 1958, USDC BC 1988a). This type of construction reduces the roof area required to cover a given floor area, thereby lowering total wood products use and construction costs per square foot of floor area. In addition, two-story construction allows enlarging house size without increasing the size of the building lot.

Rising land costs have apparently resulted in somewhat smaller lot sizes, and in increased construction of attached single-family units such as townhouses and cluster homes. Such units are characterized by having at least one common wall—frequently of masonry construction—which consequently lowers the volumes of exterior wall framing, sheathing, and siding used.

Recent increases in the use of prefabricated housing components and modular housing units has tended to lower average use of some wood products, particularly lumber, through reduction of waste and improved design. Wood roof trusses are perhaps the most widely used, factory-prefabricated structural component in single-family houses. However, floor trusses, prefabricated beams and lintels, exterior and interior wall panels, and roof and floor panels are used in onsite construction of both single and multifamily housing units. Other building components, such as doors, windows, and cabinets, are almost universally factory-fabricated for onsite installation.

In conventional onsite construction, more efficient use of wood, such as wider spacing of studs and other structural members, has tended to bring about somewhat lower use of timber products per unit. Other savings in materials have resulted from changes in design, and more realistic specifications for wood building components based on stress testing and other performance criteria.

Materials Substitution

The volumes of specific timber products used per square foot of floor area in new housing have been greatly affected by the substitution of alternate materials—both wood and nonwood—in the construction process. For example, the rising trend in use of structural and nonstructural panel products per housing unit in the 1950s, 1960s, and 1970s largely reflected substitution of these materials for lumber in such components as sheathing and subflooring. Through the early 1970s, structural plywood use showed the largest growth. Between 1959 and 1968, the proportion of new single-family houses constructed with plywood roof sheathing rose from 50 to more than 90% (Phelps 1970). However, the 1970s was the period of maximum plywood penetration of roof sheathing markets; since then, newer structural panel products such as waferboard and oriented strand board have had increasingly widespread acceptance (Anderson 1987a).

Nonwood materials, such as aluminum, steel, plastics and masonry products also compete with wood in many residential uses. Wood products have been displaced in a number of applications by metal siding, by plastic and aluminum siding and trim, and by nonwood flooring materials. For example, substitution of carpeting for oak flooring, either on a concrete slab floor or over particleboard underlayment, was an important factor in the decline of wood use—particularly hardwood lumber use—in the late 1960s and early 1970s.

Aluminum and steel have been used as alternative framing materials in light frame construction. With the price relationships existing in the early 1970s, aluminum framed exterior walls were less expensive than those framed with lumber. Since that time, aluminum prices have increased sharply. Steel framing has been used in construction of apartment buildings; but, in general, its use has been limited in single-family houses, even though at times in the 1980s the inplace cost for steel was less than for wood in some applications (USDA FS 1982).

Total Timber Products Use in New Housing

Total consumption of lumber in new housing amounted to an estimated 19.3 billion board feet in 1986 (table 3, fig. 4). Although this was less than in some prior years, it was about 75% above use in 1982 when total number of housing units produced dropped sharply, and use per unit was down because of a temporary decline in average unit size.

Consumption of structural panels in new housing in 1986 was nearly 10 billion square feet, 3/8-inch basis, about 28% above total use in 1976, and somewhat above

Table 3.—Timber products used in new housing in the United States, by product, specified years 1962–86.

Year	Lumber	Structural panels[1] (3/8-inch basis)	Nonstructural panels[2] (3/8-inch basis)
	Million board feet	*Million square feet*	*Million square feet*
1962	14,160	3,950	2,540
1970	13,350	5,590	3,680
1976	17,000	7,760	4,610
1986	19,320	9,950	4,710

[1]*Softwood plywood, waferboard, oriented strand board, and composite board.*

[2]*Hardwood plywood, hardboard, insulating board, particleboard, and medium-density fiberboard.*

Note: Volumes include allowances for onsite and manufacturing waste.

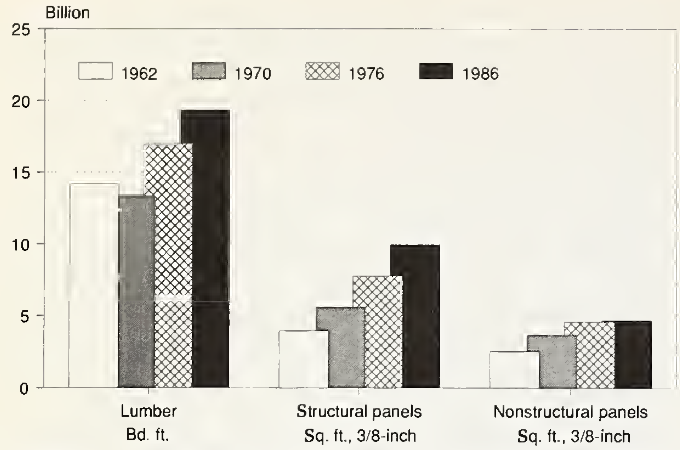


Figure 4.—Total timber products use in new housing, 1962, 1970, 1976, 1986.

consumption in most prior years. Almost 13% of total structural panel consumption in 1986 was waferboard, oriented strand board, and similar products, up sharply from about 2% in 1976. Much of this growth was at the expense of softwood plywood, as described earlier.

Nonstructural panel consumption in new housing in 1986 totaled 4.7 billion square feet, 3/8-inch basis. This was about 2% above total use in 1976, but much above consumption in the 1950s and 1960s. Among the various nonstructural panel products used in new housing, particleboard and hardboard have trended upwards in recent years; insulating board and hardwood plywood have trended down.

TIMBER PRODUCTS CONSUMPTION IN UPKEEP AND IMPROVEMENTS

In addition to use in the construction of new residential units, substantial volumes of timber products are used each year for the upkeep and improvement of units in the existing housing inventory. In 1986, about 18% of the lumber, 24% of the structural panel products, and 17% of the nonstructural panel products consumed, were used for such purposes. This market has become much more important in recent years as the Nation's housing stock has grown larger, its average age has increased, and homeowner incomes have risen (Council of Economic Advisors 1988).

Residential Upkeep and Improvement Expenditures

Expenditures for residential upkeep and improvements have more than doubled in the last 25 years, rising from $37.8 billion (1982 dollars) in 1962 to $82.2 billion in 1986 (table 4, fig. 5). Most of the increase during this period took place between 1980 and 1986 as total expenditures rose by more than 60%.

Timber Products Use Per $1,000 of Expenditure

In contrast to trends in use per square foot of floor area in new housing, lumber use per $1,000 of expenditure for upkeep and improvements has increased over the past 25 years, rising from about 115 board feet in 1962 to 121 board feet in 1986 (table 4). Structural panel products use per $1,000 also has grown; however, nonstructural panels consumption, while increasing until 1976, has subsequently declined to about the same level of use as in the early 1960s.

Table 4.—Expenditures and timber products used per thousand dollars of expenditure in residential upkeep and improvements in the United States, specified years 1962–86.

		Use per thousand dollars of expenditures[1]		
	Total expenditures	Lumber	Structural panels[2] (3/8-inch basis)	Nonstructural panels[3] (3/8-inch basis)
	Million 1982 dollars	*Board feet*	*Square feet*	*Square feet*
1962	37,830	115	44	37
1970	42,170	118	55	39
1976	52,320	120	62	42
1986	82,240	121	75	38

[1]*Includes allowance for onsite and manufacturing waste.*
[2]*Includes softwood plywood, waferboard, oriented strand board, and composite board.*
[3]*Includes hardwood plywood, hardboard, insulating board, particleboard, and medium-density fiberboard.*
Sources: Expenditures: USDC BC 1987f.

Figure 5.—Residential upkeep and improvements.

Total Use in Residential Upkeep and Improvements

Residential upkeep and improvements consumed a total of 9.9 billion board feet of lumber in 1986, up nearly

59% from use in 1976, and well over twice the volume used in the early 1960s (table 5, fig. 5). Structural and nonstructural panels consumed for residential upkeep and improvements—6.2 and 3.2 billion square feet, 3/8-inch basis, respectively—have also increased over the past 25 years, with structural panels use rising more than three-fold since 1962. Nonstructural panels consumption more than doubled in the same period.

TIMBER PRODUCTS CONSUMPTION IN NEW NONRESIDENTIAL AND RAILROAD CONSTRUCTION

New nonresidential construction accounted for about 7% of the lumber, 10% of the structural panels, and 8% of the nonstructural panels consumed in the United States in 1986. An estimated additional 2% of the lumber, and much smaller amounts of the structural panel products were used for railroad ties and rail car repair.

New Nonresidential Construction

For purposes of this analysis, new nonresidential construction has been divided into two major classes: (1) nonresidential buildings—including, for example, stores, restaurants, warehouses, hotels and motels, and office, industrial, educational, religious, hospital, institutional, and nonresidential farm buildings; and (2) all other types, such as highways and streets, water and sewer systems, dams, military and conservation and development projects, railroad construction except track, and similar types of nonbuilding construction.

The total amounts of the various timber products used in the new nonresidential sector each year are dependent on the numbers, types, and sizes of buildings and other structures produced, and the amounts and types of wood materials used in building them. Because of its diverse nature, the volume of nonresidential construction is usually expressed as expenditures in the form of value of construction put in place.

Table 5.—Timber products used in residential upkeep and improvements in the United States, by product, specified years 1962–86.[1]

Year	Lumber	Structural panels[2] (3/8-inch basis)	Nonstructural panels[3] (3/8-inch basis)
	Million board feet	*Million square feet*	*Million square feet*
1962	4,330	1,670	1,400
1970	4,975	2,320	1,655
1976	6,255	3,245	2,190
1986	9,935	6,170	3,160

[1]*Includes allowance for onsite and manufacturing waste.*
[2]*Includes softwood plywood, waferboard, oriented strandboard, and composite board.*
[3]*Includes hardwood plywood, hardboard, insulating board, particleboard, and medium-density fiberboard.*

New Nonresidential Construction Expenditures

Total expenditures for new nonresidential construction (1982 dollars) were $175.4 billion in 1986, about 14.6% higher than in 1976, and more than twice the expenditures in 1950 (table 6, fig. 6). Though fluctuating somewhat in response to changing economic conditions, total expenditures increased fairly rapidly through the late 1960s. Expenditures were up for nearly all types of building and nonbuilding construction during this period. Beginning in 1968, expenditures for most types generally trended down, or showed little growth over the next decade. After reaching a low of $146.1 billion in 1977, total expenditures increased, dropped again in 1983, and subsequently rose to $177.4 billion in 1985, the highest level on record. Total expenditures in 1987 were $176.3 billion. In general, expenditures for buildings and the other types of construction followed the same trends.

Table 6.—Expenditures for new nonresidential construction in the United States, by type, specified years 1950–87.

Year	All classes		Buildings[1]		Other types[2]	
	Expenditures	Annual rate of change	Expenditures	Annual rate of change	Expenditures	Annual rate of change
	Billion 1982 dollars	*Percent*	*Billion 1982 dollars*	*Percent*	*Billion 1982 dollars*	*Percent*
1950	79.0	...	42.0	...	37.0	...
1955	108.3	6.5	59.8	7.3	48.5	5.5
1960	125.0	2.9	66.8	2.2	58.2	3.7
1965	166.7	5.9	93.2	6.9	73.4	4.7
1970	172.2	.6	91.0	– .5	81.1	1.0
1973	176.2	.8	94.6	1.3	81.6	–1.8
1975	155.7	–6.0	81.5	–7.2	74.2	–4.6
1976	153.1	–1.7	74.8	–8.2	78.3	5.4
1977	146.1	–4.6	72.7	–2.9	73.4	–6.2
1978	159.5	9.2	81.0	11.5	78.5	7.0
1979	166.0	4.1	88.2	8.9	77.8	–1.0
1980	165.9	1.3	89.3	1.9	76.6	.6
1981	164.1	–1.1	89.4	.2	74.7	–2.4
1982	160.3	–2.3	88.3	–1.2	72.0	–3.7
1983	150.4	–6.2	81.4	–7.9	69.0	–4.1
1984	162.8	8.3	92.7	13.9	70.2	1.7
1985	177.4	9.0	104.2	12.5	73.2	4.3
1986	175.4	– .1	100.9	–3.2	74.6	1.9
1987	176.3	.5	99.9	– .1	76.5	2.5

[1]*Includes private and public industrial buildings; private office and other commercial buildings; hotels and motels; churches and other religious buildings; public and private educational buildings; public and private hospital and other institutional buildings; animal hospitals and shelters; farm buildings (except residences); amusement and recreational buildings; bus, airline, and other passenger terminals; police and fire stations; civic centers; court houses; space facilities; postal facilities; and other private and public buildings.*
[2]*Includes telephone and telegraph systems; gas, electric light and power facilities; water and sewer systems; petroleum pipelines; railroads (except track construction); highways and streets; military facilities; conservation and development projects; and all other public and private nonbuilding construction.*
Source: USDC BC 1987j.

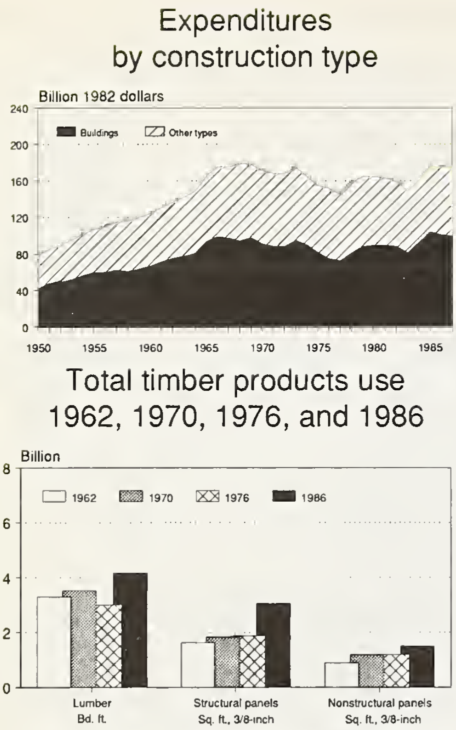


Figure 6.—Nonresidential construction.

Timber Products Use per $1,000 of Expenditure

Except for lumber, the fluctuations in total consumption of the various timber products in new nonresidential construction since the early 1960s were largely due to the variability in expenditures. Lumber use per $1,000 of construction expenditures declined in the mid 1970s, but is estimated to have subsequently increased in the 1980s (table 7). Structural and nonstructural panel use per $1,000 generally increased over the entire period.

Table 7.—Timber products used in new nonresidential construction in the United States, by product, specified years 1962–86.

Year	Lumber		Structural panels[1] (3/8-inch basis)		Nonstructural panels[2] (3/8-inch basis)	
	Total use	Use per $1,000 of expenditure[3]	Total use	Use per $1,000 of expenditure[3]	Total use	Use per $1,000 of expenditure[3]
	Million board feet	*Board feet*	*Million square feet*	*Square feet*	*Million square feet*	*Square feet*
1962	3,300	24.0	1,630	11.9	890	6.5
1970	3,530	20.5	1,840	10.7	1,190	6.9
1973	3,695	21.0	2,149	12.2	1,304	7.4
1976	3,000	19.6	1,870	12.2	1,190	7.8
1982	3,767	23.5	2,567	16.0	1,370	8.5
1986	4,180	23.8	3,060	17.4	1,510	8.6

[1]*Includes softwood plywood, waferboard, oriented strand board, and composite board.*

[2]*Includes hardwood plywood, hardboard, insulating board, particleboard, and medium-density fiberboard.*

[3]*1982 dollars. Use per $1,000 of construction expenditures computed by Forest Service. (See table 6 for construction expenditures.)*

Such trends in timber products use per $1,000 of expenditures are the result of many complex technological and institutional forces. Much of the decline in lumber use per $1,000 resulted from such things as increasing use of softwood plywood and metal for concrete forming; substitution of metal for wood in studs, joists, and decking; rising use of precast and prestressed concrete beams and other structural members in lieu of onsite forming; and other construction innovations such as slipform and tiltwall construction (USDA FS 1982). In addition, the metal buildings industry, which produced increasing numbers of pre-engineered warehouses and similar industrial buildings during the 1950s and 1960s, began to make inroads into other nonresidential markets with sophisticated designs for medium-sized, low-rise offices, motels, and shopping centers. Restrictive codes and other building regulations have also been important in limiting wood use in some types of buildings and in some locations (Spelter et al. 1987).

Countering these trends has been increased use of large wooden structural framing members such as beams, trusses and arches in some building types; improvement in the durability of many timber products; and rising use of wood siding on some types of small buildings (USDA FS 1982).

In general, wood construction is most cost effective in smaller nonresidential buildings, and its use is widespread in those types of structures. For example, in 1982, 48% of the one-story and 61% of the two-story buildings with floor areas less than 5,000 square feet had wood frames (Spelter et al. 1987). Moreover, wood structural panels are generally used with wood framing systems. These factors, in conjunction with the increasing share of buildings erected in suburban areas, where buildings tend to be low-rise and somewhat smaller than in cities, have also contributed to the increasing use of timber products per $1,000 of expenditure since the mid-1970s.

Total Timber Products Use in New Nonresidential Construction

Although total use of lumber and panel products for new nonresidential construction has fluctuated in the past, the overall trend during the past 25 years has generally been rising (table 7, fig. 6). For example, estimated consumption of lumber rose from 3.3 billion in 1962 to 3.7 billion board feet in 1973, and then declined to 3.0 billion in 1976. Over the next 10 years total use increased, reaching nearly 4.2 billion board feet in 1986—about 27% above the 1962 volume. Structural and nonstructural panels consumption showed the same general trends between 1962 and 1986, but the percentage increases—88% and 70%, respectively—were much larger.

Most of the timber products used in the nonresidential sector are used in building construction. For example, about 80% of the lumber and structural panels and more than 90% of the nonstructural panels consumed in new nonresidential construction in 1986 are estimated

Wood is being increasingly used in large nonresidential structures such as the Tacoma Dome.

to have been used in the construction of buildings. In the mid-1970s, most of the lumber and nonstructural panel products used for buildings was retained in the structure as rafters, joists, beams, wall paneling and millwork, whereas the most important use for structural panels was as concrete forming or security fencing and other facilitating purposes (Reid 1977). These general trends continued into the early 1980s (Spelter 1985c, Spelter and Anderson 1985, Spelter et al. 1987).

Railroad Construction

In 1986, about 1.1 billion board feet of lumber and 25 million square feet, 3/8-inch basis, of structural panels were used by the railroad industry for the construction of new track, and for the maintenance of existing track and rolling stock.[2] Of all lumber consumed in 1986 by the railroad industry, about four-fifths (881 million board feet) was used for the 20.4 million crossties and 1.0 million switch and bridge ties installed during the year (table 8, fig. 7). The remaining lumber, and all of the structural panels are estimated to have been used for repair and refurbishing railroad cars in industry-owned facilities. Slightly more than 90% of the lumber used for ties was hardwoods, principally oak. A somewhat smaller percentage of the lumber used for car repairs is estimated to have been hardwoods.

The number of railroad ties (crossties plus bridge and switch ties) installed each year, and the resulting volumes of lumber consumed, nearly doubled between the early 1960s and the mid-1970s. Since peaking at 29.9 million ties in 1976, however, installations have fluctuated but gradually moved lower. Although year-to-year variations are largely due to short-term economic fac-

[2]*Substantial volumes of timber products are also used in the construction and maintenance of nonresidential structures used by railroads and in the manufacture of freight cars. Past consumption of timber products in these uses are included in other sections of this chapter dealing with nonresidential construction and manufacturing.*

Table 8.—Wood railroad tie installations[1] and lumber consumption in the United States, specified years 1950–86.

Period	Total volume	Crossties Number	Crossties Volume	Switch and bridge ties Number	Switch and bridge ties Volume
	Million board feet	*Thousands*	*Million board feet*	*Thousands*	*Million board feet*
1950–59[2]	1,262	29,523	1,151	1,762	111
1960–69[2]	771	17,872	705	1,048	66
1970–74[2]	964	22,487	899	1,029	65
1975	938	21,850	874	1,016	64
1976	1,220	28,748	1,150	1,111	70
1977	1,204	28,265	1,131	1,160	73
1978	1,196	28,079	1,123	1,160	73
1979	1,162	27,057	1,100	978	62
1980	1,115	26,247	1,050	1,028	65
1981	1,122	26,719	1,069	840	53
1982	881	20,811	832	777	49
1983	871	20,553	822	779	49
1984	1,056	24,863	995	981	62
1985	1,003	23,434	937	1,035	65
1986	881	20,412	816	1,037	65

[1]*Includes ties used for replacement and for new track.*
[2]*Data shown are annual averages for the period.*
Note: Data on tie installations by class I railroads have been adjusted to include installations by all railroads. Data may not add to totals because of rounding.
Sources: Crossties, and switch and bridge ties: 1950–77—USDA FS 1982; 1978–86—Association of American Railroads 1970, 1984, 1987.

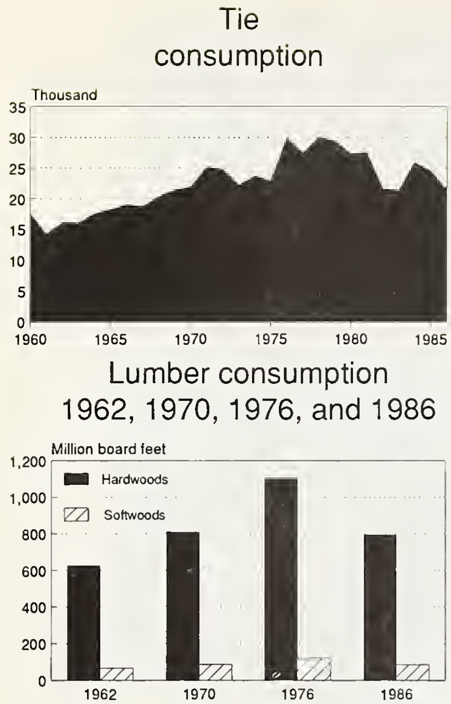


Figure 7.—Railroad ties.

tors, longer-run trends have resulted from fundamental changes in the railroad industry and its operations. For example, based on data available for Class I railroads from the Association of American Railroads (1984, 1987), the miles of track operated by all U.S. railroads dropped by at least 18% over the last two decades, the outgrowth of restructuring and streamlining systems and operations. Despite this decline, annual tie installations have been somewhat higher in the 1980s than in the 1960s. The principal reason for this has been the necessity to upgrade the remaining system to accommodate increasing track loads. Data show that average car load has increased almost 40% since the mid-1960s. Because of these trends, the average number of crossties installed annually per mile of track has about doubled (Association of American Railroads 1972, 1987).

Over the last two decades, nearly all of the crossties installed have been wood. Although a few railroads have been installing a larger percentage of concrete ties on their high-speed passenger lines, they amounted to only a very small percentage of all crossties installed in 1986 (Buekett et al. 1987).

TIMBER PRODUCTS CONSUMPTION IN MANUFACTURING

U.S. manufacturing industries, including those producing pallets and containers, rank second only to new residential construction in the use of solid-wood products. In 1986, about 8% of the lumber and more than 20% of the wood panel products consumed were used for the production of a wide variety of products made for sale, and in the production process for jigs, models, patterns, flasks and other facilitating purposes.

For this analysis, these manufactured goods have been divided into three groups: (1) household furniture, (2) commercial and institutional furniture, and (3) other products.[3] Although this latter group accounts for a moderately large part of total manufacturing timber products consumption, use for individual manufactured products is relatively small; thus, they have been combined.

In addition to the estimates presented in this section, substantial amounts of timber products are used to produce pallets, containers, prefabricated wooden buildings, structural wood members, mobile homes, millwork, and flooring. Information on timber products consumed in the production of these items is included in those sections of this chapter dealing with packaging and shipping and residential and nonresidential construction.

Recent trends in wood products use for manufacturing reflect both differential growth in the production and shipments of the various manufactured products, and technological changes which have affected the kinds and amounts of materials used in their production.

Shipments of Manufactured Products

Total shipments of the manufactured products included in this section amounted to $2,286 billion in 1986 (measured in 1982 dollars), a record volume, and about 3 times larger than in 1948 (table 9, fig. 8). In general, the manufacture and shipment of these products follow trends in the economy. Thus, growth in shipments was fairly steady at an annual rate of 3.8% during the 1950s through early 1970s period. However, the economic recessions in the mid-1970s, and particularly in the early 1980s resulted in sharp reductions. After 1982, shipments steadily increased in line with the gross national product. Per capita shipments, which rose from $4,982 in 1948 to $9,463 in 1986, have followed similar directions (McKeever and Jackson 1990: table A-1).

Household furniture shipments—$15.9 billion in 1986—have closely followed trends in total manufacturing, rising through the early 1970s, declining during the economic downturns, and increasing between 1982 and 1986. Nevertheless, shipments in 1986 were still below those for some years in the early and late 1970s. Shipments of commercial and institutional furniture and of other products have also increased fairly rapidly since 1982 reaching $15.5 billion and $2,255 billion, respectively, in 1986.

Timber Products Use Per Dollar of Shipments

There have been divergent trends in the use of lumber, structural, and nonstructural panels per dollar of

[3] Includes sporting goods, musical instruments, boat building and repair, toys and games, luggage and trunks, handles, wood pencils, mortician's goods, shoe and boot findings, wooden matches, commercial refrigeration, signs and displays, patterns and jigs, truck bodies and trailers, general machinery, agricultural implements, electrical equipment, and textile machinery supplies.

Table 9.—Value of manufacturing shipments in the United States, by commodity group, specified years 1948–86.

Year	All products		Household furniture		Commercial and institutional furniture		Other products[1]	
	Value	Annual rate of change	Value	Annual rate of change	Value	Annual rate of change	Value	Annual rate of change
	Billion 1982 dollars	*Percent*	*Billion 1982 dollars*	*Percent*	*Billion 1982 dollars*	*Percent*	*Billion 1982 dollars*	*Percent*
1948	733.3	NA	7.3	NA	1.8	NA	724.2	NA
1950	798.4	4.3	8.3	6.6	2.3	13.0	787.8	4.3
1955	1,057.3	5.8	10.6	5.0	3.3	7.5	1,043.5	5.8
1960	1,140.8	1.5	11.0	.7	5.0	8.7	1,124.7	1.5
1965	1,492.5	5.5	14.6	5.8	6.8	6.3	1,471.2	5.5
1970	1,682.7	2.4	16.1	2.0	8.5	4.6	1,658.1	2.4
1975	1,735.0	.6	13.1	−4.0	8.2	− .7	1,713.8	.7
1976	1,898.0	9.4	14.8	13.0	8.5	3.7	1,874.8	9.4
1977	2,032.0	7.1	16.0	8.1	10.2	20.0	2,005.9	7.0
1978	2,119.9	4.3	17.0	6.3	10.9	6.9	2,091.9	4.3
1979	2,138.9	.9	15.8	− 7.1	10.9	.0	2,112.1	1.0
1980	2,016.3	−5.7	14.3	−9.5	10.6	−2.8	1,991.4	−5.7
1981	2,016.1	.0	13.9	−2.8	10.4	−1.9	1,991.7	.0
1982	1,865.4	−7.5	12.8	−7.9	11.4	9.6	1,841.3	−7.6
1983	1,969.0	5.6	14.0	9.4	12.2	7.0	1,942.8	5.5
1984	2,141.6	8.8	15.0	7.1	13.9	13.9	2,112.6	8.7
1985	2,217.4	3.5	15.4	2.7	15.0	7.9	2,187.0	3.5
1986	2,286.1	3.1	15.9	3.2	15.5	3.3	2,254.8	3.1

[1]*Includes all other manufactured products except pallets, prefabricated wooden buildings and structural members, containers, mobile homes, millwork, flooring, and other similar goods reported in the construction and shipping sections of this chapter.*

Note: Value of shipments in 1982 dollars derived by dividing the value of shipments in current dollars by the producer price index for all commodities (1982 = 100). Data may not add to totals due to rounding.

Sources: Council of Economic Advisors 1988; USDC BC 1966a, 1971, 1976b, 1985, 1987a.

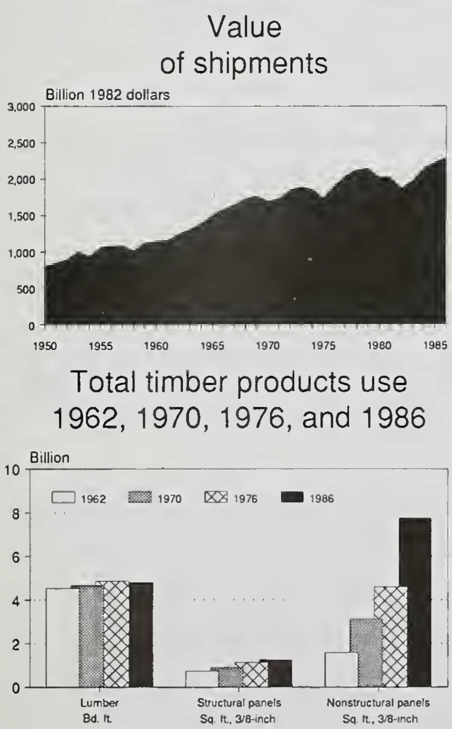


Figure 8.—Manufacturing.

shipments of manufactured products over the past three and a half decades (table 10 and McKeever and Jackson 1990: table A-2). For example, lumber consumption per dollar of shipments has dropped for each of the manufactured products groups, while structural panel use has fluctuated but shown no long-run trend, and nonstructural panels consumption has increased fairly steadily.

These trends reflect numerous technical and institutional shifts both within the manufacturing industries and their major markets. For example, part of the decline in the use of lumber and the relatively level trends in the use of structural panels per dollar of shipments reflects inroads of alternative materials. Plastics became a particularly important substitute for wood in furniture manufacture in the late 1960s and early 1970s, especially for highly ornate, detailed furniture parts and styles (Clark 1971). Lower costs, greater freedom in design, superior dimensional stability, and resistance to damage were among the principal factors contributing to its increased use during that period. Although numerous plastic components and parts continue to be used in the household furniture industry, overall consumption has apparently dropped since 1972 (USDC BC 1985). In addition to such technical factors as wood's ease of refinishing and repair, greater fracture resistance, and higher load bearing strength, the deep-seated preference for

Table 10.—Timber products used in manufacturing in the United States, by product, specified years 1948–86.

Year	Lumber		Structural panels (3/8-inch basis)		Nonstructural panels (3/8-inch basis)	
	Total	Per dollar of shipments[1]	Total	Per dollar of shipments[1]	Total	Per dollar of shipments[1]
	Million board feet	*Board feet*	*Million square feet*	*Square feet*	*Million square feet*	*Square feet*
1948	3,924	0.00535	363	0.00050	763[2]	0.00104
1960	3,865	.00339	910	.00080	1,378	.00121
1965	4,609	.00309	811	.00054	2,083	.00140
1970	4,670	.00278	902	.00054	3,128	.00186
1976	4,864	.00256	1,132	.00060	4,583	.00241
1986	4,803	.00210	1,257	.00055	7,750	.00339

[1]*Use per dollar (1982 dollars) of shipments, 1948–86, computed by Forest Service. (See table 9 for values of shipments.)*
[2]*Includes hardwood plywood only.*
Note: Timber products use by manufacturing group is shown in McKeever Jackson 1990, table A–2. Data may not add to totals because of rounding.
Sources: Merrick 1951, Gill 1965, Gill and Phelps 1969, McKeever and Martens 1983.

wood furniture by some consumers, and the return to more traditional furniture styles may have been contributing factors in plastic's decline.

For some other manufactured products—such as commercial and institutional furniture, boats, and toys—materials such as fiberglass, reinforced plastics, and metals have replaced lumber and wood panel products and continue to be used because of their lower costs or preferred performance characteristics.

Nonstructural panels have also partially displaced lumber and structural panels in some manufactured products. This substitution has been particularly rapid over the past 35 years in the manufacture of household furniture. For example, particleboard instead of lumber is now used extensively for panel corestock and hardboard has replaced plywood for such components as drawer bottoms and backs in cabinets. In addition, the superior edge-working characteristics of medium-density fiberboard has been a major factor in its substitution for lumber, plywood, and particleboard. Unlike most plywood and particleboard, its smoothness after machining permits the printing of a wood grain or other pattern directly on the surface, thus eliminating the need for a veneer or paper overlay.

Part of the decline in the use of lumber, and the relatively stable use of structural panels, per dollar of shipments also reflects a general reduction in use of all raw materials per dollar of product value. This has resulted from increases in the degree of processing of materials and rising relative costs of labor and capital per unit of production (USDC BC 1985).

Total Timber Products Use in Manufacturing

Trends in the volumes of lumber and panel products consumed in the manufacture of the products included in this section have varied greatly in recent decades as a result of the changing production and shipments, and use per dollar values discussed earlier. Total lumber consumption—4.8 billion board feet in 1986—varied, but showed little overall growth after 1965, as rising shipments were nearly offset by declining use per dollar (Gill 1965, Gill and Phelps 1969, USDA FS 1982, McKeever and Martens 1983) (tables 10, 11, McKeever and Jackson 1990: A-2, and fig. 8). Structural panel consumption, which had increased fairly rapidly during the 1950s, also slowed somewhat between 1965 and 1986, rising to 1.3 billion square feet, 3/8-inch basis. Consumption of nonstructural panels, on the other hand, has been increasing steadily since the early 1950s. As was discussed earlier in this section, much of the increase in the last two decades has come because of their substitution for lumber and structural panels. Total nonstructural panels consumption in manufacturing in 1986 was about 7.8 billion square feet, 3/8-inch basis, more than 10 times that used in 1948 and almost 4 times more than was consumed in 1965.

Until the early 1970s the household furniture manufacturing industry group consumed the largest volumes of lumber and nonstructural panel products. However, over the next 15 years, there was very rapid growth for those industries in the "other products" group, and declines and erratic and slower increases for household furniture. As a consequence, in 1986 the "other products" group was the largest consumer of lumber—2.7 billion board feet—and of nonstructural panel products—3.3 billion square feet, 3/8-inch basis (table 11). The "other products" group also consumed the largest volume of structural panel products in 1986, 840 million square feet, 3/8-inch basis, as has been the case for more than 25 years.

Although the "other products" group became the largest consumer of lumber and nonstructural panel

Table 11.—Timber products used in manufacturing in the United States, by product and commodity group, specified years 1948–86.

Year and commodity group	Lumber	Structural panels (3/8-inch basis)	Nonstructural panels (3/8-inch basis)
	Million board feet	*Million square feet*	*Million square feet*
1948			
Household furniture	1,970	195	397[1]
Commercial and institutional furniture	321	90	184[1]
Other products[2]	1,633	78	182[1]
Total	3,924	363	763[1]
1960			
Household furniture	2,116	351	719
Commercial and institutional furniture	289	137	322
Other products[2]	1,460	422	337
Total	3,865	910	1,378
1965			
Household furniture	2,987	300	1,289
Commercial and institutional furniture	280	87	427
Other products[2]	1,342	424	367
Total	4,609	811	2,083
1970			
Household furniture	2,961	327	1,912
Commercial and institutional furniture	271	114	736
Other products[2]	1,438	461	480
Total	4,670	902	3,128
1976			
Household furniture	2,317	204	1,390
Commercial and institutional furniture	285	218	993
Other products[2]	2,262	710	2,200
Total	4,864	1,132	4,583
1986			
Household furniture	1,773	154	2,150
Commercial and institutional furniture	310	263	2,300
Other products[2]	2,720	840	3,300
Total	4,803	1,257	7,750

[1]*Includes hardwood plywood only.*
[2]*Includes all other manufactured products except pallets, prefabricated wooden buildings and structural members, containers, mobile homes, millwork, flooring, and other similar goods reported in the construction and shipping sections of this chapter.*
Source: See source note table 10.

products in 1986, the manufacturers of household furniture are still the largest users among those industries manufacturing generally similar products. In addition, they also remain the most important consumers of the high quality and preferred species of domestic and imported lumber.

TIMBER PRODUCTS CONSUMPTION IN PACKAGING AND SHIPPING

In 1986, some 6.8 billion board feet of lumber; 373 million square feet, 3/8-inch basis, of structural panels; and 243 million square feet, 3/8-inch basis, of nonstructural panels were used in shipping (table 12). These materials—about 14% of the lumber, 2% of the structural panels, and 1% of the nonstructural panels consumed in 1986—were used for the manufacture of pallets, boxes, crates, hampers, baskets, and other wooden containers; and for dunnage, blocking, and bracing required for the transportation, handling, and storage of industrial, agricultural, and military products.[4]

There were increases in consumption of all of the major product groups between 1976 and 1986. Lumber consumption rose about 15%, structural panels 44%, and nonstructural panels 24%. For lumber this was a continuation of the increases in use that has been evident since 1960. However, for structural and nonstructural panels, the rise was a reversal of the declining trends over the past 25 years.

[4]*In addition to lumber and panel products, large volumes of paper and board are used for packaging and shipping. Trends in the consumption of those products are discussed in the pulpwood section of this chapter.*

Table 12.—Timber products used in shipping in the United States, by product and end use, specified years 1948–86.

Year and end use	Lumber	Structural panels (3/8-inch basis)	Nonstructural panels (3/8-inch basis)
	Million board feet	*Million square feet*	*Million square feet*
1948			
Wooden containers	3,997	313	([1,2])
Pallets	220	1	([1,2])
Dunnage, blocking, and bracing	740	([2])	([1,2])
Total	4,957	314	([1,2])
1960			
Wooden containers	1,866	304	821
Pallets	1,550	16	3
Dunnage, blocking, and bracing	800	([2])	1
Total	4,216	320	825
1965			
Wooden containers	1,829	203	393
Pallets	2,200	62	18
Dunnage, blocking, and bracing	856	4	8
Total	4,885	269	419
1970			
Wooden containers	1,754	174	262
Pallets	3,150	105	44
Dunnage, blocking, and bracing	820	6	8
Total	5,724	285	314
1976			
Wooden containers	822	97	113
Pallets	4,900	157	78
Dunnage, blocking, and bracing	195	5	5
Total	5,917	259	196
1986			
Wooden containers	275	47	53
Pallets	6,341	321	187
Dunnage, blocking, and bracing	170	5	3
Total	6,786	373	243

[1]*Includes hardwood plywood only.*
[2]*Less than 500,000 units.*
Sources: Wooden containers, and dunnage, blocking and bracing: See source note table 10; Pallets: See source note table 10, McCurdy et al. 1988, McKeever et al. 1986.

Timber Products Consumption in Pallets

The increases in shipping use of lumber since the early 1960s and of structural and nonstructural panels since 1976 have been entirely attributable to the steadily rising number of pallets produced (fig. 9). In 1960, some 62 million pallets were produced (National Wooden Pallet and Container Association 1987), consuming an estimated 1.6 billion board feet of lumber, 16 million square feet of structural panels, and 3 million square feet of nonstructural panels (table 13). Since then, pallet output, and the timber products used to produce them, has increased rapidly. Between 1960 and 1976, pallet production and lumber consumption more than tripled. Because of increasing use per pallet, structural and nonstructural panel consumption rose much faster. In the next 10 years, 1976–86, pallet production nearly doubled to 373 million units; however, lumber consumption only rose 29% to 6.3 billion board feet because of declines in use per pallet. Total consumption and use per pallet of structural and nonstructural panels continued to increase rapidly during this period.

The decline in lumber use per pallet from 25 to 17 board feet since 1976 is the result of many factors. Use of a relatively larger proportion of expendable pallets (which generally use less wood per pallet than other types), substitution of other wood and of nonwood materials, and increased efficiency in pallet design emanating from increased raw material costs and competition from other shipping media have been contributing factors (USDA FS 1982, McCurdy et al. 1988, McKeever et al. 1986).

The rapid increase in pallet production since the early 1960s has, in part, been due to the introduction of new methods of materials handling and to the construction of new facilities geared to pallet use. At the same time,

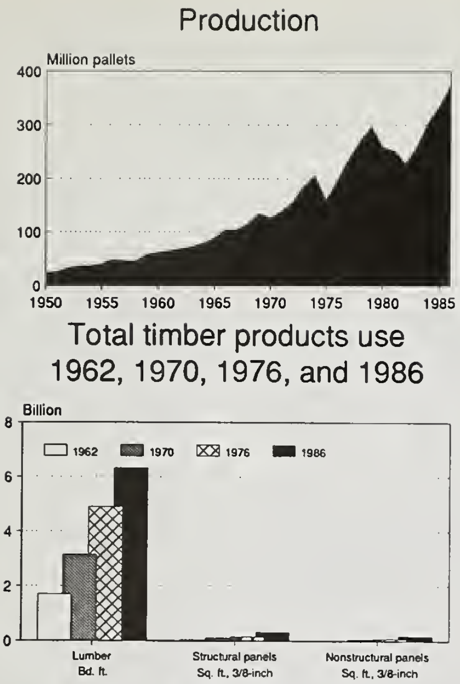


Figure 9.—Wooden pallets.

growth in industrial and agricultural production has led to increased demand in those sectors of the economy where pallet systems were already established.

Timber Products Consumption in Wooden Containers

The use of wooden containers (nailed boxes and crates, wirebound boxes and crates, and veneer and plywood containers) in the United States for agriculture, manufacturing and other uses, has been declining. Since 1970, the value of shipments for wooden containers in constant 1982 dollars has dropped from $1.2 billion to $0.6 billion in 1986 (table 14). This decline followed a small increase during the 1960s, and reflects the continued displacement of wooden containers by fiber and plastic containers, by metal, plastic, and fiber barrels and pails, and by multiwall fiber and plastic bags, that has been going on for the past 30 years.

Several factors contributed to these changes, including lower costs of substitute containers and their superior adaptability to automated packaging and shipping operations. In addition, lower shipping weights have become more important in recent years as freight costs have increased. In packaging some items, however, such as large bulky products, delicate instruments, glass, ceramics, and certain fruits and vegetables, these advantages continue to be outweighed by the need for special protection; wooden containers are still used.

The use of lumber and panel products per dollar of shipments of wooden containers has shown a consistent downward trend since the early 1960s (table 14), reflecting increasing use of nonwood materials such as plastics and paperboard in conjunction with wood, changes in the types of containers produced, and use of more efficient container manufacturing processes.

As a result of the declines in production and shipments and the decreasing wood use per unit discussed above, total timber products use for wooden containers has fallen dramatically. In 1986 just 275 million board feet of lumber; 47 million square feet, 3/8-inch basis, of structural panels; and 53 million square feet, 3/8-inch basis, of nonstructural panels were used. These volumes were far under 1960 consumption, and are probably all-time lows in this century.

Timber Products Consumption in Dunnage

The volume of lumber used for dunnage, blocking, and bracing in railroad cars, trucks, and ships remained fairly stable through the 1950s and 1960s, but experienced rapid declines in the late 1970s and early 1980s. Lumber consumed for dunnage in 1986 is estimated to be just 170 million board feet, only one-fifth as much as the 820 million board feet used in 1970 (table 15).

Table 13.—Timber products used in the manufacture of pallets in the United States, by product, specified years 1960–86.

		Lumber		Structural panels (3/8-inch basis)		Nonstructural panels (3/8-inch basis)	
Year	Pallet production	Use per pallet	Total	Use per pallet	Total	Use per pallet	Total
	Millions	*Board feet*	*Million board feet*	*Square feet*	*Million square feet*	*Square feet*	*Million square feet*
1960	62	25	1,550	0.25	16	0.05	3
1965	88	25	2,200	.70	62	.21	18
1970	126	25	3,150	.83	105	.35	44
1976	196	25	4,900	.80	157	.40	78
1986	373	17[1]	6,341	.86	321	.50	187

[1]*Based on lumber use per pallet data in McKeever et al. 1986.*

Sources: Pallet production: National Wooden Pallet and Container Association 1987, see source note table 10.

Table 14.—Value of shipments and timber products used in the manufacture of wooden containers in the United States, by product, specified years 1960–86.

Year	Value of wooden container shipments	Lumber: Use per dollar of shipments[1]	Lumber: Total	Structural panels (3/8-inch basis): Use per dollar of shipments[1]	Structural panels (3/8-inch basis): Total	Nonstructural panels (3/8-inch basis): Use per dollar of shipments[1]	Nonstructural panels (3/8-inch basis): Total
	Million 1982 dollars	*Board feet*	*Million board feet*	*Square feet*	*Million square feet*	*Square feet*	*Million square feet*
1960	1,074	1.737	1,866	0.283	304	0.764	821
1965	1,152	1.588	1,829	.176	203	.341	393
1970	1,184	1.481	1,754	.147	174	.221	262
1976	802	1.025	822	.121	97	.141	113
1986	643	0.428	275	.073	47	.082	53

[1]*Use per dollar (1982 dollars) of shipments, 1948–86, computed by Forest Service.*
Note: Value of shipments in 1982 dollars derived by dividing the value of shipments in current dollars by the producer price index for all commodities (1982 = 100).
Sources: Value of wooden container shipments: USDC BC 1966a, 1971, 1976b, 1985, 1987a; timber products use: see source note table 10.

Table 15.—Timber products used in dunnage, blocking, and bracing in the United States, by product, specified years 1948–86.

Year	Lumber	Structural panels (3/8-inch basis)	Nonstructural panels (3/8-inch basis)
	Million board feet	*Million square feet*	*Million square feet*
1948	740	([1])	([1,2])
1960	800	([1])	1
1965	856	4	8
1970	820	6	8
1976	195	5	5
1986	170	5	3

[1]*Includes hardwood plywood only.*
[2]*Less than 500,000.*
Source: See source note, table 10.

Table 16.—Timber products used for other purposes[1] in the United States, by product, specified years 1962–86.

Year	Lumber	Structural panels (3/8-inch basis)	Nonstructural panels (3/8-inch basis)
	Million board feet	*Million square feet*	*Million square feet*
1962	7,298	1,299	1,354
1970	6,444	3,264	3,228
1976	6,143	3,663	4,116
1986	11,053	5,119	864

[1]*Includes upkeep and improvement of nonresidential buildings and structures; made-on-the-job items such as advertising and display structures; and a wide variety of products and uses.*

This rapid decline reflects growth in containerized and bulk shipments of manufactured and agriculture goods, and increased use of palletized transportation systems.

Small and relatively stable volumes of structural panels have also been used for dunnage, blocking, and bracing over the past 25 years. Nonstructural panels use has declined.

TIMBER PRODUCTS CONSUMPTION IN OTHER USES

In addition to the major end uses discussed above, an estimated 11.1 billion board feet of lumber; 5.1 billion square feet, 3/8-inch basis, of structural panels; and 0.9 billion square feet, 3/8-inch basis, of nonstructural panels were used in 1986 for other purposes (table 16). These included upkeep and improvement of nonresidential structures; roof supports and other construction in mines; made-at-home or do-it-yourself projects such as furniture, boats, and picnic tables; and made-on-the-job products such as advertising and display structures.

There are no historical data on the consumption of timber products in these various uses. Accordingly, use for these purposes in 1962, 1970, 1976, and 1986 was estimated by subtracting volumes of timber products consumed in the specific end uses discussed above from the estimated total consumption of each product. These residuals probably include some lumber and panel products which properly belong in the construction, manufacturing, or shipping sectors. The "other uses" categories also include any statistical discrepancies associated with the estimates of production, imports, and exports, used in estimating total consumption.

RECENT TRENDS IN LUMBER, STRUCTURAL, AND NONSTRUCTURAL PANELS CONSUMPTION, TRADE, AND PRODUCTION

Lumber

Consumption

Lumber consumption in all uses in 1986 was 57.2 billion board feet (tables 17, 18, McKeever and Jackson 1990: A-3, and fig. 10). This was well above total use in any year in the past three and one-half decades and exceeded the levels in the early 1900s, when lumber was the most important raw material used in the United States for construction, manufactured products, and shipping.

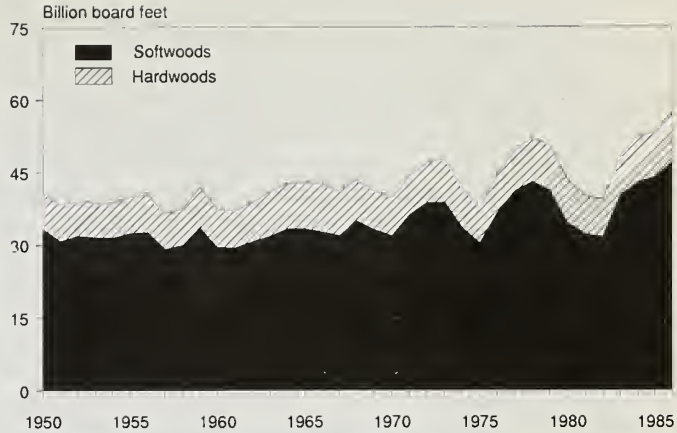


Figure 10.—Lumber consumption, by species group, 1950–1986.

Table 17.—Lumber consumption in the United States, by per capita use, softwoods and hardwoods, and end use, specified years 1962–86.

Year	Total	Per capita	Species group: Softwoods	Species group: Hardwoods	End use: New housing	End use: Residential upkeep and improvements	End use: New nonresidential construction[1]	End use: Manufacturing	End use: Shipping	End use: All other[2]
	Million board feet	*Board feet*				*Million board feet*				
1962	39,078	210	30,773	8,501	14,160	4,330	4,200	4,540	4,550	7,298
1970	39,869	194	31,959	7,910	13,350	4,980	4,700	4,670	5,725	6,444
1976	44,653	205	36,627	8,026	17,000	6,260	4,470	4,865	5,915	6,143
1986	57,203	237	47,094	10,109	19,320	9,930	5,310	4,805	6,785	11,053

[1]In addition to new construction, includes railroad ties laid as replacements in existing track and lumber used by railroads for railcar repair.
[2]Includes upkeep and improvement of nonresidential buildings and structures; made-at-home projects, such as furniture, boats, and picnic tables; made-on-the-job items such as advertising and display structures; and a wide variety of miscellaneous products and uses.
Note: Product use by market has been rounded to the nearest 5 million board feet. Data may not add to totals because of rounding.

Table 18.—Lumber consumption, imports, exports, and production in the United States, specified years 1950–86.

Year	Consumption: Total	Consumption: Softwood lumber	Consumption: Hardwood lumber	Imports: Total	Imports: Softwood lumber[1]	Imports: Hardwood lumber	Exports: Total	Exports: Softwood lumber[1]	Exports: Hardwood lumber	Production: Total	Production: Softwood lumber	Production: Hardwood lumber
						Billion board feet						
1950	40.9	33.4	7.5	3.4	3.1	0.3	0.5	0.4	0.1	38.0	30.6	7.4
1955	40.1	32.5	7.6	3.6	3.3	.3	.8	.7	.2	37.4	29.8	7.6
1960	37.7	29.6	8.1	3.9	3.6	.3	.9	.7	.2	34.7	26.7	8.0
1965	43.0	33.4	9.6	5.2	4.9	.3	.9	.8	.1	38.7	29.3	9.4
1970	39.9	32.0	7.9	6.1	5.8	.3	1.2	1.1	.1	35.0	27.3	7.7
1975	37.8	30.5	7.3	6.0	5.7	.3	1.6	1.4	.2	33.5	26.1	7.3
1976	44.7	36.6	8.0	8.2	8.0	.3	1.8	1.6	.2	38.3	30.3	8.0
1977	49.7	41.1	8.6	10.7	10.4	.3	1.7	1.4	.2	40.7	32.2	8.5
1978	52.1	43.1	9.0	12.2	11.9	.4	1.6	1.4	.3	41.5	32.6	9.0
1979	50.6	41.3	9.3	11.5	11.2	.4	2.1	1.8	.4	41.2	31.9	9.3
1980	43.4	34.5	8.9	9.9	9.6	.3	2.5	2.0	.5	36.1	27.0	9.1
1981	40.1	32.3	7.8	9.5	9.2	.3	2.4	1.9	.5	33.0	25.0	8.0
1982	39.3	31.6	7.7	9.4	9.1	.2	2.0	1.6	.4	32.0	24.1	7.9
1983	48.8	40.2	8.6	12.3	12.0	.3	2.3	1.8	.5	38.8	30.0	8.8
1984	52.5	42.9	9.6	13.6	13.3	.3	2.2	1.6	.5	41.0	31.2	9.8
1985	53.4	44.0	9.4	15.0	14.6	.4	1.9	1.5	.4	40.3	30.9	9.5
1986	57.2	47.1	10.1	14.6	14.3	.3	2.4	1.9	.5	45.0	34.7	10.3

[1]Includes small volumes of mixed species not classified as softwoods or hardwood.
Note: Data may not add to totals because of rounding.
Sources: Production: USDC BC 1987d. Trade: USDC BC 1987h, 1987i.

Per capita consumption in 1986 was 237 board feet, somewhat above per capita use in the 1960s and 1970s, but below the average for most years prior to that time. Moreover, this was far below the early 1900s, when per capita use reached a high of more than 500 board feet.

More than half of the lumber consumed in 1986 was used for housing—34% for construction of new units and 17% for the upkeep and improvement of existing units. Shipping accounted for another 12%, new nonresidential construction and railroads 9%, manufacturing 8%, and the remaining 19% was consumed in other uses.

In 1986, softwood species composed about 82% of total lumber consumption. This was very nearly the same as in 1976, but somewhat above the proportions in 1970 and 1962. Changes of this sort are largely due to differential strength of the various markets, and the wide variation in species consumption between them. As shown in the tabulation below, about 96% of the lumber used in new housing in 1986 is estimated to have been softwood species. In contrast, only 30% of the lumber used in shipping was softwood. The rise in the percentage of softwood used in housing between the early 1960s and the 1980s was largely due to the decline in hardwood flooring use; whereas the decline in shipping was the result of the growth of pallets which are mostly manufactured from hardwoods.

Exports and Imports

In addition to domestic consumption, there has been a rising demand for U.S. lumber in foreign markets over the past 35 years (table 18 and McKeever and Jackson 1990: A-3). Total exports, which had reached 2.5 billion board feet in 1980, fluctuated downward in the early 1980s in response to economic conditions in the major importing countries and the strong dollar in relation to most of the world's currencies (see Chapter 5 for more detail), but subsequently returned to 2.4 billion in 1986. This amounted to about 5% of total U.S. lumber production.

More than three-fourths of total exports in 1986 were softwood species. The most important softwood lumber export markets were Japan—which accounted for about 43% of total softwood shipments, Canada with imports of 19%, and the European Economic Community (EEC) countries who collectively purchased 16%. Canada—with 31% in 1986—was the most important export market for hardwoods, followed by the EEC with imports of 27%. Other purchasers of U.S. hardwood lumber include Japan, several countries in South and Central America, and more recently Taiwan and South Korea.

Between 1950 and 1985, U.S. imports of lumber rose from 3.4 billion to 15.0 billion board feet—an increase that accounted for nearly two-thirds of the total expansion in timber products imports during this period. Although imports dropped slightly to 14.6 billion board feet in 1986, this was second only to the 1985 record volume.

Nearly all of the increase in total lumber imports since the early 1950s has been composed of softwoods from Canada, chiefly from British Columbia. Moreover, there was particularly rapid growth after the mid-1970s, and by 1985, Canadian shipments amounted to more than a third of total U.S. softwood lumber consumption. The percentage (and the volume) of softwoods from Canada dropped somewhat in 1986. Hardwood imports from the tropical regions of the world and from Canada, have fluctuated between 0.2 and 0.4 billion board feet since 1950, but have shown no overall trend.

Production

Although there has been a great deal of fluctuation in response to changing demands in domestic and export markets, U.S. production of both softwoods and hardwoods has been somewhat higher in the late 1970s and 1980s than in 1950–69 and most prior years. In 1986, U.S. mills produced 45.0 billion board feet of lumber—the largest volume in more than seven decades and only slightly under the record 46 billion produced in 1906 and 1907 (Steer 1948). Softwood production—34.7 billion board feet—was at near record levels, surpassed only by output in 1906 and 1907. Production of hardwood species is estimated at 10.3 billion board feet. This was smaller than in most years between 1904 and 1912; however, it was the largest volume produced since that time.

Structural Panels

Consumption

Structural panel consumption totaled 25.9 billion square feet, 3/8-inch basis, in 1986 (tables 19, 20, McKeever and Jackson 1990: A-4, and fig. 11). This was a record volume, almost 9% above 1985, and more than 10 times total use in 1950. Per capita consumption has also shown a sharp upward trend during this period,

Estimates of softwood species as a percent of total lumber consumption

Year	All end uses	New housing	Residential upkeep and improvements	New nonresidential construction*	Manufacturing	Shipping	Other
1962	79	93	97	74	52	40	84
1986	82	96	97	74	47	30	97

*Includes railroad construction.

Table 19.—Structural panel consumption in the United States, by per capita use, panel type, and end use, specified years 1962–86.

			Panel type		End use					
Year	Total	Per capita	Softwood plywood	OSB/ waferboard	New housing	Residential upkeep and improvements	New nonresidential construction[1]	Manufacturing	Shipping	All other[2]
	Million square feet (3/8-inch basis)	*Square feet (3/8-inch basis)*	*Million square feet (3/8-inch basis)*							
1962	9,509	51	9,509	([3])	3,950	1,670	1,650	730	210	1,299
1970	14,229	69	14,229	([3])	5,590	2,320	1,870	900	285	3,264
1976	17,963	82	17,736	227	7,760	3,240	1,910	1,130	260	3,663
1986	25,949	107	21,665	4,284	9,950	6,170	3,080	1,255	375	5,119

[1]*In addition to new construction, includes structural panels used by railroads for railcar repair.*

[2]*Includes upkeep and improvement of nonresidential buildings and structures; made-at-home projects, such as furniture, boats, and picnic tables; made-on-the-job items such as advertising and display structures; and a wide variety of miscellaneous products and uses.*

[3]*Less than 500,000 square feet.*

Note: Estimates for manufacturing and shipping contain softwood veneer consumed in other than plywood production. Product use by market has been rounded to the nearest 5 million square feet. Data may not add to totals because of rounding.

Table 20.—Structural panel consumption, imports, exports, and production in the United States, specified years 1950–86.

	Consumption			Imports			Exports			Production		
Year	Total	Softwood plywood	OSB/ waferboard	Total	Softwood plywood	OSB/ waferboard	Total	Softwood plywood	OSB/ waferboard	Total	Softwood plywood[1]	OSB/ waferboard
	Billion square feet (3/8-inch basis)											
1950	2.6	2.6	([2])	([2])	([2])	([2])	([2])	([2])	([2])	2.6	2.6	([2])
1955	5.1	5.1	([2])	([2])	([2])	([2])	([2])	([2])	([2])	5.1	5.1	([2])
1960	7.8	7.8	([2])	([2])	([2])	([2])	([2])	([2])	([2])	7.8	7.8	([2])
1965	12.4	12.4	([2])	([2])	([2])	([2])	([2])	([2])	([2])	12.4	12.4	([2])
1970	14.2	14.2	([2])	([2])	([2])	([2])	0.1	0.1	([2])	14.3	14.3	([2])
1975	15.5	15.3	0.2	0.1	([2])	0.1	.8	.8	([2])	16.1	16.1	0.1
1976	18.0	17.7	.2	.2	([2])	.1	.7	.7	([2])	18.5	18.4	.1
1977	19.4	19.1	.3	.2	([2])	.2	.3	.3	([2])	19.5	19.4	.1
1978	20.1	19.7	.4	.3	0.1	.2	.3	.3	([2])	20.1	20.0	.2
1979	19.7	19.3	.4	.3	([2])	.3	.4	.4	([2])	19.8	19.7	.2
1980	16.4	15.9	.5	.3	([2])	.3	.4	.4	([2])	16.5	16.3	.2
1981	16.7	16.0	.7	.3	([2])	.3	.7	.7	([2])	17.0	16.7	.3
1982	16.2	15.4	.9	.3	([2])	.3	.5	.5	([2])	16.4	15.8	.6
1983	20.7	19.0	1.7	.5	([2])	.4	.6	.6	([2])	20.8	19.5	1.3
1984	22.4	19.6	2.8	.8	.1	.7	.4	.4	([2])	22.0	19.9	2.1
1985	23.8	20.0	3.8	.9	.1	.8	.3	.3	([2])	23.2	20.3	3.0
1986	25.9	21.7	4.3	.9	.1	.8	.6	.6	([2])	25.6	22.1	3.5

[1]*Includes production from both domestic and imported species.*

[2]*Less than 50 million square feet.*

Note: Data may not add to totals because of rounding.

Sources: Production: Anderson 1987b, USDC BC 1987g. Trade: USDC BC 1987h, 1987i.

rising from about 18 square feet in 1950 to 107 square feet in 1986.

More than three-fourths of all the structural panels consumed in 1986 went into construction. Of the total, major construction uses included about 38% for new residential construction, 24% for residential upkeep and improvements, and 12% for new nonresidential construction. In addition, the "all other" category includes an unknown amount that was used for other construction purposes such as nonresidential upkeep and improvements. Manufacturing uses accounted for almost 5% of the total, and shipping accounted for the remainder of the identifiable uses.

Softwood plywood, chiefly manufactured from Douglas-fir and southern pine, amounted to 21.7 billion square feet or about 83% of total structural panels consumption in 1986. The remaining 4.3 billion square feet was oriented strand board (OSB) and waferboard. Record volumes of both softwood plywood and OSB/waferboard were consumed in 1986, and growth for both has been particularly rapid since construction began to pick up after the 1980–82 economic slump. Softwood plywood consumption has increased ten-fold since the early 1950s, and by about 42% since the mid-1970s. OSB/waferboard, which was not in wide use in the United States prior to the mid-1970s, has grown much more rapidly over the past 10 years. These trends are expected, since, as was discussed earlier, much of the penetration of construction markets by OSB/waferboard has come at the expense of softwood plywood.

Exports and Imports

Structural panel exports, estimated to be nearly all softwood plywood, totaled 0.6 billion square feet, 3/8-inch basis, in 1986. Exports grew fairly slowly through the mid 1970s; however, since reaching 0.8 billion square feet in 1975, shipments have fluctuated between 0.3 and 0.6 billion square feet. About 2% of total domestic production of structural panels is currently exported. Principal foreign markets include the EEC countries, Canada, and several South and Central American nations.

Imports of structural panels in 1986 amounted to 0.9 billion square feet, 3/8-inch basis. More than 85% of the total (0.8 billion) was OSB/waferboard. Structural panel imports prior to the mid-1970s were nearly all softwood plywood and were relatively insignificant. Although softwood plywood imports have shown some growth since that time, most of the increase has been for OSB/waferboard from Canada. In 1986, about 18% of the OSB/waferboard consumed in the United States was supplied by imports, down from almost 94% in the mid-1970s. Less than 1% of softwood plywood consumption is imported.

Production

Domestic structural panel production in 1986 reached 25.6 billion square feet, 3/8-inch basis, almost 10 times

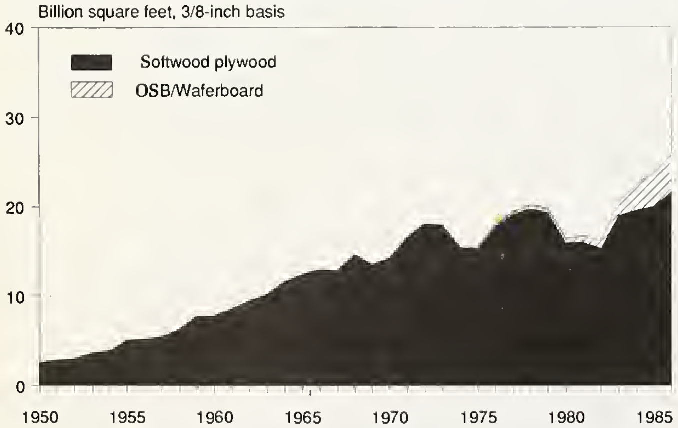


Figure 11.—Structural panels consumption, by type, 1950–1986.

the level of output in the early 1950s. As was true for consumption, this was a record production volume for both softwood plywood and OSB/waferboard.

In 1986, 48% of structural panel production was in the South, 38.8% in the Pacific Coast states of Washington, Oregon, and California, 8.9% in the North, and the remainder in the Rocky Mountain Region (Anderson 1987b). Although the South currently leads, there have been dramatic shifts in the regional production of structural panels over the last three and one-half decades (Adams et al. 1988). In the early 1950s, 100% of structural panel production—all softwood plywood at the time—was located in the Pacific Coast states. By the mid-1950s, a significant volume of softwood plywood also was being produced in the Rocky Mountain Region. However, beginning in 1964 with the first southern pine plywood production, regional output began to shift to the South. Currently, more than half of the softwood plywood produced each year comes from southern mills. U.S. OSB/waferboard production began in the North in 1973. Production came on line in the three other major regions in the 1980s; however, the North still accounted for over 75% of total OSB/waferboard output in 1986.

Nonstructural Panels

Consumption

Total consumption of nonstructural panels—hardwood plywood, insulating board, hardboard, and particleboard (including medium-density fiberboard)—amounted to 18.2 billion square feet, 3/8-inch basis, in 1986 (tables 21, 22, McKeever and Jackson 1990: A-5, and fig. 12). This was nearly 4 times larger than in the early 1950s, but somewhat less than in 1972–73 and 1977–79 when consumption of all four products was near record levels. Per capita consumption, 75 square feet in 1986, has followed the same general trends over the past 35 years.

Although consumption of each of the nonstructural panel products was larger in 1986 than in the early 1950s, use of only one, particleboard, has shown a generally upward trend over the entire period. Consumption of particleboard reached a record 9.8 billion square feet in 1986 and accounted for over half of the total use of all nonstructural panels. For each of the other three, output in 1986 was somewhat below the levels reached in the 1970s, reflecting product substitution and changing markets discussed earlier in this chapter. For example, hardwood plywood consumption—2.7 billion square feet in 1986—was only about half as much as in 1972, when use reached a high of 5.2 billion square feet. Similarly, consumption of insulating board fell from 5.3 billion square feet in 1973 to 3.8 billion in 1986; and hardboard use dropped from 2.7 billion square feet in 1978 and 1979 to 2.0 billion in 1986.

Manufacturing was the most important end use for nonstructural panels in 1986, accounting for over 42% of the total. This was more than double the 20% of total use in manufacturing in 1962 and was the result of the

Table 21.—Nonstructural panel consumption in the United States, by per capita use, panel type, and end use, specified years 1962–86.

Year	Total	Per capita	Panel type: Hardwood plywood	Insulating board	Hardboard	Particle board[1]	End use: New housing	Residential upkeep and improvements	New nonresidential construction	Manufacturing	Shipping	All other[2]
	Million square feet (3/8-inch basis)	*Square feet (3/8-inch basis)*	*Million square feet (3/8-inch basis)*									
1962	7,994	43	2,404	3,844	930	816	2,540	1,400	895	1,580	225	1,354
1970	13,198	64	3,784	4,328	1,572	3,514	3,680	1,660	1,185	3,130	315	3,228
1976	16,891	77	3,360	4,500	2,105	6,926	4,610	2,190	1,195	4,585	195	4,116
1986	18,239	75	2,650	3,815	1,952	9,822	4,710	3,160	1,510	7,750	245	864

[1]*Includes medium-density fiberboard.*

[2]*Includes upkeep and improvement of nonresidential buildings and structures; made-at-home projects, such as furniture, boats, and picnic tables; made-on-the-job items such as advertising and display structures; and a wide variety of miscellaneous products and uses.*

Note: Estimates for manufacturing and shipping contain hardwood veneer consumed in other than plywood production. Product use by market has been rounded to the nearest 5 million square feet. Data may not add to totals because of rounding.

Table 22.—Nonstructural panel consumption, imports, exports, and production in the United States, specified years 1950–86.

Year	Consumption: Total	Hardwood plywood	Insulating board	Hardboard	Particleboard[1]	Imports: Total	Hardwood plywood	Insulating board	Hardboard	Particleboard[1]
	Billion square feet (3/8-inch basis)									
1950	NA	NA	3.0	0.3	(2)	(2)	(2)	(2)	(2)	(2)
1955	6.5	1.8	4.0	.5	0.1	0.6	0.4	0.1	(2)	(2)
1960	6.5	1.8	3.8	.7	.5	.9	.7	.1	0.1	(2)
1965	10.4	3.1	4.5	1.2	1.6	1.3	1.0	.1	.2	(2)
1970	13.2	3.8	4.3	1.6	3.5	2.3	2.0	.1	.2	(2)
1975	13.9	2.9	3.9	1.7	5.4	2.1	1.9	(2)	.1	(2)
1976	16.9	3.4	4.5	2.1	6.9	2.7	2.4	.1	.2	.1
1977	18.6	3.4	4.6	2.3	8.3	2.9	2.3	.1	.2	.3
1978	20.1	3.6	4.6	2.7	9.1	3.4	2.5	.2	.3	.4
1979	18.8	3.2	4.5	2.7	8.4	3.0	2.1	.2	.3	.4
1980	15.5	2.2	3.8	2.1	7.4	2.0	1.2	.1	.2	.5
1981	14.4	2.4	2.8	2.0	7.2	2.3	1.5	.1	.2	.5
1982	12.6	2.0	2.5	1.9	6.2	1.9	1.1	.2	.2	.5
1983	15.8	2.6	3.2	2.1	7.9	2.8	1.6	.3	.2	.7
1984	17.0	2.4	3.7	2.0	8.9	3.2	1.5	.4	.3	1.1
1985	17.6	2.5	3.9	2.0	9.2	3.7	1.7	.5	.3	1.2
1986	18.2	2.7	3.8	2.0	9.8	3.8	1.9	.5	.3	1.1
	Exports					**Production**				
1950	0.1	(2)	0.1	(2)	(2)	NA	NA	3.1	0.3	(2)
1955	.1	(2)	.1	(2)	(2)	6.0	1.4	4.0	.5	0.1
1960	.1	(2)	(2)	(2)	(2)	6.1	1.1	3.8	.6	.5
1965	.1	(2)	.1	(2)	(2)	9.1	2.0	4.5	1.0	1.6
1970	.2	0.1	.1	(2)	(2)	11.0	1.8	4.3	1.4	3.5
1975	.4	.1	.1	0.1	0.2	12.2	1.1	3.9	1.7	5.5
1976	.4	.1	.1	.1	.2	14.6	1.1	4.5	2.0	7.0
1977	.4	.1	.1	.1	.1	16.1	1.2	4.6	2.2	8.1
1978	.3	(2)	.1	(2)	.1	17.0	1.2	4.6	2.5	8.8
1979	.3	(2)	.1	(2)	.2	16.1	1.2	4.4	2.4	8.1
1980	.4	(2)	.1	(2)	.2	13.8	1.0	3.7	2.0	7.1
1981	.5	(2)	.1	.1	.2	12.6	1.0	2.8	1.9	6.9
1982	.3	(2)	.1	(2)	.1	11.0	.9	2.4	1.8	5.9
1983	.4	(2)	.1	.1	.2	13.3	1.0	3.0	2.0	7.4
1984	.4	(2)	.1	.1	.2	13.5	.9	3.4	1.2	8.0
1985	.4	(2)	.1	.1	.2	14.3	.8	3.5	1.8	8.2
1986	.6	.1	.2	.1	.3	15.0	.8	3.5	1.7	9.0

[1]*Includes medium-density fiberboard.*

[2]*Less than 50 million square feet.*

Note: Data may not add to total because of rounding.

Sources: Hardwood plywood production: USDC BC 1987b; insulating board and hardboard: USDC BC 1987e; particleboard production: USDC BC 1977b; National Particleboard Association 1987; trade: USDC BC 1987d, 1987h.

large and increasing amounts of particleboard and medium-density fiberboard used primarily in furniture production. Most of the remainder in 1986 was used in construction: 26% in new residential construction, 17% in residential upkeep and improvements, and 8% in nonresidential construction.

Exports and Imports

Exports of nonstructural panels totaled 0.6 billion square feet, 3/8-inch basis, in 1986, up from 0.1 billion square feet in 1950, and the peak in a very gradually rising trend over the past three and one-half decades. Total nonstructural panel imports have fluctuated; however, the overall trend has also risen, as increases in particleboard and insulating board offset declines in hardwood plywood.

Production

Production of nonstructural panels totaled 15.0 billion square feet, 3/8-inch basis, in 1986, about 3.2 times output in the early 1950s, but down somewhat from the mid-1970s. Although production of all four products generally rose through the late 1960s and early 1970s, subsequent declines in the output of insulating board, hardboard, and particularly hardwood plywood, more than offset continuing increases in particleboard production. As a result, total production of nonstructural panels in 1986 was nearly 12% below the high reached in 1978.

PULPWOOD CONSUMPTION

More than a fourth of the roundwood timber products and large volumes of byproducts from other primary wood products manufacturing processes are consumed annually in the United States for the manufacture of woodpulp. Most of the woodpulp produced in U.S. mills is used in the production of paper and board products that are consumed in the United States. Thus, the discussion of pulpwood demands in this section begins with trends in paper and board consumption.

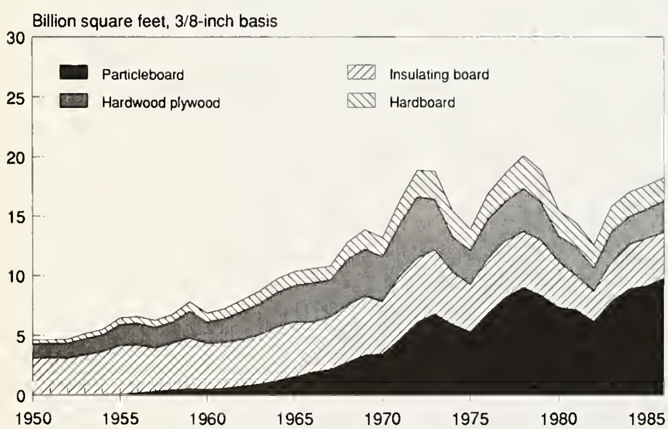


Figure 12.—Nonstructural panels consumption, by type, 1950–1986.

An extremely wide range of paper and board products are consumed in the United States for a variety of purposes, embracing communication, sanitary, packaging and wrapping, construction and industrial uses. In this analysis this large number of products is classified into three major groups: paper, including printing and writing paper, newsprint, packaging and special industrial paper, tissue paper, and construction paper; paperboard, including unbleached kraft paperboard, solid bleached paperboard, semichemical paperboard, recycled paperboard, and wet machine board; and building board, which includes insulating board and hardboard.

Paper and Board Consumption, Trade, and Production

Consumption

Total U.S. paper and board consumption increased to an all time high of 81.7 million tons in 1986 (table 23, McKeever and Jackson 1990: A-6, and fig. 13). The economic recessions in the mid 1970s and the early 1980s severely impacted paper and board consumption. However, with the exception of these two periods, paper and board consumption has increased fairly steadily since 1950, and nearly tripled over the 36 year span. Per capita paper and board consumption followed the same general trends, reaching a record 677 pounds in 1986, about 77% more than average consumption in 1950 and 15% more than in 1976.

Many factors have contributed to the increases in total and per capita consumption of paper and board over the past three and one-half decades. Although increases in population, economic activity, and per capita disposable income have been the major driving forces, the substitution of paper and board for nonpaper products and the development of new products and markets has also been important. Examples of the former include the substitution of paper and paperboard for lumber and plywood in packaging and shipping containers; and of the latter, the development of special paper products for the fast food, convenience food, and computer and copier industries. Consumption likely would have risen more rapidly

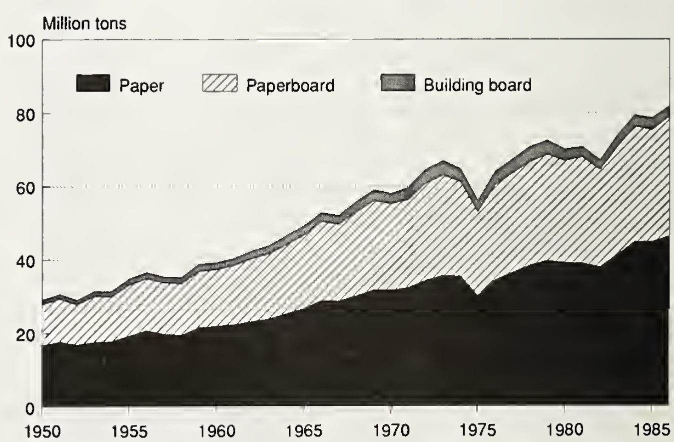


Figure 13.—Paper and board consumption, by type, 1950–1986.

Table 23.—Paper and board consumption, exports, imports, and production in the United States, specified years 1950–86.

Year	Consumption[1] Total	Consumption[1] Per capita[2]	Exports	Imports	Production
	Thousand tons	Pounds		Thousand tons	
1950	29,076	381.9	298	4,999	24,375
1955	34,804	419.5	736	5,382	30,178
1960	39,217	434.1	902	5,674	34,444
1965	49,219	506.6	1,641	6,769	44,091
1970	58,058	566.3	2,698	7,237	53,517
1975	55,955	518.2	2,876	6,309	52,522
1976	63,951	586.6	3,196	7,249	59,897
1977	67,329	611.4	2,953	7,560	62,723
1978	70,732	635.6	2,922	9,318	64,333
1979	72,476	644.1	3,142	9,290	66,329
1980	70,081	615.3	4,611	8,858	65,834
1981	70,779	615.2	4,095	8,434	66,440
1982	67,052	576.8	3,717	8,070	62,699
1983	73,829	628.9	4,045	9,073	68,801
1984	79,343	669.6	3,883	11,127	72,099
1985	78,529	656.3	3,646	11,521	70,654
1986	81,720	676.5	4,222	11,838	74,104

[1]Includes hardboard.
[2]Per capita consumption computed by Forest Service.
Note: Data may not add to totals because of rounding.
Source: Ulrich 1989.

had not paper and board met strong competition from, for example, plastics in grocery bags and in packaging of food and other materials. The increased use of electronic media for data communications and financial transactions has also acted to slow the increases in recent years.

Paper.—U.S. consumption of paper has increased relatively rapidly over the past 36 years, rising from 16.8 million tons in 1950 to a record 46.3 million tons in 1986 (table 24, fig. 13). Per capita paper consumption also grew, expanding from 221 to 384 pounds. With the exception of the economic recession years, total and per capita paper consumption have increased steadily. Since 1950, total consumption has increased at an average annual rate of 2.8%. The growth rate during the 1980s has remained fairly consistent with this long-term average.

More printing and writing paper is consumed in the United States than any other grade of paper, paperboard, or building board. In 1986, almost 22 million tons—nearly half of all paper and more than a quarter of total paper and board was used for printing and writing (McKeever and Jackson 1990: table A-7). Printing and writing has been the fastest growing paper grade during the past decade, largely due to strong demand for office papers and advertising material.

Newsprint is the paper grade used in second largest amounts—14 million tons in 1986. This was about 29% of all paper consumed during the year. U.S. consumption of newsprint increased by just over 75% between 1960 and 1986; however, production rose by more than 200%. As a result, imports currently supply about 62% of total newsprint consumption compared to about 74% 25 years ago.

Tissue papers, and packaging and special industrial papers each accounted for 11% of total paper consumption in 1986. Packaging paper consumption, in contrast to other paper grades, has declined markedly since 1979, largely due to the penetration of plastic products. Construction paper consumption is small compared to other paper grades, and accounted for just 1% of total paper consumption in 1986.

Paperboard.—Paperboard consumption in the United States nearly tripled between 1950 and 1986, increasing from 11.0 million to 32.6 million tons (table 25, fig. 13). Per capita consumption increased from 145 to 270 pounds. With the exception of the economic recession years, total paperboard consumption has increased fairly steadily since 1950 rising at an annual rate of 3.0%, just slightly higher than the 2.8% rate for paper. Since 1976, however, growth in paperboard consumption has dropped to a rate of about 2.1%, while paper consumption, as mentioned earlier, maintained its long-term average rates of growth. One possible explanation for this recent trend is a shift in the economy from manufacturing to services. Many paper products are used largely in the service sectors, while most paperboard grades are associated with manufacturing.

Consumption of unbleached kraft paperboard, used mostly as linerboard facing material for corrugated boxes, totaled 15.6 million tons in 1986, nearly 48% of total paperboard use (McKeever and Jackson 1990: table A-8). Growth in unbleached kraft paperboard consumption be-

Table 24.—Paper consumption, exports, imports, and production in the United States, specified years 1950–86.

Year	Consumption: Total	Consumption: Per capita[1]	Exports	Imports	Production
	Thousand tons	*Pounds*		*Thousand tons*	
1950	16,802	220.7	175	4,913	12,064
1955	19,341	233.1	414	5,273	14,503
1960	21,983	243.3	361	5,534	16,809
1965	26,769	275.5	500	6,508	20,761
1970	31,699	309.2	548	7,027	25,219
1975	30,137	279.1	975	6,190	24,922
1976	34,466	316.2	958	7,041	28,383
1977	36,490	331.4	732	7,274	29,948
1978	38,452	345.5	580	8,863	30,168
1979	39,703	352.8	635	8,890	31,448
1980	39,142	343.7	939	8,549	31,532
1981	39,034	339.2	1,031	8,072	31,994
1982	37,942	326.2	860	7,752	31,050
1983	41,364	352.3	794	8,583	33,576
1984	44,831	378.3	837	10,503	35,166
1985	44,842	374.8	801	10,927	34,716
1986	46,328	383.5	910	11,128	36,110

[1]*Per capita consumption computed by Forest Service.*
Note: Data may not add to totals because of rounding.
Source: Ulrich 1989.

Table 25.—Paperboard consumption, exports, imports, and production in the United States, specified years 1950–86.

Year	Consumption: Total	Consumption: Per capita[1]	Exports	Imports	Production
	Thousand tons	*Pounds*		*Thousand tons*	
1950	11,047	145.1	98	55	11,090
1955	13,796	166.3	295	45	14,045
1960	15,365	170.1	521	35	15,851
1965	19,885	204.7	1,112	18	20,979
1970	23,530	229.5	2,105	19	25,616
1975	22,765	210.8	1,814	12	24,567
1976	25,850	237.1	2,140	20	27,970
1977	27,039	245.5	2,128	32	29,135
1978	28,137	252.8	2,289	102	30,324
1979	28,942	257.2	2,454	85	31,312
1980	27,764	243.8	3,617	100	31,281
1981	28,918	251.4	2,957	132	31,742
1982	26,508	228.0	2,782	117	29,173
1983	29,301	249.6	3,155	171	32,285
1984	31,443	265.3	2,944	245	34,142
1985	30,493	254.9	2,746	187	33,052
1986	32,592	269.8	3,201	285	35,509

[1]*Per capita consumption computed by Forest Service.*
Note: Data may not add to totals because of rounding.
Source: Ulrich 1989.

tween 1960 and 1986 was dramatic. Total consumption more than tripled, and average growth exceeded 4.5% per year. Although somewhat slower in recent years, growth in unbleached paperboard consumption remains well above that for any other paper or board grade. Over the past several decades, the United States has shifted to corrugated containers as the principal types used by its manufacturing industries.

Recycled paperboard is second in total consumption to unbleached kraft among the paperboard grades. In 1986, 7.8 million tons were consumed, half as much as unbleached kraft. Recycled paperboard has a variety of uses, including corrugating medium, folding cartons, and gypsum wallboard facings. Consumption has been fairly constant throughout the years, fluctuating between about 6 and 8 million tons. Use of recycled paperboard, and recycled grades of paper and board, likely could increase in the future as disposal costs and environmental concerns increase.

Semichemical paperboard, used primarily as a corrugating medium, accounts for about 17% of total paperboard consumption; solid bleached paperboard, used for folding cartons and other food and drug packaging for 11%; and wet machine board, which is used for such products as counter board, shoe board, and luggage, less than 1% of total paperboard consumption.

Building board.—Building board consumption rose steadily between 1950 and the early 1970s, declined during the mid-1970s recession, and then peaked at 4.1 million tons in 1978 (table 26, fig. 13). Following the construction downturn in the early 1980s, consumption increased slightly to 2.8 million tons in 1986.

Hardboard is the larger of the two building board grades, accounting for about two-thirds of total consumption in 1986. Hardboard consumption generally increased through the 1960s and 1970s, rising to nearly 2.7 million tons in 1978 (McKeever and Jackson 1990: table A-9). Consumption then dropped by about 20% in 1980, and has since remained constant.

Consumption of insulating board, which includes wallboard, exterior sheathing, and acoustical tiles, reached its highest levels in the early 1970s. Thereafter, use dropped and the declines in housing construction in the early 1980s, coupled with the increased use of foamed plastic exterior sheathing, reduced insulating board use to 0.8 million tons by 1982. Consumption increased somewhat in 1983–86 to about 1.0 million tons.

Imports and Exports

The United States has long imported larger volumes of paper and board than it has exported. In 1986, imports amounted to 11.8 million tons, 2.8 times the 4.2 million tons exported (table 23). Although the volume of imports has grown, U.S. dependency on imports has declined over the years. Currently, the U.S. imports a smaller proportion—14% in 1986—of its paper and board consumption than in 1950—17%. About 5% of total production was exported in 1986 in contrast to about 1% in 1950.

The United States is a net importer of paper, principally newsprint and, more recently, printing and writing paper. In 1986, an estimated 11.8 million tons of paper were imported, compared to just over 0.9 million tons exported (table 24). Most of the paper imported each year comes from Canada.

Unlike the situation for paper, the U.S. exports more paperboard than it imports. Exports of paperboard totaled more than 3.2 million tons in 1986 (table 25). Unbleached kraft paperboard, which accounts for about

Table 26.—Building board[1] consumption, exports, imports, and production in the United States, specified years 1950–86.

Year	Consumption		Exports	Imports	Production
	Total	Per capita[2]			
	Thousand tons	*Pounds*		*Thousand tons*	
1950	1,227	16.1	25	31	1,221
1955	1,667	20.1	27	64	1,630
1960	1,869	20.7	20	105	1,784
1965	2,565	26.4	29	243	2,351
1970	2,829	27.6	45	191	2,682
1975	3,053	28.3	87	107	3,033
1976	3,635	33.3	98	188	3,544
1977	3,800	34.5	93	254	3,640
1978	4,143	37.2	53	353	3,841
1979	3,831	34.0	53	315	3,569
1980	3,176	27.9	55	210	3,021
1981	2,828	24.6	107	230	2,704
1982	2,602	22.4	75	201	2,476
1983	3,164	27.0	95	319	2,940
1984	3,069	25.9	101	379	2,791
1985	3,194	26.7	99	407	2,886
1986	2,799	23.2	111	426	2,485

[1]*Hardboard and insulating board.*
[2]*Per capita consumption computed by Forest Service.*
Note: Data may not add to totals because of rounding.
Source: Ulrich 1989.

two-thirds of the total, and solid bleached board are the two grades exported in greatest amounts (McKeever and Jackson 1990: table A-8). In recent years, paperboard imports have begun to increase; however, they were still less than 10% as large as exports in 1986, reaching about 0.3 million tons.

The United States is a net importer of building board products with imports exceeding exports by 0.3 million tons in 1986 (table 26). Net imports account for less than 10% of total U.S. building board consumption.

Production

Total paper and board production reached an all-time high of 74.1 million tons in 1986 (table 23). With the exception of the recessions in the mid-1970s and early 1980s, paper and board production have increased steadily, rising more than three-fold over the 36 year period since 1950.

Production of both paper and paperboard were at record levels in 1986 at 36.1 and 35.5 million tons, respectively (tables 24 and 25); however, building board production totaled just 2.5 million tons in 1986, down from peak production in the early 1970s (table 26).

Woodpulp Consumption, Trade, and Production

Consumption

The 74.1 million tons of paper and board produced in 1986 required 75.9 million tons of fiber to produce, including 60.0 million tons of woodpulp, 15.5 million tons of wastepaper, and 0.4 million tons of other fibers such as cotton linter, kenaf, bagasse, fiber glass, rag, etc. (table 27, fig. 14). The trends in consumption of all fibrous material has closely paralleled trends in paper and board production, increasing almost 3 times between 1950 and 1986.

In 1950, about 64% of all fiber consumed was woodpulp; 31% recycled wastepaper, and nearly 6% other fibers. During the 1950s and 1960s, trends began to shift toward increased use of woodpulp, with consequent reductions in wastepaper and other fiber use. During the 1970s, woodpulp reached about 79% of total consumption, and with some slight fluctuation has remained at about that level. Wastepaper consumption fell to about 19% before increasing to about 20% in the 1980s, while other fiber dropped to less than 1%. These proportions could change in the future as increased amounts of wastepaper are made available through mandatory municipal recycling programs, and new technologies to more effectively sort, clean, and transport waste paper. Nonwood fiber is now used primarily for high-quality writing paper, and for specialty industrial and packaging papers.

Wastepaper use varies considerably by grade of paper and board. Among the paper grades, tissue and newsprint use the greatest amount of recycled fiber, and have exhibited the largest increases in recycled fiber use

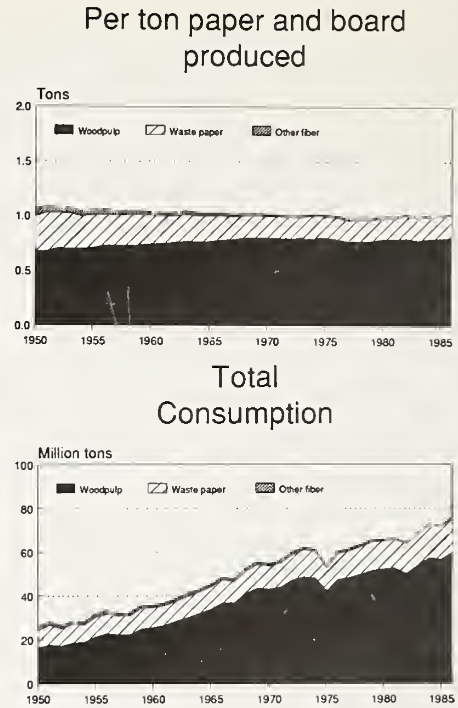


Figure 14.—Fiber consumed in paper and board, by type, 1950–1986.

over the past two decades. Recycled paperboard, and some construction board grades also use large amounts of recycled fiber.

A dramatic development during the past decade has been the large increase in exports of wastepaper. Exports rose from 0.4 million tons in 1970 to 3.7 million tons in 1986 (American Paper Institute 1987a). Much of this increase is attributable to a more rapid adoption of technologies in Europe and Japan which allow greater use of recycled fiber. Wastepaper utilization rates in excess of 50% in Japan partially reflect the adoption of these technologies.

Total apparent consumption of woodpulp in the manufacture of both paper and board and nonpaper products in the United States in 1986 totaled 60.7 million tons (table 28).[5] This was a record volume, some 25% above consumption in 1976, and nearly 3.6 times more than in 1950 (McKeever Jackson 1990: table A-11).

Woodpulp use per ton of paper and board.—Fiber consumption per ton of paper and board produced declined very slowly through the 1950 to mid-1970s period. Since then, use has remained fairly constant, averaging about 1.02 tons (table 27, fig. 14).

While total fiber use per ton of paper and board produced has varied little in recent years, the mix of fiber types has changed markedly. During the 1950s and 1960s, woodpulp use per ton of paper and board produced increased from 0.68 tons to 0.81 tons (McKeever

[5]The woodpulp consumption data shown in tables 27 and 28 differ because those in table 28 are "apparent consumption" (production plus imports minus exports) for paper and board and for nonpaper products such as rayon, cellulose acetate, plastics, and molded pulp products, while those shown in table 27 are "actual consumption" (contain allowances for inventory changes) only in paper and board production. In the early 1980s, about 800 million tons of woodpulp were used for nonpaper products. More current data are not available.

Table 27.—Paper and board production, and fibrous material used, total and per ton of product in the United States, specified years 1950–86.

Year	Paper and board production	Fiber consumption in paper and board production				Fiber consumption per ton of paper and board produced			
		Total	Wood-pulp	Waste paper	Other	Total	Wood-pulp	Waste paper	Other
		Thousand tons				*Tons*			
1950	24,375	25,904	16,509	7,956	1,439	1.062	0.677	0.326	0.059
1955	30,178	31,835	21,454	9,041	1,340	1.056	.711	.300	.045
1960	34,444	35,703	25,700	9,032	971	1.036	.746	.262	.028
1965	44,091	45,116	34,006	10,231	879	1.023	.771	.232	.020
1970	53,516	54,614	43,192	10,594	828	1.021	.807	.198	.015
1975	52,521	53,422	42,431	10,367	625	1.017	.808	.197	.012
1976	59,898	60,156	47,541	11,874	742	1.004	.794	.198	.012
1977	62,722	61,406	48,477	12,103	826	.979	.773	.193	.013
1978	64,333	63,273	49,834	12,586	854	.984	.775	.196	.013
1979	66,329	65,316	51,577	13,012	727	.985	.778	.196	.011
1980	65,834	65,633	52,448	12,583	602	.997	.797	.191	.009
1981	66,440	66,161	52,779	12,872	510	.996	.794	.194	.008
1982	62,699	64,145	50,187	13,563	396	1.023	.800	.216	.006
1983	68,801	68,554	53,970	14,170	413	.996	.784	.206	.006
1984	72,099	72,848	57,466	14,944	438	1.010	.797	.207	.006
1985	70,654	71,757	56,639	14,818	301	1.016	.802	.210	.004
1986	74,104	75,940	60,049	15,491	400	1.025	.810	.209	.005

Note: Data may not add to totals because of rounding.
Source: Ulrich 1989.

Table 28.—Woodpulp consumption, exports, imports and production in the United States, specified years 1950–86.

Year	Consumption		Exports	Imports	Production
	Total	Per capita[1]			
	Thousand tons	*Pounds*	*Thousand tons*		
1950	17,138	225	96	2,385	14,849
1955	22,323	269	631	2,214	20,740
1960	26,563	294	1,142	2,389	25,316
1965	35,721	368	1,402	3,130	33,993
1970	43,969	429	3,095	3,518	43,546
1975	43,380	402	2,782	3,078	43,084
1976	48,930	449	2,518	3,727	47,721
1977	50,363	457	2,640	3,871	49,132
1978	51,443	462	2,599	4,023	50,020
1979	52,559	467	2,935	4,318	51,177
1980	53,204	467	3,806	4,051	52,958
1981	53,199	462	3,678	4,087	52,790
1982	51,247	441	3,395	3,656	50,986
1983	54,505	464	3,644	4,093	54,055
1984	58,644	495	3,594	4,490	57,747
1985	58,364	488	3,796	4,466	57,693
1986	60,697	503	4,459	4,594	60,562

[1]*Per capita consumption computed by Forest Service.*
Note: Data may not add to totals because of rounding.
Source: Ulrich 1989.

and Jackson 1990: table A-10), but then leveled off at about 0.80 tons. As woodpulp use per ton was increasing, recycled wood fiber use was declining to a low of 0.191 tons per ton of paper and board in 1980. There has been a slight increase since that time.

Imports and Exports

Woodpulp imports totaled 4.6 million tons in 1986, exports, 4.5 million tons (table 28). Exports of woodpulp have increased much more rapidly than imports over the past three and one-half decades. As a result, the United States currently imports about 8% of its woodpulp consumption compared with 14% in 1950. Conversely, U.S. exports of woodpulp amounted to 7% of production in 1986 compared to less than 1% in 1950.

Production

Since 1950, woodpulp production has more than quadrupled. In 1986, U.S. pulpmills produced 60.6 million tons of woodpulp (table 28). Nearly 75% of all woodpulp produced was sulfate (kraft) pulp. Sulfate pulp is used to produce various printing and writing papers, packaging papers, and linerboard. During the past 26 years, sulfate production increased steadily, primarily at the expense of sulfite, soda, and other chemical pulp types. In 1986, sulfite accounted for just 3% of total production, compared to an estimated 12% in 1960.

In recent years, a gradual substitution of mechanical pulps for sulfite and other chemical pulps, especially in the production of newsprint and printing and writing papers, has occurred. Mechanical pulpmills require much lower capital investment per ton of product output than chemical pulpmills, and can be built economically with smaller capacity because of smaller economies of scale. In 1986, mechanical woodpulps made up 9% of total production.

Most woodpulp is produced in mills integrated with a paper and/or board mill. However, in 1986, about 7.6 million tons of market pulp (usually from nonintegrated facilities) were produced. Of this total—about 12% of all woodpulp production—3.1 million were sold to domestic paper and board producers and 4.5 million were exported (American Paper Institute 1987a). Woodpulp exports are mostly bleached sulfate.

Pulpwood Consumption, Trade, and Production

Consumption

Trends in pulpwood consumption in the United States closely follow trends in woodpulp production. In 1986, 92.1 million cords of pulpwood were consumed in U.S. mills (table 29, fig. 15).[6] This includes roundwood pulpwood, chips from logging and mill residues, and whole-

[6] *The pulpwood consumption data shown in tables 29 and 30 differ because those shown in table 29 are "apparent consumption" (production plus imports minus exports), while those in table 30 are "actual consumption" (contain allowances for inventory changes).*

Table 29,—Pulpwood consumption, exports, imports, and production, specified years 1950–86.

				Production				
					Roundwood			
Year	Consumption	Exports	Imports	Total	Total	Softwoods	Hardwoods	Chips[1]
				Thousand cords				
1950	22,100	25	1,410	20,715	19,465	16,680	2,785	1,250
1955	32,655	60	1,765	30,950	28,600	23,365	5,235	2,350
1960	41,170	160	1,320	40,010	33,465	25,450	8,015	6,545
1965	53,470	155	1,305	52,320	40,290	29,250	11,040	12,030
1970	69,620	1,965	1,120	70,460	50,220	36,660	13,560	20,240
1975	67,165	2,645	765	69,040	44,280	31,660	12,610	24,760
1976	75,255	3,270	1,115	77,410	47,650	32,970	14,680	29,760
1977	77,745	3,370	1,350	79,760	45,800	31,100	14,700	33,970
1978	78,700	3,055	1,675	80,080	47,130	30,900	16,230	32,950
1979	83,815	3,790	1,405	86,200	51,550	34,810	16,740	34,650
1980	86,490	3,700	1,590	88,600	54,940	37,810	17,120	33,660
1981	83,780	2,955	1,490	85,250	51,800	35,160	16,640	33,450
1982	80,780	2,355	1,405	81,730	50,010	33,350	16,660	31,720
1983	87,195	2,040	1,715	87,520	52,410	32,970	19,440	35,110
1984	91,450	1,920	1,825	91,540	54,750	34,740	20,010	36,790
1985	86,120	1,870	650	87,340	52,360	33,050	19,310	34,980
1986	92,060	1,945	630	93,380	57,130	35,290	21,840	36,250

[1] *Roundwood equivalent. Includes whole tree chips, and chips provided from primary processing plant byproducts, such as slabs, edgings, and veneer cores, and chips from logging residues.*
Note: Data may not add to totals because of rounding.
Source: Ulrich 1989.

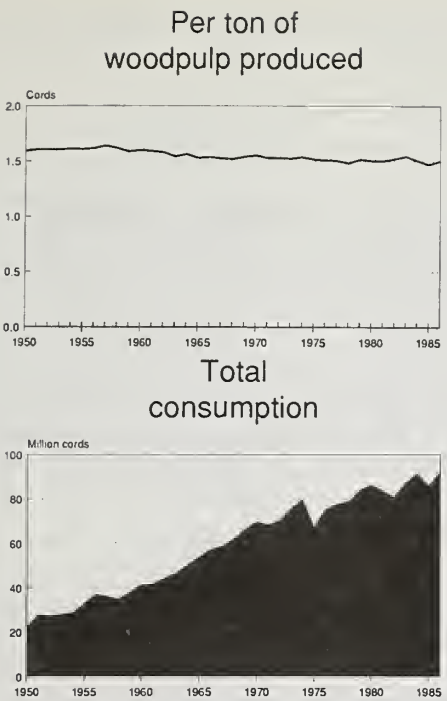


Figure 15.—Pulpwood consumption, 1950–1986.

Table 30.—Pulpwood consumed in the manufacture of woodpulp in the United States, specified years 1950–86.

Year	Consumption: Total	Consumption: Per ton of woodpulp	Woodpulp production
	Thousand cords	*Cords/ton*	*Thousand tons*
1950	23,627	1.591	14,849
1955	33,356	1.608	20,740
1960	40,485	1.599	25,316
1965	51,970	1.529	33,993
1970	67,562	1.552	43,546
1975	65,421	1.518	43,084
1976	72,011	1.509	47,721
1977	73,935	1.505	49,132
1978	74,170	1.483	50,020
1979	77,595	1.516	51,177
1980	79,703	1.505	52,958
1981	79,350	1.503	52,790
1982	77,573	1.521	50,986
1983	83,493	1.545	54,055
1984	86,948	1.506	57,747
1985	84,840	1.471	57,693
1986	90,083	1.500	60,562

Source: Ulrich 1989.

tree chips. Except for the recession years of the 1970s and 1980s, pulpwood consumption increased fairly steadily between 1950 and 1986, rising more than 4 times (McKeever and Jackson 1990: table A-12).

Softwoods have long been the preferred species group for many pulp and paper products. Their relatively long, more flexible fibers result in higher interfiber bonding resulting in paper and board products with superior strength properties compared to those produced from hardwoods (USDA FS 1982). In recent years, however, the use of hardwoods has increased dramatically. In 1950, less than 15% of the pulpwood consumed in U.S. mills was hardwood; but by 1986 hardwoods composed more than 31%. This increase, in part, is due to relatively lower-cost hardwoods in some areas; improvements in pulping and papermaking technology; and the realization that, where strength is not a critical factor, the shorter hardwood fibers can improve the quality of some grades of paper and paperboard. For example, semichemical paperboard, used for corrugating medium, and tissue paper use larger proportions of hardwood fibers than packaging and special industrial papers and unbleached kraft linerboard. Printing and writing papers have been using increasing amounts of hardwood fiber in recent years to improve printability, smoothness, and opacity (Ince 1986). Adoption of the press-drying process, which permits the use of the shorter hardwood fibers in a broad range of products, could further increase hardwood pulpwood consumption in the future (Setterholm and Ince 1980, Ince 1981).

Pulpwood use per ton of woodpulp produced.—Pulpwood consumption per ton of woodpulp produced has been slowly declining, with some fluctuation, since the early 1950s (table 30, McKeever and Jackson 1990: A-13, and fig. 15). In 1986, about 1.5 cords per ton were required, down from 1.6 cords in 1950. One reason for the decline has been a shift from the sulfite and soda pulping processes to higher yielding sulfate, semichemical, and, more recently, high-yield mechanical processes. Other reasons include increased use of higher yielding hardwoods and better fiber recovery. Offsetting these technological shifts, to some extent, has been an increase in the production of semi-bleached and bleached grades of pulp which require more fiber to produce than unbleached grades.

Imports and Exports

Prior to the late 1960s, the United States was a net importer of pulpwood. Since then, exports—largely composed of chip shipments to Japan from the West Coast and more recently to Scandinavia from the South—have exceeded imports. Imports and exports of pulpwood are small compared to domestic production and consumption. Just 1.9 million cords of pulpwood were exported in 1986, compared to 0.6 million cords imported. Most imports came from Canada (American Paper Institute 1987a).

Production

Domestic production of pulpwood in the United States has increased rapidly over the past three and one-half decades, rising from 20.7 million cords in 1950 to 93.4 million in 1986 (fig. 16). The pulpwood produced in the United States comes from three principal sources—

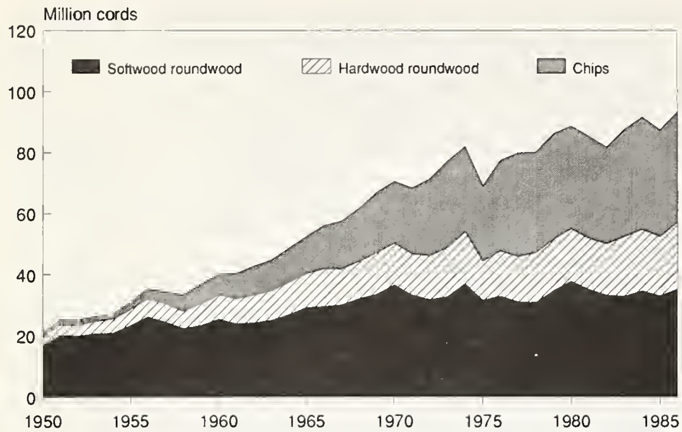


Figure 16.—Pulpwood production, by type, 1950–1986.

roundwood; plant byproducts such as slabs, edgings, veneer cores, sawdust, and other materials; and logging residues and whole-tree chips. Currently available data on chip production do not distinguish between chips from byproducts and from whole-tree and other sources.

Roundwood.—In 1986, pulpwood production from domestic roundwood totaled 57.1 million cords, the high in a trend that has generally been rising since early in the century. About 35.3 million cords were softwood species and 21.8 million hardwoods. Although softwoods predominate, their proportion of the total has been declining over the past 35 years. In 1986, 62% of total roundwood production was softwoods, down from 86% in 1950. As discussed earlier, a combination of technological, cost, and supply factors have been responsible for the increasing proportion of hardwoods consumed in U.S. mills over the past several decades.

Chips.—Production of chips for pulpwood has increased much more rapidly than the consumption of roundwood in recent years, rising from 1.3 million cords in 1950 to 36.3 million in 1986. Over this period, the proportion of pulpwood produced from chips increased from about 6% to almost 39%. Because the volumes of timber products produced from softwood species are far larger than the volumes of those produced from hardwoods, most of the plant byproducts available, and used, are softwoods. Consequently, the proportion of softwood roundwood cut for pulpwood is somewhat smaller than the proportion of softwoods (roundwood and chips) used in domestic mills.

MISCELLANEOUS INDUSTRIAL TIMBER PRODUCTS CONSUMPTION

As shown in table 31, a variety of other industrial roundwood products is consumed in the United States each year in addition to the solid-wood and pulp-based products discussed earlier in this chapter. Total consumption of these products amounted to 473.3 million cubic feet in 1986. This was somewhat above the levels in the 1960s and 1970s, but still below the 1950s and especially the early 1900s when consumption exceeded 2 billion cubic feet per year. About 54% of the total was from softwood species. International trade in these products is relatively small and consumption has been roughly equal to production.

Poles and Piling

Combined use of wood poles for the construction and maintenance of utility lines and other structures and of piling for the construction of docks, bridges, and buildings has been relatively stable over the past 35 years. Total consumption in 1986 was 95.8 million cubic feet, down about 18% from use in 1976, but up about 2% from 1970. Nearly all of the poles and piling consumed in 1986 were manufactured from softwood species and more than 80% of the total came from forests in the South—and principally the South Central Region.

Posts

Use of round and split posts for farm fencing and other purposes such as highway barricades and residential property enclosures has declined sharply over the past three and one-half decades, dropping from 194.1 million cubic feet in 1952 to 40.0 million in 1986. This was a continuation of the trend that has been ongoing since the early 1920s, when consumption exceeded an estimated 1 billion cubic feet. This decline has resulted from a number of factors, including substitution of steel posts, increased use of preservative-treated wood posts thereby lengthening useful post life, and changes in farm size and farming methods that involve less use of fencing.

More than 80% of the posts consumed in 1986 were softwoods—a reversal of the situation in 1952 when hardwoods were most important. The shift away from hardwoods, which are generally more durable than softwoods but less easily cut and shaped, has resulted from increased use of preservative-treated softwood posts. The South accounted for about 47% of the posts produced in 1986; about two-thirds of these came from the South Central Region.

Mine Timbers

Consumption of round and split timbers in mines has also fallen since the early 1950s, dropping from about 81.0 million cubic feet in 1952 to 19.3 million in 1986. In 1986, about 91% of these were hardwoods and all from eastern forests. The most important producing region was the Northeast, which accounted for about 64% of all production in 1986.

Cooperage

Cooperage logs and bolts used for the manufacture of barrels, kegs, pails and tubs made of wood staves has been declining since early in this century as a result of changing consumer buying habits and competition from plastics, wood-based fiber containers, and other pack-

Table 31.—Miscellaneous industrial timber products consumption in the United States, by product and species group, specified years 1952–1986.

Product	1952	1962	1970	1976	1986
			Thousand cubic feet		
Poles and piling					
Softwoods	112,938	116,900	93,114	115,268	95,335
Hardwoods	2,698	3,153	1,095	1,416	415
Total	115,636	120,053	94,209	116,684	95,750
Posts					
Softwoods	68,993	48,803	39,868	35,310	32,453
Hardwoods	125,087	62,118	28,110	10,268	7,595
Total	194,080	110,921	67,978	45,578	40,048
Mine timbers					
Softwoods	18,508	8,062	8,794	5,955	1,815
Hardwoods	62,452	40,312	23,294	17,662	17,528
Total	80,960	48,374	32,088	23,617	19,343
Cooperage					
Softwoods	26,420	3,495	2,136	1,008	50
Hardwoods	46,527	24,961	28,955	13,587	9,739
Total	72,947	28,456	31,091	14,595	9,789
Other products[1]					
Softwoods	99,458	61,457	85,444	80,848	124,744
Hardwoods	135,705	96,142	113,209	96,179	183,583
Total	235,163	157,599	198,653	177,027	308,327
All products					
Softwoods	326,317	238,717	229,356	238,389	254,397
Hardwoods	372,469	226,686	194,663	139,112	218,860
Total	698,786	465,403	424,019	377,501	473,257

[1]Includes roundwood used in the manufacture of particleboard and OSB/waferboard; charcoal wood; bolts used for shingles, wood turnings, and handles; poles and rails used in fencing; and other miscellaneous items such as hop poles, and wood used for chemicals.

aging and shipping materials. In 1986, total consumption of cooperage logs and bolts amounted to 9.8 million cubic feet, down from 72.9 million in 1952 and more than 350 million cubic feet in the early 1900s.

More than 99% of the cooperage logs and bolts consumed in 1986 were hardwoods, and most was used for the manufacture of tight cooperage for the bourbon industry. Nearly all of this material—more than 99%—came from eastern U.S. forests. The North Central Region, with about 64% of the total, was the leading producing region.

Other Industrial Timber Products

Consumption of wood for a wide variety of products such as particleboard, oriented strand board, waferboard, charcoal, shingles, wood turnings, and other miscellaneous products amounted to about 308.3 million cubic feet of roundwood in 1986. This was 74% more than in 1976, and the largest volume used for these products in more than 35 years. Although definitive data are not available, most of the increase since 1976 was probably due to the rising use of roundwood for the production of oriented strand board and waferboard.

About 60% of the other industrial timber products were hardwood species, and 75% of the hardwoods were from the North Central Region. Output of softwood species was evenly divided between the East and the West. The Rocky Mountain Region was the largest producer of softwood used for these products.

SILVICHEMICALS CONSUMPTION

Many chemicals and chemical compounds are derived from wood and its byproducts. These chemicals include, but are not limited to, naval stores products such as rosin, turpentine and fatty acids, and byproducts from pulping liquors, such as lignin derivatives, ethyl alcohol, vanillin and acetic acid. In 1982, shipments of all such products were valued at $762 million dollars (USDC BC 1985).

Rosin and turpentine are the two major chemicals derived from wood. Rosin is used for sizing paper to control water absorptivity and in the production of synthetic resins and adhesives. Turpentine, once used mainly as a paint solvent, is now used as a chemical raw material to produce synthetic pine oils, and polyterpene resins used in transparent tape adhesives.

Historically, naval stores were derived from oleoresin (gum) collected from southern pine trees, and extractives from shredded and processed pine stumps. In 1940, all the rosin and 91% of the turpentine came from these sources (Slatin 1986). However, development of the sulfate (kraft) pulping process, for which naval stores are a byproduct, provided an alternative source. The rapid growth in sulfate pulp production after World War II greatly diminished the use of collected oleoresins and pine stump extractives for naval stores production. By 1985, 82% of all rosin, and 95% of all turpentine came from sulfate pulping, with total rosin production being estimated at 262 thousand short tons, and total turpentine production being estimated at 22.2 million gallons (Naval Stores Review 1987).

Fatty acids are also derived from the sulfate pulping process through distillation of crude tall oil. They are used as intermediate chemicals in the production of resins for inks, adhesives and coatings, and also used in paints, varnishes, soaps and detergents. Production in 1986 was estimated at 215,000 tons, 5,000 tons greater than in 1985 (Naval Stores Review 1987).

Other byproducts of chemical pulping processes (sulfate and sulfite), derived from spent pulping liquors, include various lignin derivatives, ethyl alcohol, acetic acid, and vanillin. Shipments in 1982 were estimated to be 1.1 million tons, and valued at $85.7 million (USDC BC 1985). Lignin derivatives make up the majority of these products, and are used as drilling thinners in oil wells, in adhesives and dispersants, and for water treatment.

FUELWOOD CONSUMPTION

In 1986, the United States produced about 76.6 quads (quadrillion BTU's) of energy. Of this total, an estimated 2.65 quads, or 3.5%, came from wood-derived fuels (table 32). This was up from 2.1% in 1970 and 2.8% in 1980 (USDE 1985c).

Wood used for fuel comes from many sources. In 1986, about 3.1 billion cubic feet (39 million cords)—17% of the estimated 18 billion cubic feet of roundwood timber harvested in the United States—was used for fuelwood (table 33, fig. 17). This was the largest volume harvested for fuelwood since before World War II, and more than 6 times production in 1970. Most of the round fuelwood harvested was consumed by households, with limited amounts used by industry, commercial buildings, and utilities. In addition, it came mainly from sources not traditionally used to produce lumber, panel products, and woodpulp. For example, less than 0.8 billion cubic feet was from the main stem portions of growing stock trees on timberland, while more than 2.3 billion was from other roundwood sources.[7] In total, fuelwood accounted for less than 6% of all growing stock timber harvested in 1986.

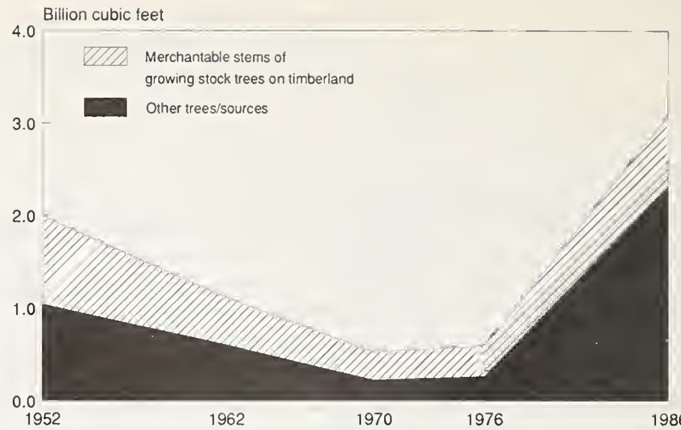


Figure 17.—Roundwood fuelwood harvest, by source, specified years, 1952–1986.

Table 32.—Wood and black liquor fuel consumption in the United States, specified years 1977–1986.

Sector	1977	1980	1983	1984	1986
			Quad[1]		
Wood fuel[2]			1.92		
Black liquor	.81	.82	.82	.85	.90
Total			2.74		
Department of Energy total	1.55		2.48		2.65

[1]One quad equals 10^{15} BTU's.
[2]Assumes 17.2 million BTU's per ton of wood.
Sources: Wood fuel and black liquor: see source note table 33; Department of Energy total: USDE 1985c, USDE 1988.

Wood and wood fiber is also consumed for fuel after it has been removed from the forest for other purposes. In 1986, 1.4 billion cubic feet, solid-wood equivalent, of sawdust, slabs, chips, veneer clippings, and similar materials from primary wood products mills were burned (table 33). In addition, 17.8 million dry tons of bark from these sources were used for fuel (Waddell et al. 1989: table 31). The proportion of all primary wood residues and bark that are used for fuel is estimated to have increased from 25% in 1970 (Grantham and Howard 1980) to 41% in 1986. Secondary wood products plants provided a smaller, but unknown, amount of fuel, and pulp and paper mills burned an estimated 79.8 million tons (0.9 x 10^5 BTU equivalent) of spent liquor for process steam, heat, and electricity (American Paper Institute 1987b). Discarded wood products, such as demolition waste, are also used for fuel; an estimated 7 million households acquired such material for burning in 1980–81 (Skog and Watterson 1986).

Uses of Fuelwood

As noted earlier, roundwood has long been used by households for heating, cooking, and more recently in fireplaces for esthetic purposes. However, increasing amounts are being chipped and burned in nonforest products plants and electric utilities. Data for 1983 shows the distribution of roundwood and residue consumption by major end user (table 34). Households account for 54% while the forest products industry accounts for 42% of the total. Nonwood products plants,

[7]Other roundwood sources on timberland are rough, rotten, or salvable dead trees, trees of noncommercial species, trees less than 5 inches dbh, and tree limbs and tops. Roundwood also comes from trees on woodlands where growth is less than 20 cubic feet per acre per year, and trees on nonforest lands which includes rural fence rows and all urban trees.

Table 33.—Wood energy production and consumption in the United States, by wood source and end user, specified years 1952–86.

Sector	1952	1962	1970	1976	1980	1981	1983	1984	1986
	Million cubic feet								
Production of roundwood fuelwood for all users									
Merchantable stem of growing stock trees on timberland	965	517	311	334					798
Other trees/sources	1,042	606	227	267					2,316
Total	2,008	1,123	538	601					3,114
Consumption of roundwood and mill residue in homes									
Merchantable stem of growing stock trees on timberland[1,2]					559				
Other trees/sources and logging residue[1,2]					2,544				
Mill residue[1,2]					223				
Total[1]					3,326	3,406		3,881	3,382
Mill residue use for fuel									
Wood residue (excludes bark)	2,486	900	727	752					1,400

[1]*Volume in cords times 79.2 cu. ft. per cord.*
[2]*Mill residue fraction in 1980 is 3.0/44.8, growing stock fraction of remainder is 18% (Skog and Watterson 1986).*
Sources: Production: 1952—USDA FS 1958; 1962—USDA FS 1965; 1970—USDA FS 1973; 1976—USDA FS 1982. Consumption: 1980—Skog and Watterson 1986; 1981—USDE EIA 1984; 1984—USDE EIA 1986.

Table 34.—Roundwood, and wood and bark residue consumption in the United States, by end user, specified years 1977–86.

Sector	1977	1980	1983	1984	1986
	Million cubic feet[1]				
Residential		3,326	3,722	3,881	
Wood products industry			1,650		
Pulp and paper industry					
Hog wood	311	433	783	828	923
Bark	320	366	418	432	469
Nonforest products industry			184		
Commercial buildings			80		
Utilities			9		
Total			6,846		

[1]*Assumes 32.6 pounds of wood per cubic foot.*
Sources: Residential: see source note table 33; wood products industry: Goetzl and Tatum 1983; pulp and paper industry: American Paper Institute 1987b; nonforest products industry, commercial buildings, and utilities: USDE EIA 1984.

nonresidential buildings, and electric utilities account for 4% of the total.

Residential

Residential fuelwood use, which had been declining for many years, began to rise after 1973 as the price of electricity, fuel oil, and natural gas increased (fig. 18; USDE 1985d, 1987). Studies show that between 1950 and 1973, the estimated number of wood-burning stoves in U.S. homes dropped from 7.3 million to 2.6 millon units. In the late 1970s, however, stove shipments increased by 1.0–2.5 million units per year and the inventory grew to an estimated 11 million in 1981 (USDE 1982). Other estimates indicate as many as 14 million stoves and fireplace inserts in homes in 1981 (Skog and Watterson 1986). These trends in wood-burning stove inventories suggest a four-fold rise in residential fuelwood use during the 1970s and early 1980s.

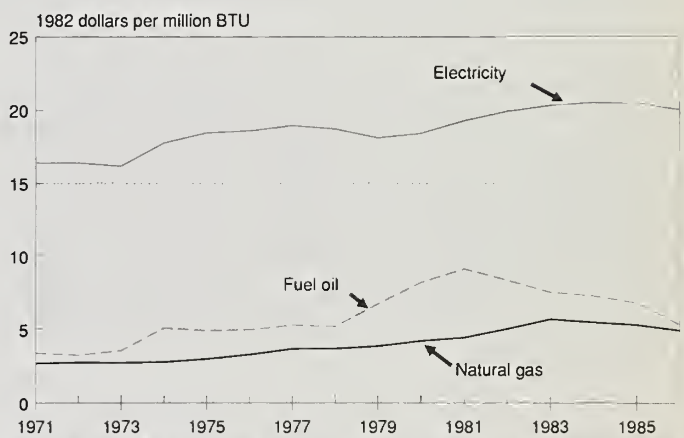


Figure 18.—Residential electricity, fuel oil, and natural gas prices, 1971–1986.

Surveys of consumers indicate that residential fuelwood use had increased to 3.3 billion cubic feet by

1980–81 and that it increased further to a peak of 3.9 billion in 1984, but subsequently declined to 3.4 billion in 1986. Similar trends were shown by fuelwood harvests—largely for residential use—from the national forests, which increased sharply to 5.1 million cords in 1982, before dropping to 2.1 million in 1986 (Paulson 1987). These trends largely paralleled the rise in the real prices of electricity, fuel oil, and natural gas and their declines in the mid-1980s (fig. 18, USDE 1987).

In the early 1980s, 28% of all U.S. households burned wood, averaging 1.8 cords each. However, wood use was much more common in rural areas. For example, 45% of all rural households burned wood and average annual use was 2.7 cords, whereas only 23% of urban households, many using fireplaces, burned 1.4 cords each (Skog and Watterson 1986). By 1984, about 27% of all households, rural and urban, are estimated to have used wood as a primary or secondary heating fuel (not including some esthetic fireplace use) for an average of 2.1 cords (USDE 1986).

Although households use both roundwood and mill residue for fuelwood, roundwood accounts for more than 90% of the total; and about three-fourths of all roundwood consumed by households is cut by household members (Skog and Watterson 1986). About one-fourth of all roundwood cut by households came from merchantable stem portions of growing stock trees on timberland. The remainder was from other sources including dead trees, cull trees, noncommercial species, or from nonforest lands, such as fence rows and urban tree trimming. In 1986, 82% of the roundwood harvested for fuelwood was hardwood species (Waddell et al. 1989: table 30).

The 3.3 billion cubic feet of fuelwood burned by households during the 1980–81 heating season contributed 0.8 quads of gross energy or about 9% of the total gross energy of all nonwood fuels used. The average efficiency of converting fuelwood to heat in stoves and fireplaces, however, is less than half the heat-conversion efficiency for electricity, fuel oil, and natural gas—30% versus more than 60%. As a consequence, the actual residential fossil fuel displaced by fuelwood was only 2 to 3% of the total used (Skog and Watterson 1986).

Industrial

Almost all of the 1.4 billion cubic feet (20.7 million bone dry tons) of wood residue (table 33) and the 17.6 million tons of bark from primary wood processing plants that was used for fuel in 1986 was burned to make steam, heat, or electricity in wood products mills and to a lesser extent, by nonforest products industries and commercial buildings. And the use of primary processing residues has been rising in recent years. For example, in 1970 about 25% of all primary wood and bark residues was used for fuel (Grantham and Howard 1980); by 1986, 41% of the total was used (Waddell et al. 1989: table 31). This increase may, in part, be due to the effects of the Public Utilities Act of 1978 which encourages businesses to generate and sell excess electricity made from renewable resources to electric utilities.[8]

The use of wood and bark residue for energy by the solid-wood products industries grew fairly rapidly during the 1970s, rising from 19.4 million oven dry tons in 1970 to 26.9 million in 1981 (Goetzl and Tatum 1983). In addition, during the latter year a small amount of roundwood—13,700 tons—was used for space heating. By 1981, 70% of the solid-wood products industries' total energy requirements were obtained from wood-derived fuels.

For the pulp and paper industry, it is estimated that wood and bark used for energy increased from 8.7 million oven dry tons in 1972 to 24.7 million in 1986 (American Paper Institute 1987b) and the use of spent pulping liquor grew from 62.2 million to 81.3 million tons over the same time period. Pulp and paper mills obtained about 40% of their energy requirements from residues or spent liquor in 1972; 57% in 1986.

Although their consumption is far smaller, industries producing other than primary wood-based products also use wood-derived fuels for energy production. Studies of eight major groups of industries producing a wide range of nonwood products indicate a combined total use of 3 million oven dry tons of roundwood and residues in 1983 (USDE 1984).[9]

Commercial Buildings

In addition to residential and industrial fuelwood consumption, an estimated 1.3 million oven dry tons of wood-derived fuel was used in commercial buildings in 1983 (USDE 1983).[10] Wood consumption in commercial buildings also increased in the early 1980s. For example, in 1980, 2.9% of all commercial buildings used wood as fuel; by 1983 about 3.4% burned wood (USDE 1983, 1985b). Although the incidence of wood use increased fairly rapidly over the 3-year period (by 1983 about 134,000 buildings burned wood), the impact on total fossil fuel use was somewhat less than the rise in the number of wood-burning buildings would seem to indicate. The average size of buildings using wood in 1983 was only about 6,400 square feet, while the average for all commercial buildings was almost 12,000 square feet. Moreover, less than half of the commercial buildings using wood were as large as 3,000 square feet.

[8]The Public Utilities Regulatory Policies Act of 1978 requires electric utilities to buy electricity generated by renewable resources at a rate equal to their full avoided cost of production (USDE 1985c).

[9]In addition to the lumber and wood products and paper and allied products industries, industry groups studied include textile mill products; furniture and fixtures; chemicals and allied products; stone, clay, and glass products; food and kindred products; printing and publishing; petroleum and coal products; and rubber and miscellaneous products.

[10]For the study from which these data are derived, commercial buildings include nonresidential buildings except those where industrial activities occupy more square footage than any other activity. The types of commercial buildings included in the study are those used for the assembly, sales and service of automobiles, education, food sales, health care, lodging, offices, residential (but with some commercial activity), retail/sales, and warehouse/storage.

Electric Utilities

One of the major uses of fossil fuels in the United States is for the generation of electricity in steam-electric facilities. As a result of the rise in fossil fuel prices in the 1970s there was much interest expressed in the increased use of wood and wood residues for this purpose. In 1983, there were 9 utilities producing electricity and using about 150,000 oven dry tons of wood and wood residue annually. Although consumption fluctuated somewhat, this was only slightly larger than the 141,000 tons used in 1973 (USDE 1982). By 1985, there were only 8 wood-using utilities active, and their total production of electricity was about 130 megawatts (USDE 1985a).

Energy Plantations

With practices similar to those used in modern agriculture, intensively cultivated plantations of fast-growing trees can produce as much as 10 tons per acre (dry basis) per year of wood, bark, and foliage. The possibility of establishing such plantations on a scale large enough to provide a steady source of fuel for steam-electric utilities, or raw material for chemical conversion to liquid fuels, received much attention from scientists and policymakers in the late 1970s (USDA FS 1982). The Short Rotation Woody Crops Program begun by the U.S. Department of Energy in 1977 has made progress toward its goal of developing technology to grow and deliver woody biomass at prices competitive with the lowest-cost fossil fuel, coal (Ranney et al. 1985, 1986). Average growth rates for promising species on various sites range up to 6.7 dry tons per acre per year (Klass 1986).[11] At the current time, it appears that coppicing and high speed harvesting systems are essential to keep overall costs low.

TIMBER CONSUMPTION SUMMARY

The consumption of timber products discussed in this chapter has been shown in standard units of measure; that is, board feet of lumber, square feet of panel products, cords of pulpwood and fuelwood, and cubic feet of miscellaneous industrial roundwood products. In order to compare consumption of these products with timber supplies, these various units must be converted to common units of measure—cubic feet of roundwood.

Improvements in Utilization

In recent decades, primarily in response to increasing costs of stumpage, there have been large improve-

[11] *Species showing promise in various regions include* Eucalyptus grandis, Eucalyptus saligna, Populus deltoides, Populus trichocarpa, Populus *spp. hybrids, and* Robina pseudoacacia.

Table 35.—Roundwood consumption in the United States, by softwoods and hardwoods, and product, specified years 1952–86.

Species group and product	1952	1962	1970	1976	1986
	Billion cubic feet, roundwood equivalent				
Softwoods					
Saw logs	5.0	4.8	5.0	5.7	7.4
Veneer logs	.2	.7	.9	1.3	1.5
Pulpwood[1]	2.4	2.6	3.4	3.3	3.8
Miscellaneous products[2]	.3	.2	.2	.2	.3
Fuelwood	.5	.2	.1	.1	.5
Total[3]	8.4	8.5	9.7	10.7	13.5
Hardwoods					
Saw logs	1.1	1.3	1.2	1.3	1.7
Veneer logs	.2	.2	.3	.3	.2
Pulpwood[1]	.3	.7	1.0	1.1	1.6
Miscellaneous products[2]	.4	.2	.2	.1	.2
Fuelwood	1.5	.9	.4	.5	2.6
Total[3]	3.5	3.3	3.1	3.3	6.3
Total, all species					
Saw logs	6.1	6.0	6.2	7.0	9.1
Veneer logs	.4	.9	1.2	1.5	1.7
Pulpwood[1]	2.7	3.3	4.4	4.4	5.3
Miscellaneous products[2]	.7	.6	.4	.4	.5
Fuelwood	2.0	1.1	.5	.6	3.1
Total[3]	11.9	11.9	12.7	14.0	19.8

[1] *Includes both pulpwood and the pulpwood equivalent of the net imports of pulp, paper, and board.*
[2] *Includes cooperage logs, poles, piling, fence posts, round mine timbers, box bolts, shingle bolts, roundwood used in waferboard, oriented strand board, and particleboard manufacture, and other miscellaneous items.*
[3] *Includes imported logs not shown by product use.*
Note: Data may not add to totals because of rounding.

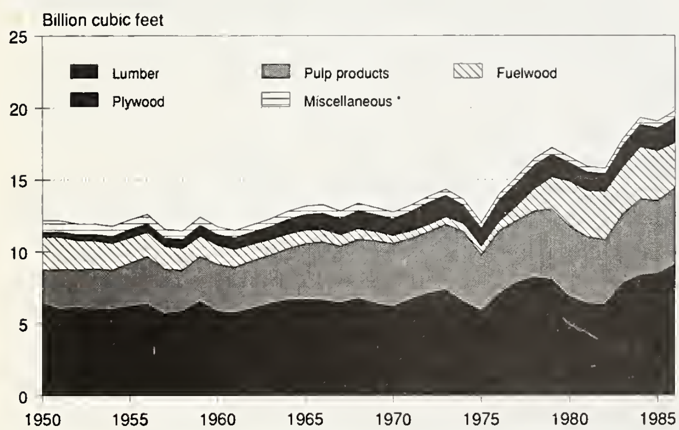
ments in converting the timber harvested from the Nation's forests into the various wood products. These improvements, discussed in detail in Chapter 10, have involved increasing use of slabs, edgings, sawdust, veneer cores, shavings, and other wood processing byproducts for pulp, particleboard, and similar products. In addition, various technological developments such as thinner saws, computer-controlled head rigs, and innovations such as best opening face in the lumber industry; and powered back-up rolls, spindle-less lathes, and automated handling systems in the plywood industry have led to increased product yield per unit of wood input. To some extent these improvements have been offset by other changes such as the use of smaller and lower quality material, and the use of the chipping headrig for lumber production. Nevertheless, the overall increases in conversion efficiency have been substantial.

Roundwood Consumption

In 1986, total U.S. consumption of timber products in terms of roundwood volume was 19.8 billion cubic feet (table 35, McKeever and Jackson 1990: A-14, and fig. 19). This is 41% above consumption in 1976, and the peak in a trend that—with some variation—has been increasing since the early 1960s. Roundwood consumption in 1986 was also materially above the levels attained in the early 1900s when lumber and fuelwood were the principal building and heating materials used in the United States.

About 46% of the roundwood consumed in 1986 was saw logs, 27% pulpwood, 16% fuelwood, and the remainder veneer logs and miscellaneous products. This was quite different than in the 1970s when roughly half of the total was saw logs, one-third pulpwood, and less than 5% fuelwood. Although consumption of all of the roundwood products rose between 1976 and 1986, a large part of the overall growth was due to the rapid rise in fuelwood consumption.

Growth in roundwood consumption in the 1950s, 1960s, and early 1970s consisted entirely of timber from softwood species, as hardwood roundwood consumption fell in response to declines in use of miscellaneous industrial timber products and fuelwood (McKeever and Jackson 1990: tables A-15 and A-16). In the mid-1970s softwoods accounted for more than 76% of total consumption. This trend was reversed in the late 1970s, however, largely due to the relatively more rapid increases in hardwood use for pulpwood and fuelwood, and in 1986 softwoods accounted for only about 68% of total roundwood consumption (fig. 20).



* Includes imported logs.

Figure 19.—Roundwood consumption, by product, 1950–1986.

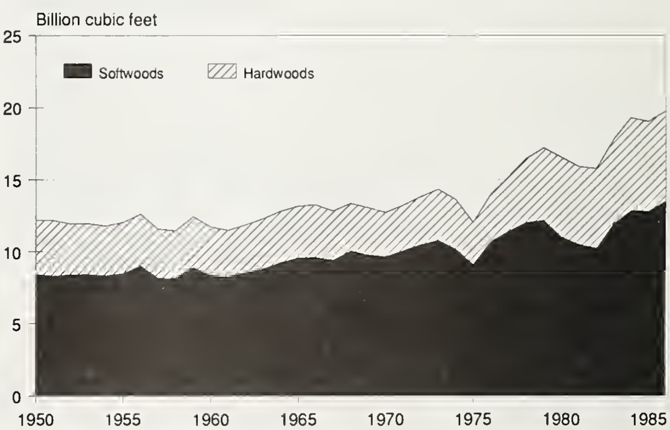


Figure 20.—Roundwood consumption, by species group, 1950–1986.

CHAPTER 3. DOMESTIC TIMBER RESOURCES

The timberlands of the United States and the forests that grow thereon are an important, diverse, and dynamic resource. In 1985, this resource produced 14% of the world output of industrial roundwood (United Nations Food and Agriculture Organization 1986b). The Nation's timberlands, which are found in every state, support many different tree species—both hardwoods and softwoods. These domestic timber resources provide essentially all of the wood raw material consumed by the Nation's primary wood processing industry.

These timber resources are in a state of perpetual change. There are changes in the timberland area base due to conversion or dedication to other uses, and due to planting or tree seeding of areas formerly not forested. The forests are dynamic, living resources, undergoing a continuing process of birth of new trees, growth of existing trees, and loss of trees through mortality or harvest for conversion to wood products. In the last decade, the Nation's timberland area has decreased slightly (1.6%). During the same period, timber volume on those lands increased 4%, and timber growth increased 3%. In 1986, removals of timber—mostly in the form of harvest for wood products—was 16% more than reported for 1976. This overall picture of a relatively stable resource situation for the Nation's timber resources masks many regional and local changes in the timber resources and timber outputs. This chapter provides a general discussion about the nature and extent of the Nation's timber resources, and how they have changed in the last decade. Included are discussions about the timberland area base characteristics, including location, ownership, and productive potential. There is also a characterization of the timber resources found on these lands—species composition, timber volumes, and the elements of change (growth, mortality, and timber removals).

The focus of this chapter is the national timber situation, but considerable discussion is directed to four major sections of the country—North, South, Rocky Mountains and Pacific Coast (see back cover for a map). Detailed regional and state level statistics for the Nations's timberland resources are provided in Waddell et al. 1989. The data supporting this chapter were derived from the periodic forest inventories conducted by the regional Forest Experiment Stations and the Forest Service Administrative Regions.

FOREST LAND AREAS

Forests occupy approximately one-third (731 million acres) of the Nation's land area (table 36). The forests are found in every section, region and state. They vary tremendously, from sparse scrub forests of the arid interior west, to the highly productive forests of the Pacific Coast and the South, and from pure hardwood forests to multispecies mixtures, and coniferous forest.

Two-thirds of the Nation's forests are timberland, forests capable of producing 20 cubic feet per acre of industrial wood annually and not reserved from timber harvest. An additional 35 million acres of timberland, reserved for nontimber uses, is managed by public agencies as parks or wilderness areas.

In addition to the timberlands, there are 213 million acres of other forest land not capable of producing 20 cubic feet of industrial wood annually, but of major importance for watershed protection, wildlife habitat, domestic stock grazing and other uses. Almost all of the other forest land is in the West; over half is in Alaska.

Rain or shine, trees or stumps, our forest inventory goes on.

Table 36.—Land area of the United States, by section and type of land, 1987.

Type of land	Total United States	North	South	Rocky Mountains	Pacific Coast
			Million acres		
Total forest land	731.4	165.5	203.5	142.3	220.1
Timberland	483.3	154.7	195.4	61.1	72.1
Timberland, reserved	34.5	6.7	3.0	12.0	12.9
Other forest land	213.5	4.1	5.1	69.2	135.1
Other land	1,526.2	247.2	330.9	598.3	349.6
Total land area	2,257.6	412.7	534.4	740.7	569.8

Although the other forest lands produce little industrial roundwood, they do produce other wood and tree products which are often important for local use. Fuelwood is a primary use in many areas having nontimber forests, such as the oak woodlands of California and the pinyon-juniper forests of the Southwest.

Timberland Area

Though found in abundance in all regions of the country, the Nation's timberlands are concentrated in the eastern part of the United States. Much, if not most, of the eastern United States was forested before settlement, and although much timberland has been converted to nonforest use, timberlands remain a dominant feature of the landscape. Seventy-two percent of the Nation's timberlands are in the eastern United States.

The West, characterized in part by vast plains and interior basins, and the tundra of interior Alaska, was not predominately forested upon first habitation. And timberlands are now, as in the past, a minor part of the total forest area in the West, although timberland does constitute more than half of all forest land in Oregon and Washington in the Pacific Northwest region, and Colorado, Montana, and Idaho in the Rocky Mountains (table 36, Waddell et al. 1989: table 1).

Timberland Ownerships

Timberland ownership patterns vary throughout the United States. For descriptive and analytical presentation, timberland ownership has been divided into four broad classes: national forests; other public; forest industry; and farmer and other private. Private lands are concentrated in the eastern part of the country; public lands in the West (fig. 21). For the United States as a whole, 72% of all timberlands are owned by private individuals and firms; federal, state, and other public owners account for the remaining 28%. The balance between public and private has not appreciably changed since 1977 (USDA FS 1982).

Farmer and other private.—Timberlands in this owner group include individuals, trusts, and corporations. In total, owners in this group probably number

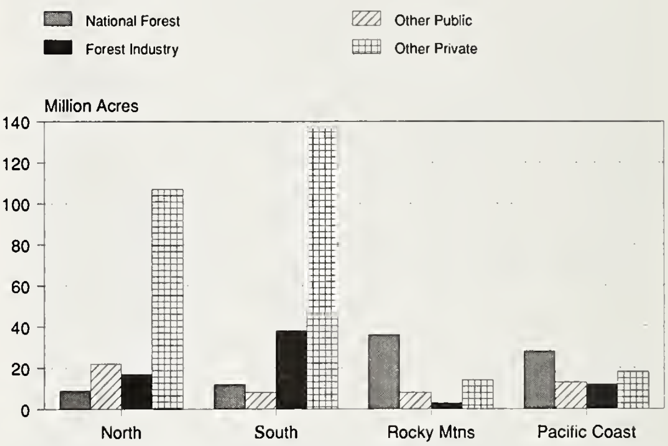


Figure 21.—Area of timberland in the United States, by section and ownership, 1987.

in the millions, and represent the diversity of the Nation. Private forest industry holdings are excluded from this broad owner class.

Not surprisingly, this owner group accounts for most (57%) of the timberland area in the United States. Within this broad owner class, the largest identifiable group are farmers, who control 97 million acres, 20% of all timberland in the United States.

Farmer and other private timberlands are concentrated in the eastern sections of the country; 88% of all such land is found in the North and South, accounting for about 70% of all timberland in both areas. In contrast, in the Rocky Mountain and Pacific Coast sections, this owner group accounts for about one-quarter of all timberlands.

Farmer and other private ownerships include many small parcels, and a smaller number of large tracts of land. The forested parcels in this owner group are found near urban areas, intermingled with cultivated land or land of other nonforest uses, as well as in remote areas. Many different management objectives are held among the owners of this group; at any given time some of the area is not available for the production and harvest of timber. But ownership of timberland is transitory in this group as are individual owner's objectives; changes in ownership and objectives often bring formerly unavailable resources into the market. These timberlands continue to be extremely important to the health of

Using topographic maps to determine acreage of area to be sampled. In forest inventories, for every person-day spent in the woods, an additional day is required for map work, aerial photo interpretation, ownership collection, and related office preparations.

timber economies and to the users of wood products; nowhere is that more evident than in the South.

Forest industry.—Forest industry timberland holdings in the United States total over 70 million acres. These timberlands are owned by operators of primary wood products manufacturing facilities. They have historically been treated as an identifiable owner group because—unlike the farmer and other private group—they are thought to have common objectives for ownership and management of timberland. Most of the forest industry timberland is in the eastern United States; 54% of all such lands are in the South; 24% are in the North, primarily in the Northeast Region. The Pacific Coast has 18% of all industry timberlands, the Rocky Mountain section only 4%. The location of forest industry timberlands has been strongly influenced by the location and availability of highly productive forest land. The importance of these timberlands as a continuing source of wood raw material far exceeds what their proportional area indicates.

National forest.—National forest timberlands in the United States total 85 million acres or 18% of all timberlands. Because national forests were created from unclaimed public lands around the turn of the century, most national forest timberlands are in the West (75%). By the time of selection, much of the more accessible, highly productive forested area was no longer in the public domain. As a consequence, national forest timberland is, on average, of lower productivity and on steeper, higher elevation terrain than are private timberlands.

Other public.—This owner group includes all public owners other than national forest. Included are lands administered by the Bureau of Land Management, lands administered in trust for Native Americans by the Bureau of Indian Affairs, and state, county, and municipal lands. Timberlands in this owner group account for almost 11% of all timberlands. State-owned timberlands, of which every state has some, account for over half of the timberland area in other public ownership (Waddell et al. 1989: table 2).

The largest concentration of other public timberland is in the North (42% of the nationwide total). Pennsylvania in the Northeast Region and Michigan, Minnesota, and Wisconsin in the North Central Region all have large concentrations of other public timberlands. In these regions, timberlands which reverted to the states through tax delinquency during the depression account for much of the other public ownership. In the West, Oregon, Washington, and Alaska have large acreages of other public timberland—mostly state land in Alaska and Washington, and Bureau of Land Management (BLM) land in Oregon.

Forest Types of the East and West

The timberlands of the United States span a wide range of latitudes, elevations, precipitation, and soils. As a consequence the species composition of the forests found on these timberlands is quite diverse, ranging from pure stands of ponderosa pine in the semiarid west to the complex multispecies hardwood forests of the Northeast.

Eastern hardwood forests.—The eastern hardwood forests in total account for 52% of the timberland area of the United States, and 72% of the timberland area in the East. This group of multispecies types covers the majority of timberland in all four eastern regions—North Central, Northeast, South Central, and Southeast. The most wide spread forest type is oak-hickory, which is found throughout the South and the southern half of the North; timberlands in this type total 118 million acres (table 37).

The oak-gum-cypress forests, which total 28 million acres, are the mainstay of the southern hardwood industry. Although much of this forest type has been lost through conversion of bottom lands to agriculture, it appears that the acreage has stabilized in recent years.

Elm-ash-cottonwood forests are bottomland forests of the North and South. They account for 14 million acres, mostly in the North Central and Northeast regions. White ash from these forests is used for a number of specialty wood products.

Maple-beech-birch forests are found on 44 million acres of timberland in the Northeast and North Central regions. These forests, which have expanded in acreage in recent years, contain a number of prized hardwood species, including sugar maple and the birches. This is the forest type famed for fall color. Most of the 18 million acres of aspen-birch forests are in the North Central region. This forest type is made up of pioneer species that often take over areas following disturbance or removal of other forest types. This type is a major source of fiber for the pulpwood industry in the North.

Table 37.—Area of timberland in the United States, by forest type, 1987.

Forest type	Area
	Million acres
Eastern types	
Softwood Types	
Loblolly-shortleaf pine	48.6
Longleaf-slash pine	15.5
Spruce-fir	16.8
White-red-jack pine	13.9
Total	94.8
Hardwood Types	
Oak-hickory	117.7
Oak-pine	31.3
Oak-gum-cypress	28.1
Maple-beech-birch	44.2
Elm-ash-cottonwood	14.3
Aspen-birch	17.8
Total	253.4
Non-stocked	5.5
Total, East	353.7
Western types	
Softwood Types	
Douglas-fir	32.6
Ponderosa pine	24.6
Fir-spruce	26.9
Lodgepole pine	11.6
Hemlock-sitka spruce	11.0
Larch	2.6
White pine	.3
Redwood	1.1
Other western softwoods	.8
Total	111.5
Western hardwoods	15.8
Non-stocked	2.4
Total, West	129.7
Total, United States	483.3

The oak-pine forests of the East are found primarily in the South. Many of these stands on Southern timberlands have emerged following selective harvesting of natural pine forests. The acreage in this type has declined almost 10% in the last decade, due to conversion of these forests to pine forests for the production of softwoods.

Eastern softwood forests.—The eastern softwood forests, though occupying a much smaller area of timberland than the hardwood forests, are the most important timber production forests throughout much of the East. Nowhere is this more true than in the pine region of the South. In both the southeast and southern regions, the longleaf-slash pine and loblolly-shortleaf pine forests, which combined account for 64 million acres of timberland, provide the raw material for the South's huge and still growing forest products industries. The loblolly-shortleaf pine forests account for over half of the 95 million acres of conifer-bearing timberlands in the East.

Longleaf-slash pine forests, which account for less than one-quarter of the southern pine type acreage, are found in states bordering the South Atlantic and Gulf coasts, but most of the area in this type is concentrated in Florida and Georgia.

The white-red-jack pine and spruce-fir forests are the softwood forests of the North. Combined, they account for one-third of the softwood forests of the East, but only 6% of all of the Nation's timberlands. The spruce-fir forests of the Northeast are an important source of pulpwood in that region.

The white-red-jack pine forests total 14 million acres. The species composition of this forest type varies; in the Northeast, white pine predominates, while red and jack pines are the common pines of the North Central region.

Western forests.—The timberlands of the West are forested primarily with softwood species. Eighty-six percent of the timberland area in the West is forested with softwoods; 12% has hardwood stands, and 2% is currently nonstocked.

Three forest types account for two-thirds of the forests on the West's timberlands. The Douglas-fir type, which is found in the Rocky Mountains, and in the Pacific Northwest and Pacific Southwest regions, totals 33 million acres, and is the most abundant and important species in the West. The Douglas-fir forests on the Pacific slope in the Northwest are perhaps the most productive softwood forests in the United States. Ponderosa pine forests occupy about 25 million acres of timberland in the West, over 55% of which is in the Rocky Mountains. This species is also abundant east of the Cascade Range in the Northwest region, and in California. The ponderosa pine forests of the West are a major source of raw material for the manufacture of lumber. The fir-spruce forests are found on 27 million acres of western timberlands. These forests, found at medium to higher elevations throughout the forested West, have gained in value and use for wood products in recent decades, with tightening supplies for other species. The area of fir forests has increased in some areas such as California, due in part to selective harvesting of pine in mixed conifer stands.

Hemlock-sitka spruce forests are found primarily on the Pacific slope in Oregon and Washington, and in coastal Alaska. These forests account for about 8% of the West's timber forests, and are important timber species, providing raw material for lumber products, pulping, and log export on the Pacific Coast.

Lodgepole pine is another significant forest type on western timberlands. Lodgepole stands total almost 12 million acres. Although present throughout much of the West, this species is most abundant in the Rocky Mountains; it is present in significant quantities in the ponderosa pine subregion of the Northwest.

The other western softwood types—larch, redwood, western white pine, and other minor species—total less than 5 million acres, and are much more localized in occurrence and importance than the major forest types of the West.

There are about 16 million acres of hardwood forests on western timberlands. In California, oaks predominate in hardwood stands; in the Rocky Mountains, aspen is the most abundant hardwood. In the Northwest Region, red alder is the most abundant hardwood species. In recent years this species has increased in area, volume, and value to the wood products industry. It is currently used for fuelwood, lumber and specialty millstock, and pulp chips for both domestic use and export.

Forest inventory data collector in a western hemlock stand entering tree and understory vegetation data into a portable electronic recorder.

Timberland Productivity

Timberland productivity is sometimes measured in terms of the maximum amount of wood that can be produced annually in fully stocked natural stands of timber. It is a measure of potential, not of what the land is currently producing. An assessment of inherent productivity of timberlands provides a basis for comparison of timberlands in different regions and sections of the country. Although it gives some indication of what could be produced, were all timberlands fully stocked at all times with natural stands, this measure of productivity does not consider the increases in yields that could be expected with active management of plantations for timber production. Millions of acres of timberland in the United States produce in excess of the estimates included in this discussion because of active management to increase yields and use of genetically improved planting stock.

Forest lands that cannot produce 20 cubic feet of wood annually are not considered timberland, due to the nature and slow rate of growth of the trees that are generally found on such lands. There are 203 million acres of such forests in the United States, areas potentially available for harvest of trees, but not capable of producing crops of industrial wood. Fir-spruce forests in interior Alaska and pinyon-juniper forests in the Rocky Mountain Region together account for 112 million acres of these forests with low potential for industrial wood product production (Waddell et al. 1989: table 5).

Recent inventories of timberlands throughout the United States indicate that 11% of the Nation's timberlands can produce in excess of 120 cubic feet of industrial roundwood per acre annually. The South—largely the loblolly-shortleaf pine, oak-pine, oak-hickory, and oak-gum-cypress forests in the South Central Region—accounts for 45% of these highly productive timberlands (fig. 22). The Pacific Coast has 37% of these timberlands, although accounting for only 15% of the Nation's total timberland area. The Douglas-fir, hemlock, and red alder stands in the Douglas-fir subregion, and redwood and fir stands in California are among the most productive forests in the West.

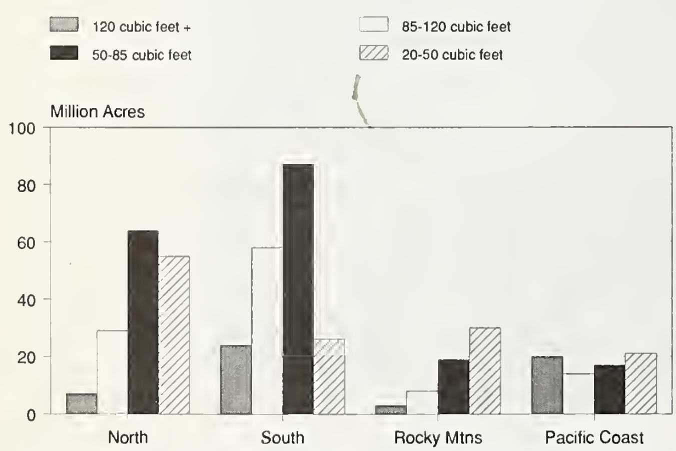


Figure 22.—Area of timberland in the United States, by section and productivity class, 1987.

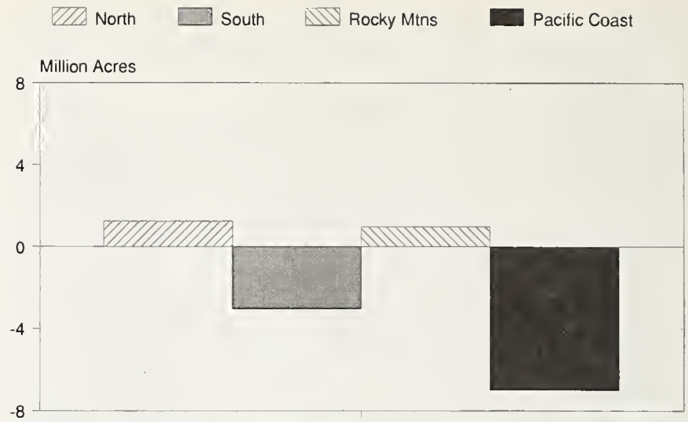


Figure 23.—Change in timberland area by section, 1977-1987.

There are 110 million acres capable of producing 85 to 120 cubic feet; 53% of this area is in the South, forested by the same species that are found on the higher productivity lands. The North accounts for 26% of the 85 to 120 cubic foot potential timberland; oak-hickory, maple-beech-birch, and aspen-birch account for much of the northern acreage in this productivity class.

Although discussion usually focuses on the most highly productive timberlands, two-thirds of the Nation's timberlands do not have the capability to produce 85 cubic feet per acre annually; 39% of all timberland area has the capacity to produce 50 to 85 cubic feet annually; 27% has the capacity to produce 20 to 50 cubic feet. Because of their abundance, and because they make up an overwhelming majority of all timberlands in some regions, these lower productivity timberlands are important regionally and nationally. They account for 77% of timberlands in the North, 58% in the South, 81% in the Rocky Mountains, and 52% in the Pacific Coast.

Trends in Timberland Area

Changes in timberland areas can be difficult to track. Some areas have just been inventoried for the first time. In other areas, new and more precise techniques of measuring productivity have resulted in forest land being excluded or included in the timberland base for the first time. And changes in definitions and procedures make comparisons between old and new inventories difficult. So, not all apparent change is real change. Given that caution, a look at the change in the reported timberland base since 1977 is in order.

For the entire United States, timberland area has remained fairly stable over the last decade, with an apparent loss of 8 million acres or 1.6%. Net gains were reported in the North (0.8%) and in the Rocky Mountains (1.6%). On the Pacific Coast, timberland area decreased 7 million acres or 9% from 1977 to 1987 (fig. 23). Most of the decrease was in Alaska, which experienced major shifts in timberland ownership and status; almost 4 million acres of timberland were withdrawn and placed in reserved status as parks and wilderness. Oregon and Washington combined had an apparent loss of 3.2 million acres; much of this loss was due to national forest timberland withdrawals to wilderness status. But some of the apparent timberland loss in these two states was due to land reclassified from timberland to other forest as a result of reevaluation of site productivity. For example, estimates of nonfederal timberlands in eastern Washington were reduced 950,000 acres from earlier estimates, but 87% of the apparent change was due to reclassification of 830,000 acres of timberland to other forest. These "apparent" changes, mingled with real accretions and losses, often make determination of real change difficult. The South has apparently lost 3 million acres or 1.5% of its timberland area in the last decade. Although clearing of bottomland forests for agriculture has slowed in recent years, losses of forest land to urban and other development pressures have increased. Some of the most recent state inventories have shown a slight increase in forest land area.

TIMBER VOLUME, GROWTH AND REMOVALS

The Nation's timberlands support a variety of uses, as do its other forest lands. The primary issue of concern in this report, however, is the volume of timber available now or prospectively for manufacture of wood products. The volume of timber now standing on these timberlands, including the growth that will accrue, constitutes the wood raw material that will provide wood for our forest industries and wood and paper products for our population in the decades to come.

Timber Volume

The Nation's timberlands contain trees of a large variety of species, as was discussed earlier in this chapter. In addition there is variability as to the condition of the trees, which has considerable bearing on their value for use in wood products. It is estimated that the Nation's timberlands contain 831 billion cubic feet of timber, of which 91% is in growing stock—live, sound trees suited for roundwood products (table 38). About 7% of all timber volume is in live cull trees that because of form or rot are not suited for the production of all roundwood products. Almost 2% of the volume of all timber is in dead trees that are sound enough to have value for some product uses. Softwood species have a higher proportion (95%) of all timber volume in growing stock; hardwood volume is 86% growing stock. The remainder of this discussion on timber volume will focus on growing stock.

Softwood Timber Volume

The Nation's softwood timber volume totals 451 billion cubic feet or 60% of all growing stock (table 39). Softwood growing stock is concentrated in the West; the Pacific Coast alone accounts for 44% of all softwood growing stock, despite it's relatively small timberland base. The West contains all of the United States' remaining forests of old timber; these stands have high per-acre

Table 38.—Volume of timber on timberland in the United States, by species group and class of timber, 1987.

Class of timber	All species	Softwoods	Hardwoods
		Species group	
		Million cubic feet	
Growing stock trees	755,935	450,881	305,054
Live cull trees	60,025	13,018	47,007
Sound dead trees	15,354	12,372	2,982
Total, all classes	831,314	476,271	355,043

Table 39.—Volume of growing stock in the United States, by species group and section, 1987.

Section	All species	Softwoods	Hardwoods
		Species group	
		Million cubic feet	
North	187,040	47,400	139,640
South	238,034	103,798	134,236
Rocky Mountains	107,979	100,298	7,681
Pacific Coast	222,882	199,385	23,497
United States	755,935	450,881	305,054

volumes, and many of the younger mature forests on the Pacific Coast have higher per-acre volumes due to the high productivity of much of the timberland. Most of the remainder of softwood timber is evenly distributed between the South and the Rocky Mountains (fig. 24).

Douglas-fir is the most abundant softwood species; it totals 91 billion cubic feet or 20% of all softwood timber volume in the United States. Sixty-one percent of all Douglas-fir volume is in Oregon and Washington (Waddell et al. 1989: table 15). Other important western softwood species in order of volume abundance are: true firs (41 billion cubic feet); western hemlock (38 billion cubic feet); ponderosa pine (33 billion cubic feet); lodgepole pine (27 billion cubic feet); spruce (21 billion cubic feet). The location of volume concentration of these species follows closely the distribution of the namesake forest types discussed earlier.

Eastern softwood species are primarily in the South, an area which in recent years has become a focal area for new investments by forest industries. This change in balance in terms of timber harvest and industrial development between the Pacific Coast and the South has resulted, in part, from the declining supplies of large old timber on private lands on the Pacific Coast, and increases in inventories of softwoods in the South in recent decades. Eastern softwoods account for one-third of the Nation's softwood timber; Southern pines alone account for 23%.

Loblolly and shortleaf pines total 69 billion cubic feet or 66% of all softwood timber volume in the South and 46% of all softwood volume in the East (Waddell et al. 1989: table 11). Other important Eastern softwoods include: longleaf and slash pines (17 billion cubic feet); red and white pines, located in the Northeast and North Central regions (14 billion cubic feet); spruce and balsam fir, located in the North (18 billion cubic feet); other yellow pines (11 billion cubic feet).

Hardwood Timber Volume

Hardwoods account for 40% of all growing stock volume in the United States. Fully 90% of all hardwood timber volume is in the eastern United States, almost evenly distributed between the North and the South. Most of the remaining 10% is on the Pacific Coast (table 39).

The hardwoods of the East are numerous, and their unique characteristics warrant tracking many of them as separately identifiable species (Waddell et al. 1989: table 12). The oaks total 98 billion cubic feet. The select species, which include select white and red oaks, hard maple, yellow birch, sweet gum, yellow-poplar, ash, black walnut, and black cherry, total 114 billion cubic feet or 41% of all hardwood growing stock in the eastern United States. Although there is an apparent abundance of select species, much of the volume is in relatively small trees of limited use for many products where quality is important (Waddell et al. 1989: table 22). In the East, 42% of all hardwood timber volume is in trees less than 11 inches in diameter.

Western hardwoods are of little importance when compared to the vast softwood resources in the West, or the hardwood resources in the East. But locally they are important, and their use is growing as softwoods become more limited in supply. Red alder, with an inventory of almost 8 billion cubic feet, has had a substantial increase in use in recent years. It is located almost entirely in the Douglas-fir subregion of Oregon and Washington. The aspens in Colorado and other states in the Rocky Mountains are also locally important.

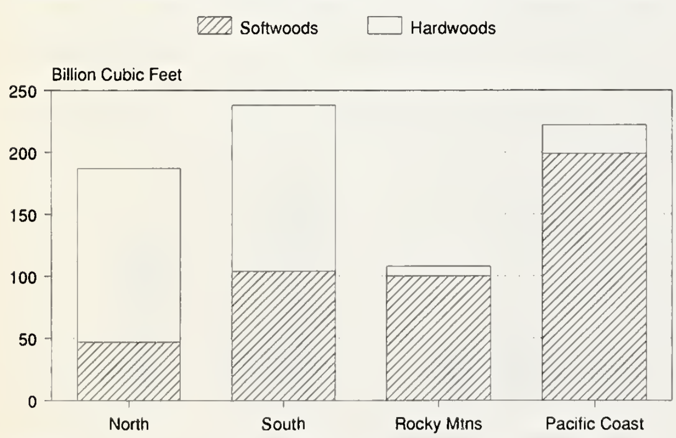


Figure 24.—Volume of growing stock in the United States, by section, 1987.

Ownership of Timber Volume

The pattern of ownership of timberland area is not a good indication of distribution of timber volumes among the same owner groups. Because of many factors, among them history of use, land productivity, and degree of management, the timber volumes are distributed unevenly among owners. National forests, which account for only 18% of the Nation's timberland, have 28% of all timber volume, and 41% of all softwood timber volume (table 40). The national forests still have considerable area in old stands with high per-acre volumes. The national forests have less hardwood volume than the other owner groups (fig. 25).

Other public owners—states, federal agencies other than the Forest Service, counties and municipalities—account for about 12% of all timber, about two-thirds

Table 40.—Volume of growing stock in the United States, by species group and ownership, 1987.

Class of timber	All species	Softwoods	Hardwoods
	Million cubic feet		
National forest	211,099	186,388	24,711
Other public	88,319	56,839	31,480
Forest industry	107,275	72,340	34,935
Other private	349,242	135,314	213,928
All ownerships	755,935	450,881	305,054

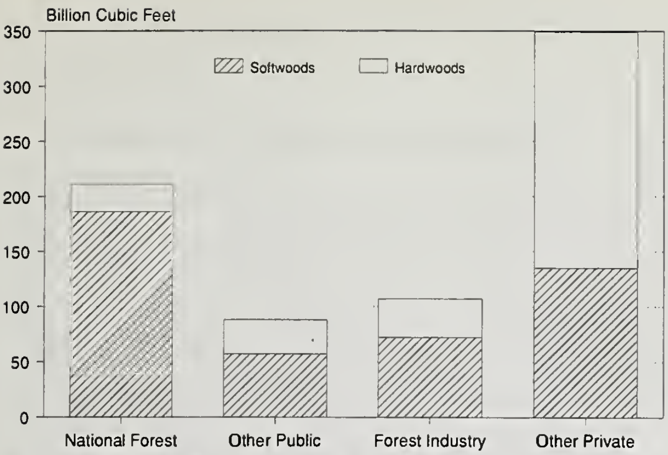


Figure 25.—Volume of growing stock in the United States, by species group and ownership, 1987.

of which is softwoods. The hardwood volume in this owner group is concentrated in the North; the softwood volume is mostly in the West, the largest share in Oregon and Washington.

Forest industries account for about 15% of all timber volume in the United States, and 16% of all softwood volume. This group of timberland owners accounts for a small part of total timberland and timber volume in most regions, but is locally important in many states and areas. Industry timber is important beyond its relative abundance because industry owners hold and manage timber for harvest. Inventory turnover—the rate of harvest and replacement of timber inventories—is higher on forest industry land than on other ownerships.

Farmer and other private timberlands account for 46% of all growing stock in the United States, a proportion less than the timberland area share of this owner group might indicate, but nevertheless a large and important resource. This owner group controls 30% of all softwood timber, and 70% of all hardwood timber. Both softwood and hardwood timber volume in this owner group is concentrated in the eastern United States, softwoods in the Northeast, Southeast, and South Central regions; hardwoods are abundant in this ownership throughout the East.

Trends in Timber Volume

Earlier national assessments reported 5% net gains in timber between 1962 and 1970, and between 1970 and 1977, despite losses of timberland area in some regions (USDA FS 1982). For the period 1977–1987, we have found an overall increase of about 4% (31 billion cubic feet) nationally (table 41). This net trend masks some offsetting trends for individual regions, and for some species of timber. Timber volume on the Pacific Coast decreased 9% during the 1977–1987 period; softwood volume, which was responsible for the downward trend in that section of the country, decreased over 12%, and was responsible for the slight decline in softwood timber volume nationally. Softwood timber volume was up 5 to 8% in all other sections of the country.

Hardwood timber volume increased significantly in all sections of the country, continuing a trend that dates to the early 1950s and before. The North and South accounted for most of the hardwood volume increase, but the rate of increase was greatest in the Rocky Mountains and Pacific Coast, at 25%.

Because changes in timberland area account for part of the change in total timber volume, scrutiny of volume change on a per-acre basis sometimes provides different insights about the rates and locations of changes in volumes. For instance, the South, which had a 10% increase in total volume in the last decade, experienced a 12% gain in volume on a per-acre basis; while in the North, timber volume increased 13% per acre compared to a 15% total volume increase. The per-acre volumes remove area changes from the comparisons, and provide a better tool for looking at dynamics of the forests, in terms of growth, removals, and growing stock volume. Figure 26 also provides ready comparisons of the average concentrations of timber volume in the different sections of the country.

Although average timber volume per acre has declined on the Pacific Coast, this section's timberland still has almost three times the volume per acre of the timberlands of the South and North. As the old timber in the Pacific Coast and Rocky Mountain sections is harvested, the per-acre volumes will continue to decrease. But most of the

Table 41.—Change in growing stock volume in the United States, by species group and section, 1977–1987.

Section	Species group: All species		Softwoods		Hardwoods	
	Million cubic feet	*Percent*	*Million cubic feet*	*Percent*	*Million cubic feet*	*Percent*
North	24,032	14.7	3,550	8.1	20,482	17.2
South	22,650	10.5	4,902	5.0	17,748	15.2
Rocky Mountains	6,730	6.6	5,187	5.5	1,543	25.1
Pacific Coast	−22,544	−9.2	−27,406	−12.1	4,862	26.1
United States	30,868	4.3	−13,767	− 3.0	44,635	17.1

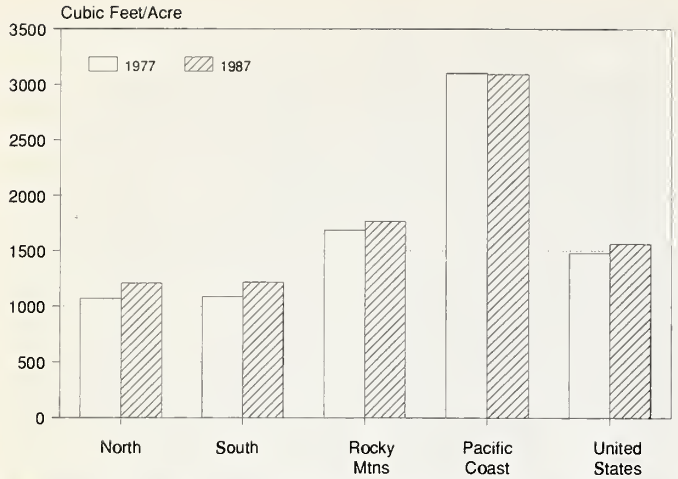


Figure 26.—Volume of growing stock per acre in the United States, by section, 1977 and 1987.

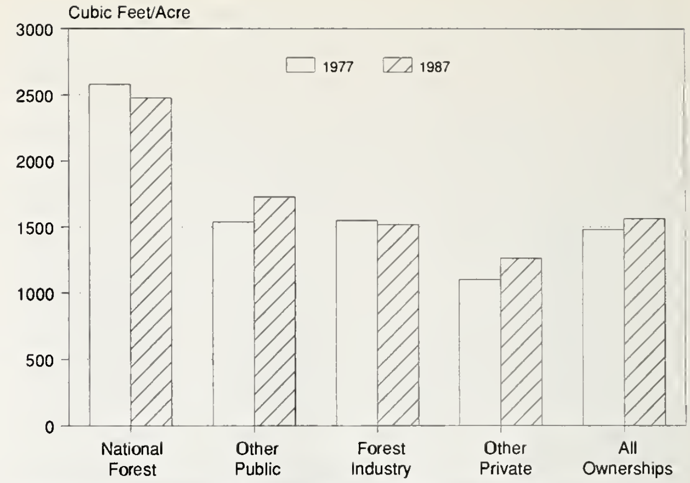


Figure 27.—Volume of growing stock per acre in the United States, by ownership, 1977 and 1987.

old timber is gone on all but national forest lands in the Pacific Coast; in this section of the country, longer rotation ages for young timber and relatively high productivity of timberlands result in high per-acre volumes in restocked young forests. Industry timberlands in the Northwest Region, though they have little remaining old timber, have about three times the volume per acre of industry timberlands in the Southeastern region. The increase in per-acre volume in the Rocky Mountains is of interest because of the commonly held perception that this section, whose forests are mostly publicly owned, has old forests whose growth has stagnated. Although timber growth in this section of the United States is lower than in some other sections of the country, it far exceeds the demands made on the timber resource by timber harvest. As a result, growing stock volumes have increased in this section of the country.

Changes in Timber Volume by Ownership

Timber volume increased in the last 10 years for all ownerships except national forests, which had an 8% decrease in volume (table 42). Growing stock volume increased 4% on other public lands, and 14% on farmer and other private timberlands. On industry lands, total timber volume increased 1%. The totals for all species mask declines in softwood timber volume on other public and forest industry lands. The decline in softwood timber volume on industrial lands during the decade was a modest 2.4%; on other public lands it was 3.5%, and on national forests, 10%. On farmer and other private lands, softwood timber volume increased about 9%. Hardwood timber volume increased substantially on all ownerships over the last decade.

Per-acre analysis of volume change by owner over the last decade does indicate some differences in magnitudes of change, but not direction (fig. 27). On national forests, volume per acre decreased about 4%, half of the decline rate for total timber in this ownership. The analysis of volume change on a per-acre basis removes from the analysis the impact of timberland loss to wilderness withdrawals and other uses, and provides a clearer picture of the impacts of harvest, mortality, and growth dynamics. On other public timberlands, the percentage volume increase on a per-acre basis (12%) over the last decade is over three times the percentage increase in total volume. On a per-acre basis, forest industry shows a slight loss (1%) versus a slight increase (1%) in total volume, because the impact of volume increase through timberland purchase is nullified when using the per-acre approach. For farmer and other private ownerships, both

Table 42.—Change in growing stock volume in the United States, by species group and ownership, 1977–1987.

	Species group					
Ownership	All species		Softwoods		Hardwoods	
	Million cubic feet	*Percent*	*Million cubic feet*	*Percent*	*Million cubic feet*	*Percent*
National forest	−17,922	−7.8	−21,589	−10.4	3,667	17.4
Other public	3,115	3.7	− 2,081	− 3.5	5,196	19.8
Forest industry	1,358	1.3	− 1,752	− 2.4	3,110	9.8
Other private	44,317	14.5	11,655	9.4	32,662	18.0
All ownerships	30,868	4.3	−13,767	− 3.0	44,635	17.1

total volume and per-acre volume increased about 15% over the last decade.

Elements of Change in Timber Volume

Timber inventories are dynamic. The net change in timber volume is affected by a number of factors, some within owners' or managers' control, and some beyond their control. In the previous section, the impact of area change on inventory was alluded to in comparing the difference in rates of change achieved when looking at per-acre values. When timberland area is shifted from one owner to another, converted to another use, or withdrawn from timber production (for example, park or wilderness use), volume is removed from the inventory of one owner group, and may or may not be added to another. The impacts on timber volume change are not precisely known, but if the average volume on the lost acres is representative of average volume for the entire ownership class, the volume loss/gain due to timberland transfer or withdrawal is proportional to the timberland area lost. While such inventory losses can be estimated, they tell us little about the dynamics of forests and their uses as timberland. The focus here will be on the elements of dynamic change within forests—mortality, growth, and harvest.

Timber Volume Lost to Mortality

Timber mortality is commonly defined as the net volume of timber dying annually (or for some other period) due to insects, disease, suppression, fire, and windthrow. Mortality is a part of every living forest. Usually, losses due to insects, disease, and suppression occur at a low and predictable rate. Little of this type of timber loss is captured for harvest because the dead trees are widely scattered, not providing economic concentrations of timber volume needed to support profitable harvest operations.

Timber volume loss to mortality can also occur in huge concentrations in localized areas, through epidemic insect infestations, wildfire and windstorms. Timber killed, but not destroyed, in such catastrophic events is often salvaged and utilized for the production of timber products.

Loss of growing stock to mortality totaled 4.5 billion cubic feet in 1986 (table 43), about 0.6% of the growing stock volume in the United States. The distribution of mortality is consistent and very predictable, absent periodic catastrophes. For both softwoods and hardwoods, and for each owner group, the mortality rate (volume loss to mortality as a percent of growing stock) varied between 0.5 and 0.7%. The highest mortality rate in 1986 was for farmer and other private softwoods; the lowest was for other public softwoods. But the differences, even at the extremes are of little practical significance. The largest losses to mortality occur where the largest concentrations of timber are found. But even in areas of high timber volumes, the concentration of mortality is so small at the acre level, barring catastrophic loss, that trying to capture mortality for harvest is not a realistic concept. For the United States as a whole, mortality averages only 9 cubic feet per acre annually. On the Pacific Coast, mortality averages about 15 cubic feet per acre annually; in the eastern regions, it ranges from 7 to 11 cubic feet per acre.

Table 43.—Mortality of growing stock in the United States, by species group and ownership, 1986.

Ownership	Species group: All species	Softwoods	Hardwoods
	Million cubic feet		
National forest	1,053	912	141
Other public	502	294	208
Forest industry	635	408	227
Other private	2,271	982	1,289
All ownerships	4,461	2,596	1,865

Table 44.—Net annual growth of growing stock in the United States, by species group and ownership, 1986.

Ownership	Species group: All species	Softwoods	Hardwoods
	Million cubic feet		
National forest	3,433	2,810	623
Other public	2,355	1,381	974
Forest industry	4,371	3,216	1,155
Other private	12,367	5,463	6,904
All ownerships	22,526	12,870	9,656

Timber Growth

Net annual growth is a commonly used measure of productivity and performance of timber resources. Net annual growth is annual growth of timber volume, less the volume lost through mortality and increase in cull volume. In other words, it is the net effect of natural gains and losses to timber volume. Although net growth is sometimes used as an indication of timber available for harvest, this simple concept of harvest availability is often misleading and is best not used.

Net annual timber growth.—Net annual timber growth (net growth) totaled 22.5 billion cubic feet in 1986 (table 44). Fifty-five percent of all timber growth and 72% of all hardwood growth was on farmer and other private timberlands. Forest industry accounted for 19% of all timber growth, and 25% of all softwood growth, percentages much larger than their share of timberland and timber volume.

On a per-acre basis, net growth on forest industry timberlands averaged 62 cubic feet annually, far in excess of any other ownership (fig. 28). This high level of growth reflects the high productivity of timberlands in this ownergroup, as well as the age, stocking levels, and levels of management of the timber stands thereon. National forests have lands of poorer productivity and many old stands with relatively slow growth. As a consequence they have the lowest per-acre growth of any owner group (40 cubic feet).

Timber growth is distributed among all the sections and regions of the country. The South accounts for about 46% of all timber growth, softwood growth, and hardwood growth (table 45). The South and North combined account for most (91%) of total hardwood growth. The Rocky Mountains and Pacific Coast combined have 45% of all softwood growth.

On a per-acre basis, the Pacific Coast has the highest rate of growth (62 cubic feet) of all sections of the country (fig. 29). The Rocky Mountains and North have the lowest per-acre growth rates, considerably lower than those for the Pacific Coast and South.

Trends in timber growth.—Total timber growth increased about 3% between 1976 and 1986. These trends are best examined by looking at per-acre growth to minimize the effects of change in area estimates. Net growth per acre increased 38% in the Pacific Coast, due largely to the emergence of young stands of timber following the extensive harvest of old timber on nonfederal lands during the post World War II era (fig. 29). Per-acre growth in the South remains relatively high, but a negative trend is evident, in keeping with studies that have identified declining growth rates in the South in recent years (Sheffield et al. 1985). Per-acre growth has been stable in the North. In the Rocky Mountains, growth per acre has increased 21%; the per-acre growth in the Rocky Mountains is now about the same as per-acre growth in the North.

Growth trends by ownership.—On national forests, per-acre growth has increased 14% in the last decade; on other public lands, growth per acre increased about 26% (fig. 28). Per-acre growth on forest industry land increased about 2%. A slight decrease in per-acre growth occurred on farmer and other private timberlands.

The decreases in growth on farmer and other private timberlands in the South mark a change in direction from recent trends of increasing growth. The reasons for change in long-term growth trends are currently the subject of much study and considerable speculation. Causal factors for the declines in growth have not yet been conclusively determined.

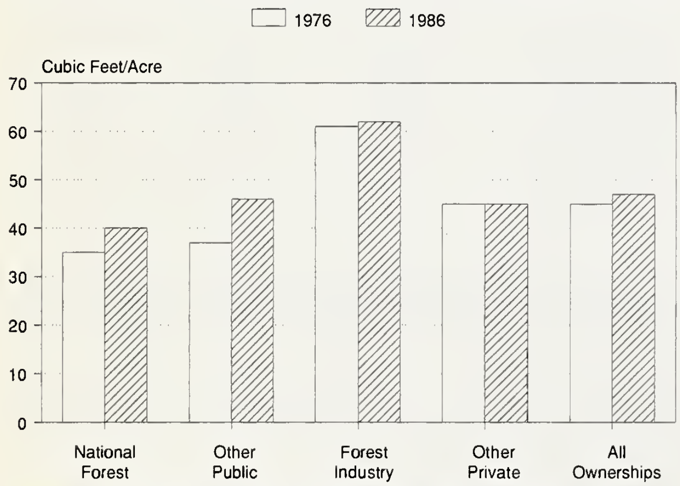


Figure 28.—Net annual growth of growing stock per acre in the United States, by ownership, 1976 and 1986.

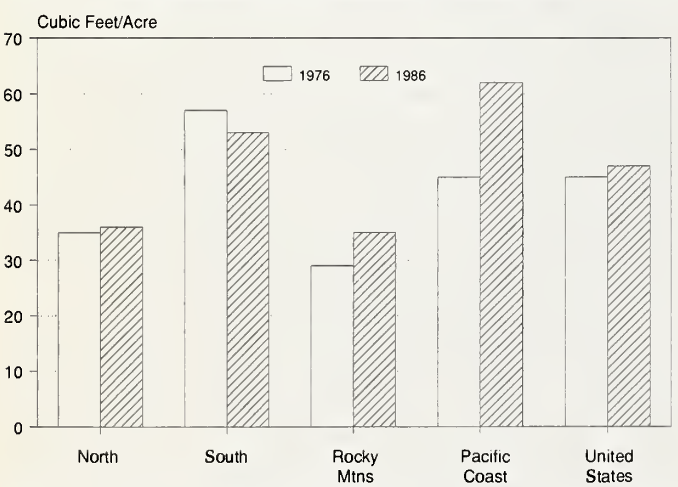


Figure 29.—Net annual growth of growing stock per acre in the United States, by section, 1976 and 1986.

Table 45.—Net annual growth and removals of growing stock in the United States, by species group and section, 1986.

Item	Species group		
	All species	Softwoods	Hardwoods
	Million cubic feet		
North			
Net growth	5,512	1,288	4,224
Removals	2,708	726	1,983
Ratio of growth to removals	2.04	1.77	2.13
South			
Net growth	10,429	5,849	4,580
Removals	8,698	5,741	2,958
Ratio of growth to removals	1.20	1.02	1.55
Rocky Mountains			
Net growth	2,127	1,957	170
Removals	871	843	28
Ratio of growth to removals	2.44	2.32	6.07
Pacific Coast			
Net growth	4,458	3,776	682
Removals	4,173	4,058	115
Ratio of growth to removals	1.07	.93	5.93
United States			
Net growth	22,526	12,870	9,656
Removals	16,451	11,367	5,083
Ratio of growth to removals	1.37	1.13	1.90

Removals of Timber Volume

Removals from timber inventories are losses that occur by other than natural causes (mortality). Removals, mortality, and land dedication to nonforest uses are the negative elements of change that, with growth and reforestation of abandoned agricultural land as positive elements, determine the direction or trend in timber volume over time. Timber removals from growing-stock volume include: (1) harvest of roundwood products; (2) logging residues; and (3) other removals, such as precommercial thinning, and land clearing with resultant destruction of timber. Not included in the removals discussed herein are the timber inventories on timberlands withdrawn intact for parks and wilderness. We have focused here on timber removals from growing-stock inventory that are or can be potentially used for wood products.

Timber removals from growing-stock inventory in 1986 totaled 16.5 billion cubic feet (table 45). Almost 53% of all timber removals came from the forests of the South, which continued to increase its share of timber harvest in the United States. Twenty-five percent of all removals came from the Pacific Coast forests, 16% came from the North, and only 5% from forests in the Rocky Mountains.

Softwoods accounted for 69% of all growing-stock removals in 1986. The forests of the South accounted for 50% of all softwood removals, the Pacific Coast 36%, the Rocky Mountains 7%, and the North 6%. Hardwood removals in 1986 were centered in the North and South, which together accounted for 97% of the United States total. The South accounted for 58% of all hardwood removals from growing stock in 1986.

Timber removals were concentrated on private ownerships in 1986. Farmer and other private owners had 50% of all timber removals, industrial forests accounted for 30% (table 46). The national forests, although a major factor in the West, accounted for only 13% of total growing-stock removals in 1986. Other public, with 7% of total removals, was the least important source of removals nationally, but was important in some states and local areas, including the Douglas-fir subregion in the Northwest.

The ownership distribution of removals by species group was somewhat different than the all-species distribution due to the differences in species volume distribution between the owner groups. Forest industry accounted for 37% of all softwood removals, farmer and other private 38%, national forests 18%, and other public 7%. Hardwood removals came primarily from farmer and other private forests (76%).

Changes in timber removals.—Comparison of removals in 1986 with those in 1976 indicates that recent (1986) removals are 16% higher than those in 1976 (table 47). These data are for two points in time and, in themselves, do not establish a trend.

Hardwood removals in 1986 were higher than in 1976 by 21%; softwood removals increased 14%. Removals from national forests were 5% higher in the recent year. Removals from other public lands changed little in 1986,

Table 46.—Net annual growth and removals of growing stock in the United States, by species group and ownership, 1986.

Item	Species group		
	All species	Softwoods	Hardwoods
	Million cubic feet		
National forest			
Net growth	3,433	2,810	623
Removals	2,172	2,010	162
Ratio of growth to removals	1.58	1.40	3.85
Other public			
Net growth	2,355	1,381	974
Removals	1,083	862	221
Ratio of growth to removals	2.17	1.60	4.41
Forest industry			
Net growth	4,371	3,216	1,155
Removals	5,007	4,195	812
Ratio of growth to removals	87	.77	1.42
Other private			
Net growth	12,366	5,462	6,904
Removals	8,189	4,300	3,889
Ratio of growth to removals	1.51	1.27	1.78
All ownerships			
Net growth	22,526	12,870	9,656
Removals	16,451	11,367	5,083
Ratio of growth to removals	1.37	1.13	1.90

Table 47.—Removals of growing stock in the United States, by ownership and species group, 1976 and 1986.

Ownership and Species group	1976	1986	Percentage Change
	Thousand cubic feet		*Percent*
National forest			
Softwoods	1,990	2,061	3.6
Hardwoods	128	162	26.6
Total	2,118	2,223	5.0
Other public			
Softwoods	850	858	0.9
Hardwoods	226	220	–2.7
Total	1,076	1,078	0.2
Forest industry			
Softwoods	3,616	4,214	16.5
Hardwoods	599	812	35.6
Total	4,215	5,026	19.2
Other private			
Softwoods	3,543	4,234	19.5
Hardwoods	3,242	3,889	20.0
Total	6,785	8,123	19.7
All owners			
Softwoods	9,999	11,367	13.7
Hardwoods	4,195	5,083	21.2
Total	14,194	16,450	15.9

compared to 1976. On forest industry lands, removals were much higher in the recent year, with a 36% increase for hardwoods and a 16% increase for softwoods. On farmer and other private lands, both hardwood and softwood removals were about 20% higher in 1986 than in 1976.

In the North, removals increased 8%; all of the increase occurred in the North Central region (table 48, Waddell et al. 1989: table 29). In the South, removals increased 30% with substantial increases in both the South Central and Southeast regions. In the Rocky Mountains and the Pacific Coast, removals were about the same for both years.

Table 48.—Removals of growing stock in the United States, by section and species group, 1976 and 1986.

Section and Species group	1976	1986	Percentage Change
	Million cubic feet		*Percent*
North			
Softwoods	692	726	4.9
Hardwoods	1,803	1,983	10.0
Total	2,495	2,708	8.5
South			
Softwoods	4,436	5,741	29.4
Hardwoods	2,242	2,958	31.9
Total	6,678	8,699	30.3
Rocky Mountains			
Softwoods	843	843	0.0
Hardwoods	24	28	16.7
Total	867	871	0.5
Pacific Coast			
Softwoods	4,028	4,058	0.7
Hardwoods	126	115	−8.7
Total	4,154	4,173	0.5
United States			
Softwoods	9,999	11,367	13.7
Hardwoods	4,195	5,083	21.2
Total	14,194	16,451	15.9

Timber products output.—Timber products output from growing stock accounts for most of the timber removed from timberlands (table 49). In 1986, 88% of all softwood removals and 76% of all hardwood removals were in the form of roundwood used as raw material for the manufacture of wood products.

Roundwood products accounted for 88 to 90% of total softwood removals in all sections of the country. Hardwood roundwood products accounted for 78% and 73%, respectively, of the total hardwood removals in the North and South.

Logging residues.—Logging residues are materials removed from growing stock in the process of timber harvest, which are left unutilized at the harvest site. Theoretically, they represent raw material that could be used in the manufacture of wood products. But the size, species, concentrations, and/or condition of the material has rendered it unsuited for manufacture of products at that time, or simply not economic to transport to the processing facilities. Thus logging residues are not unjustified waste, but they may be a source of raw material in the future as products, the price of raw materials, or the economics of manufacturing change.

Logging residues accounted for 9% of all softwood growing-stock removals and 11% of all hardwood removals in 1986 (table 49). In the Rocky Mountains and Pacific Coast, softwood logging residues were 11 and 12%, respectively, of total removals; but in the South and North, softwood logging residues were only 6 and 4%, respectively, of total removals. The higher proportion of removals left as logging residue in the West is due, in part, to breakage and other factors associated with logging of old timber, and due to operation in steep, remote terrain.

Hardwood logging residues as a percent of total removals varied from 7% in the Pacific Coast to 18% in the Rocky Mountains. In the eastern part of the United

Table 49.—Roundwood products, logging residues, and other removals from growing stock timberland in the United States, by species group and section, 1986.

	Species group											
	All species				Softwoods				Hardwoods			
Section	Total	Round-wood products	Logging residues	Other removals	Total	Round-wood products	Logging residues	Other removals	Total	Round-wood products	Logging residues	Other removals
	Million cubic feet											
North	2,708	2,202	201	305	726	654	31	40	1,983	1,548	171	264
South	8,698	7,260	764	674	5,741	5,091	364	286	2,958	2,169	400	389
Rocky Mountains	871	771	96	4	843	752	91	—	28	20	5	3
Pacific Coast	4,173	3,651	520	2	4,058	3,545	512	1	115	106	8	1
United States	16,451	13,884	1,582	984	11,367	10,042	998	327	5,083	3,843	584	657

States, where hardwood removals are concentrated, hardwood logging residues totaled 571 million cubic feet, and accounted for 9% of hardwood removals in the North, 14% in the South.

Although logging residues cannot be considered an immediate raw material resource, the economics and technology of harvest and manufacture and the nature of raw material used for wood products do change with the passage of time. In the past, the result of such change has been an increase in degree of utilization and a decreasing proportion of growing stock left as logging residue. Since 1976, the proportion of softwoods left as logging residues has remained at 8%; but hardwood logging residues have decreased from 14% to 11% of hardwood growing-stock removals. However slowly, decreasing trends in logging residues will likely continue. The expansion of available raw material for manufacture will result from these trends, not from utilization of what was left on the ground in 1986.

Other removals.—Other removals consist largely of growing stock cut and burned or otherwise destroyed in the process of conversion of forest land to nonforest uses. A secondary source of other removals is growing stock killed and not utilized in forestry cultural operations such as precommercial thinning. These removals, like logging residues, are not a potential immediate source of raw materials; but changing economics may some day make more of this material available for product manufacture. In 1986, 6% of all growing-stock removals fell into the category of other removals (table 49). Only 3% of softwood removals were in this category, but fully 13% of hardwood removals were so classified. The hardwood growing stock lost to other removals was in the South and the North; the losses were due largely to continued clearing of bottomland hardwood stands in the South for farmland; in the North, the hardwood forests were removed to yield land to a number of nonforest uses.

Most of the softwood growing stock classified as other removals in 1986 was in the South, and likely was scattered softwoods in predominantly hardwood stands that were converted to nonforest uses.

When timberland is converted to nonforest use, some wood raw material is usually destroyed in the process. But wood that is valuable for product manufacture, if in economic concentrations, is usually utilized and is included in the roundwood products category of removals.

Products from growing stock and other timber.—Roundwood timber products come largely from growing stock. Most attention is focused on roundwood products from growing stock because of the overwhelming importance of that source, and because harvest from growing stock has an effect on growing-stock inventories which are tracked and studied because of their commercial importance. But roundwood products also come from such nongrowing-stock sources of wood raw material as dead trees, live cull trees that are largely rotten or are rough in form, very small trees, trees of seldom used species, and trees from nonforest land (fencerows, etc.).

In 1986, roundwood products from all domestic sources in the United States totaled 17.6 billion cubic feet, of which growing stock accounted for 79%, other sources 21% (table 50). Only 11% of all softwood roundwood products came from nongrowing stock. But the situation was different for hardwoods; 38% of all hardwood roundwood products came from nongrowing-stock sources.

The major reason for the high proportion of nongrowing stock in total hardwood harvest is fuelwood. Hardwoods accounted for 82% of all roundwood harvested for fuelwood in 1986. And nongrowing stock accounted for 77% of all hardwood used for fuelwood. For fuelwood use, species, tree form and size are of minor importance to the value of wood. Location, availability, and low cost are primary concerns; as a consequence, much fuelwood comes from species of lesser value for other roundwood products, and small trees or trees that are too poorly formed for timber and other products. Nongrowing stock accounted for a minor part of the wood supply for all other products. The fuelwood harvest was concentrated in the eastern United States. Sawlogs accounted for 40% of total roundwood harvest in 1986. This roundwood product, used in the production of lumber, accounted for 48% of all softwood harvested, but only 27% of all hardwood. Sawlog harvest was concentrated in the South Central and Southeast

Table 50.—Volume of roundwood harvested in the United States, by source of material, species group, and product, 1986.

Product	All sources			Growing stock			Other sources		
	Total	Softwoods	Hardwoods	Total	Softwoods	Hardwoods	Total	Softwoods	Hardwoods
	Million cubic feet								
Sawlogs	7,064	5,395	1,668	6,722	5,175	1,546	342	220	122
Pulpwood	4,788	3,103	1,685	3,894	2,481	1,413	894	622	272
Veneer logs	1,540	1,433	107	1,439	1,337	102	101	96	5
Fuelwood	3,114	545	2,568	798	206	592	2,316	339	1,977
Other products	1,087	868	219	1,031	842	189	56	26	30
All products	17,593	11,345	6,248	13,884	10,042	3,843	3,708	1,303	2,405

regions, and in the Pacific Coast; these regions combined accounted for 77% of the timber harvested for sawlogs (Waddell et al. 1989: table 30).

Pulpwood roundwood accounted for 27% of total timber harvest in the United States in 1986. Almost two-thirds of the pulpwood harvested was softwoods. Eighty-nine percent of all pulpwood roundwood was harvested in the Eastern United States, the South alone accounting for 69%. Although the Pacific Coast has a substantial pulp industry, most of the wood raw material is chips produced as byproduct of the manufacture of lumber.

Other products include roundwood harvested for cooperage, mine timbers, poles, pilings, posts, shakes, shingles, and logs for export. In 1986, timber harvested for these products totaled almost 1.1 billion cubic feet or 6% of all roundwood harvests. Eighty percent of the harvest for these products was softwoods. Sixty percent of the harvest for other products was concentrated on the Pacific Coast, the majority of which was logs for export. Most of the remainder of harvest for other products was in the North (21%) and the South (15%).

Timber Growth/Removal Balances

Comparisons of net growth and removals provide a spot check of the balance between the two, and by inference, an indication of what will happen to the inventory for the year of comparison. But while annual growth for any one year gives a good indication of what growth might be expected for the next few years, the removals for any given year, such as 1986, can be substantially different than the year preceding or the year following, due to the overwhelming impact of market demand on levels of timber harvest, which is the major component of removals. So, although these comparisons are interesting, they should not be used to draw inferences about long-term growth/removals balance and their effect on trends in timber inventories.

Growth/removals balance can be expressed as a ratio of growth to removals. A ratio exceeding 1 means that growth exceeds removals for the year in question; a ratio of less than 1 indicates removals in excess of growth and, for that year, a resulting decrease in inventory volume.

The growth/removals balance for the United States is positive for all species (1.37), for softwoods (1.13), and for hardwoods(1.90) (table 45). These ratios are lower than comparable ratios for 1976. The ratios in the North are very high, indicating continued substantial increases in growing-stock volume if harvests and removals remain at 1986 levels. The softwood ratio in the South is approaching 1—a stable inventory situation. The growth/removals ratio in the Rocky Mountains exceeds 2, and is higher than the 1976 ratio, due largely to increased growth. The ratio on the Pacific Coast is 1.07; for softwoods it is .93. For this section of the country, the ratio has improved by about .2 since 1976, due to growth increases in excess of increases in removals. These ratios do indicate continued decreases in softwood inventory on the Pacific Coast.

The current ratios by ownership are positive for all owner groups but forest industry. The 1986 growth/removals ratio for national forests is 1.6; for other public forest it is 2.2 for all species and 1.6 for softwoods; farmer and other private lands have a ratio of 1.5 for all species, 1.3 for softwoods, and 1.8 for hardwoods (table 46). For forest industry forests, the 1986 ratio of growth to harvest for all species is .87; for softwoods it is .77, due to high timber harvest levels in 1986. The hardwood growth/removals ratio for this owner group is 1.4.

Some words of caution are in order with reference to these ratios. They indicate balance only for the year or years cited, because the levels of removals are not stable from year to year, but can change suddenly. And the ratios here are developed for very large aggregates of forested areas, timber species, and owners. A high ratio for hardwoods as a whole means nothing with reference to individual, highly prized species such as black walnut. Any individual species, or a state or local area, may have a far different growth/harvest balance than the aggregate in which it occurs.

CHAPTER 4. ECONOMIC IMPORTANCE OF THE TIMBER PROCESSING INDUSTRIES

THE IMPORTANCE OF THE FOREST INDUSTRIES

The value of the timber produced from our Nation's forests made timber the number one agricultural crop in this country in 1986. The lumber and other solid-wood products industry ranks in the top three manufacturing industries in most regions in the country, while the paper and allied products industry ranks in the top five in one subregion. Many areas rely upon harvesting and processing of forest products for major support of local and regional economies. Many people depend upon these industries to provide both employment and income and to contribute to the economic diversity of the communities in which they live.

Timber consumption in the United States is determined by both the demand for wood products such as houses, furniture, and paper, and the available timber supplies to manufacture these products. A large and varied forest products industry has evolved within the United States to meet these demands. The primary timber processing industries are the point at which consumer demands for wood products and available timber supplies first meet. These industries provide the initial conversion of the timber resource into the wood products demanded by consumers. The secondary wood processing industries are dependent upon the products of the primary timber processing industries for their raw materials to further process wood products for final consumption. The conversion of standing timber into forest products requires a high level of industrialization and diversity within the forest products industries in the United States.

Over time, the timber processing industries have responded to changes, in both consumer demand and timber supply, by developing new products and processing technologies. These developments help to satisfy existing demands, while creating new demands for wood products. New products and technologies also use existing components more efficiently and create new uses for previously unused components. They also assist in maintaining competitiveness in national and international markets. Improvements in conversion of the forest resource are most apparent in product recovery, where new technologies increase the production of forest products from roundwood. Since our consumption of wood products is ultimately determined by this ability of the timber processing industries to convert roundwood into usable wood products, it is important to understand how these industries operate if we are to ensure that projected levels of consumer demand can be satisfied.

This chapter begins with a discussion of the volume and value of the roundwood products harvested in the United States. These values are then compared with agricultural crops to provide a sense of scale for the forest products industry. The scope of forest industry manufacturing is discussed in the context of regional and national economies. Next, a comparison with all other manufacturing industries is provided. This is followed by a discussion of the relative importance of the timber processing industries, by industry type and region. The chapter ends with a detailed discussion of the primary timber processing industries, nationally and regionally, focusing on employment, wages and salaries, value added by manufacture, value of shipments, production capacity, production costs, recovery factors, and production trends in each industry.

Volume and Value of Roundwood Timber Products

The timber harvested from our Nation's timberlands is initially processed as logs, bolts, and other roundwood products. Most roundwood comes from growing stock sources on timberlands. Removals of dead, rough, rotten, and small trees, stumps, tops, and limbs, as well as trees from fencerows, urban areas, and other nontimberland sources also increase total roundwood supply.

Production of Roundwood Timber Products

In 1986, an estimated 17.6 billion cubic feet of roundwood timber products were harvested in the United States. Of this, over 11.3 billion cubic feet came from softwood species, and 6.3 billion cubic feet came from hardwood species (Waddell et al. 1989: table 30).

The estimated value of this roundwood timber harvest in 1986 was $5.7 billion, with 84% being derived from the harvest of softwood timber and the remaining 16% from hardwood species (McKeever and Jackson 1990: table B-1). These values are based on softwood and hardwood stumpage prices provided by the Regional Offices of the National Forest System of the U.S. Forest Service. When the value added from harvesting the timber and moving it to a local point of delivery, such as a rail siding or concentration yard, is included, the value of the 1986 roundwood output in the United States was approximately $12.6 billion (table 51).

Relative Importance of Roundwood Products

A diversity of timber products used for both industrial and consumer applications is represented in the total roundwood harvest. Better quality trees are processed into lumber, while many of the largest and best logs become veneer logs and are processed into plywood. Together, 8.6 billion cubic feet of sawlogs and veneer logs were harvested in 1986, accounting for 49% of total roundwood production. Softwood harvest for sawlogs constituted 5.4 billion cubic feet (31%), while hardwoods harvested for sawlogs were 1.7 billion cubic feet (9.5%). The volume of softwood roundwood produced

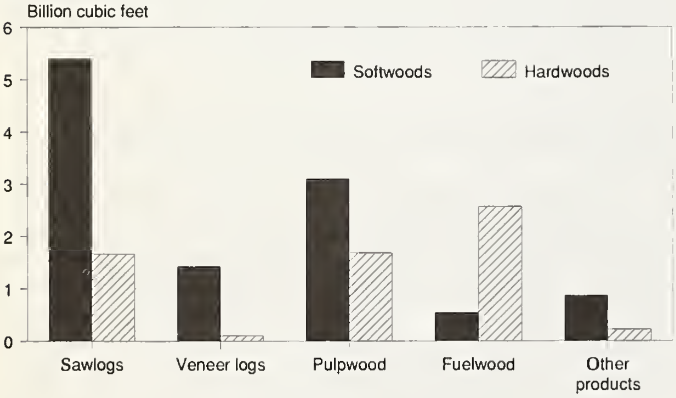
Table 51.—Estimated values at local points of delivery of roundwood timber products[1] and other agricultural crops[2] in the United States, by region and subregion, 1986.

Region and subregion	Value of roundwood timber products	Value of other agricultural crops	Value of roundwood timber products as a percentage of other agricultural crops
	Million dollars		*Percent*
North			
Northeast	867	2,910	30
North Central	760	20,125	4
Total	1,627	23,035	7
South			
Southeast	2,311	5,689	41
South Central	2,799	8,078	35
Total	5,110	13,767	37
Rocky Mountain			
Great Plains	15	7,540	([3])
Rockies	789	4,357	18
Total	804	11,897	7
Pacific Coast			
Pacific Southwest	1,032	7,730	13
Pacific Northwest[4]	3,946	2,517	157
Alaska	104	5	2,080
Total	5,082	10,252	50
United States	12,624	59,445	21

[1]*Includes logs, bolts, or other round sections cut from trees.*
[2]*Includes field crops, fruits and nuts, and vegetables of commercial significance.*
[3]*Less than 0.5%.*
[4]*Data for the Pacific Northwest-West and Pacific Northwest-East subregions are not available.*
Sources: Timber: Waddell et al. 1989: table 30; USDA FS estimates. Agricultural crops: USDA Statistical Reporting Service, Crop Reporting Board 1987.

for veneer logs was 1.4 billion cubic feet (8.2%); hardwood roundwood produced for the same purpose was 107 million cubic feet, or less than 1% of total harvest (fig. 30, Waddell et al. 1989: table 30).

Smaller and lower-grade trees are harvested as pulpwood to supply pulp, paper, and paperboard mills. In 1986, 3.1 billion cubic feet of softwood roundwood and 1.7 billion cubic feet of hardwood roundwood was harvested for pulpwood. This represents nearly 27% of total roundwood timber production (Waddell et al. 1989: table 30).



Source: Waddell et al. 1989; table 30

Figure 30.—Volume of roundwood timber products harvested, by type and species group, 1986.

Fuelwood for industrial and residential use has increased in importance during recent periods of high energy prices. The 1986 hardwood share of the roundwood fuelwood harvest accounted for over 82% of all fuelwood and 41% of the total hardwood roundwood harvest. Most roundwood fuelwood is used for residential heating, as industries usually rely on wood processing byproducts for fuel. A substantial amount of fuelwood is self-cut by households and comes from nongrowing stock sources that do not otherwise produce industrial timber (Skog and Watterson 1983, Rudis 1986). Markets for fuelwood are very diversified, and wide variations in prices exist, depending upon vendor, species, timing, condition, availability, and other factors. Consequently, fuelwood, although an important component of roundwood production, is very difficult to measure.

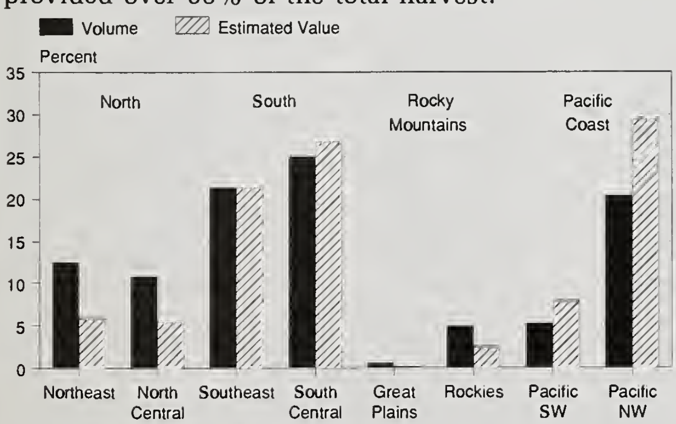
Production of roundwood for other products accounted for 6.1% of the total 1986 roundwood timber production (fig. 30). Other products include roundwood used for cooperage, pilings, poles, posts, shakes, shingles, charcoal, and export logs.

The value of these roundwood timber products varies greatly by product. Across all regions, the average price paid for softwood sawtimber and used for sawlogs and veneer logs is over three times higher than the price paid for softwood pulpwood, fuelwood, or miscellaneous products. The value of the total roundwood production in the United States was over $5 billion, with $4.8 billion attributable to softwood products and less than $1 billion to hardwood roundwood products (McKeever and Jackson 1990: table B-1). Softwood sawlogs accounted for 56% of the total value of all roundwood products; softwood veneer logs for 16%. Higher prices paid for softwood sawtimber, relative to softwood pulpwood, hardwood products and fuelwood account for much of this difference, as does the larger quantity of softwoods harvested. However, prices for scarce or premium hardwoods may be several times the average for either softwood sawtimber or mixed hardwoods.

Relative Importance of Regions

Generally, the roundwood output from individual supply regions represents the timber resources within each region. Historically, this has been demonstrated by cyclic levels of production across the country. As the timber resources of a region became economically accessible production increased, peaked, and eventually declined. The result has been a gradual westward movement, from the northern and southern regions, into the Midwest, then eventually spreading throughout the West. Concurrent with the reduction of the supply of high quality, old-growth timber in the Pacific Coast, the abundant timber supplies in the South have again matured, offering new opportunities for increasing roundwood production in this region. Consequently, a shift from roundwood production in the West back to the South has been slowly occurring in the last several decades.

Roundwood production in 1986 came primarily from three subregions (fig. 31). The Southeast subregion provided 21.2% of all roundwood production, the South Central 24.7%, and the Pacific Northwest 20.3% of total production. The combined northern subregions provided 23.2%, and the Rockies and Pacific Southwest subregions each contributed 5% of the total roundwood produced in 1986. Over 65% of the 1986 roundwood production in the two southern regions came from softwood species, while in the Pacific Northwest, softwoods provided over 96% of the total harvest.



Source: Waddell et al. 1989; table 30

Figure 31.—Percentage volume and value of roundwood timber products harvested, by region and subregion, 1986.

In terms of the value of this roundwood produced, the gap between the combined Southeast and South Central subregions (48.2%) and the Pacific Northwest subregion (29.3%) is smaller (McKeever and Jackson 1990: table B-1). Again, this is due to differences in the regional characteristics of the available timber resources. Since the harvest in all three of these subregions is predominately softwoods, the stumpage prices paid for roundwood is heavily weighted by higher softwood roundwood stumpage prices, especially in the Pacific Northwest.

Relative Importance of Regional Products

Nationwide, sawlogs and pulpwood are the major roundwood products produced. Regionally and subregionally, the importance of these two outputs varies. Sawlog production is ranked first in the Pacific Northwest, Rockies, Pacific Southwest, and Alaska subregions. In both the Southeast and South Central subregions, pulpwood production is the major roundwood output, while in the Northeast and North Central subregions, fuelwood is the major component of total regional roundwood production. These rankings demonstrate the effects of regional timber supply characteristics, as do the regional softwood-hardwood proportions of the total roundwood harvest.

Sawlog production in the West (Pacific Coast and Rocky Mountain regions) is composed primarily of softwood species, averaging over 95% of total sawlog production (Waddell et al. 1989: table 30). Pulpwood production in the South is also predominately from softwood species, averaging about 67%. Fuelwood production in the North, however, is over 92% hardwoods.

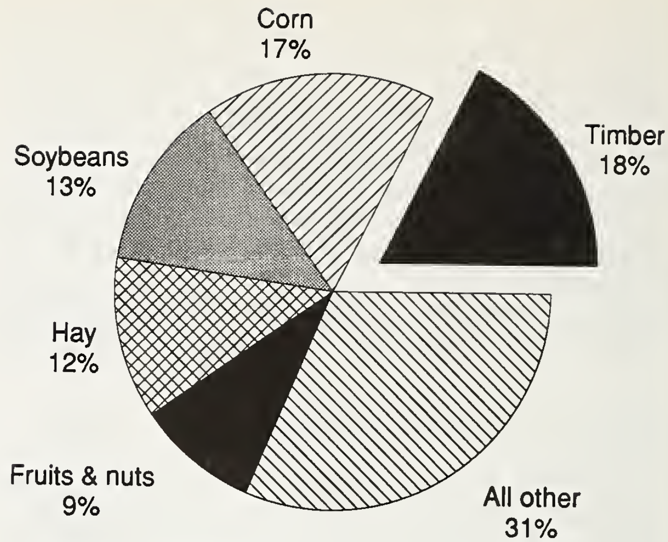
The estimated value of these regional outputs reflects both regional timber characteristics and relative valuations placed on those outputs. The timber economy of the Western regions is largely supported by softwood sawlog outputs, which accounted for 38% of the value of all sawlog production and 26% of the value of all roundwood production. The Pacific Northwest subregion was responsible for most of this, providing over 27% of the value of sawlogs and 29% of the value of all roundwood production (McKeever and Jackson 1990: table B-1).

Sawlog values, as a percent of the value of total roundwood, are almost equal in the Southeast (15%) and South Central (17%) subregions. The value of veneer logs in these two subregions is higher than the value of pulpwood, although the volume of pulpwood production is greater. Similarly, although much of the roundwood harvest in the Northeast and North Central subregions is fuelwood, the valuation of this roundwood output is low.

Value of Timber Products Compared with Agricultural Crops

Timber products comprise a large part of the total value of agricultural crops produced in the United States annually. In 1986, roundwood timber products, at local points of delivery, were valued at $12.6 billion, compared to $59.4 billion for other agricultural crops (table 51). Timber products value at local points of delivery are defined here to be timber products output volumes multiplied by estimated stumpage prices and logging and hauling costs. Timber products were valued at about 21% of the value of other agricultural crops; for every dollar of timber products produced, about $4.75 of other agricultural crops were produced.

In addition to timber, there are 28 individual agricultural crops identified by the Crop Reporting Board of the USDA Statistical Reporting Service. Timber was the single, highest-valued crop produced in the United States in 1986. Timber (at $12.6 billion) exceeded corn, the second largest crop valued at $12.4 billion, by $200 million (McKeever and Jackson 1990: table B-2). Timber accounted for 18% of total crop values; corn 17% (fig. 32). Just three other crops—soybeans, hay, and fruits and nuts—had values of more than half that of timber. The remaining 25 crops had values less than half the timber value, 18 crops had values less than 10% of timber.



Sources: see table 51

Figure 32.—Percentage value of roundwood timber products and other major agricultural crops, 1986.

The relative importance of timber compared to other agricultural crops varies by region and subregion of the country. Timber is the highest valued crop in the South, the Pacific Northwest, and in Alaska (table 52). The value of timber in the South is more than three times that of tobacco, the second highest valued crop. Within the two southern subregions, timber values are about twice that of the second largest crops. Since the second largest crops are different in each of the two southern subregions, combined timber values for the region far exceed other crop values for the South as a whole.

As in the South, timber is the highest valued crop in the Pacific Northwest subregion, and in Alaska. Timber values in both exceed the combined value of all other crops produced there, and timber values in the Pacific Northwest exceed timber values in all other regions (table 52). In the Pacific Southwest, timber ranks third, well below fruits and nuts, and vegetables. The large

Table 52.—Estimated values at local points of delivery of roundwood timber products[1] and the highest valued agricultural crops[2] in the United States, by region and subregion, 1986.

Region and subregion	First		Second		Third		Fourth		Fifth	
	Crop	Value	Crop	Value	Crop	Value	Crop	Value	Crop	Value
	Million dollars									
North	Corn	8,887	Soybeans	6,725	Hay	3,672	Timber	1,627	Fruit & nut	802
Northeast	Hay	1,093	Timber	867	Fruit & nut	511	Corn	472	Vegetables	267
North Central	Corn	8,415	Soybeans	6,602	Hay	2,579	Timber	760	Wheat	648
South	Timber	5,110	Tobacco	1,690	Soybeans	1,641	Hay	1,630	Cotton	1,451
Southeast	Timber	2,311	Fruit & nut	1,317	Tobacco	1,033	Peanuts	749	Vegetables	740
South Central	Timber	2,799	Cotton	1,349	Hay	1,300	Soybeans	1,222	Wheat	790
Rocky Mountains	Wheat	2,666	Hay	2,323	Corn	2,265	Soybeans	960	Timber	804
Great Plains	Corn	2,052	Wheat	1,838	Hay	1,055	Soybeans	960	Sorghum	608
Rockies	Hay	1,268	Wheat	827	Timber	789	Potatoes	517	Barley	393
Pacific Coast	Timber	5,082	Fruit & nut	4,109	Vegetables	2,216	Hay	1,022	Cotton	665
Pacific Southwest	Fruit & nut	3,331	Vegetables	1,980	Timber	1,032	Cotton	665	Hay	617
Pacific Northwest[3]	Timber	3,946	Fruit & nut	778	Wheat	429	Hay	402	Potatoes	355
Alaska	Timber	104	Hay	3	Potatoes	2	Barley	1	Oats	[4]
United States	Timber	12,624	Corn	12,387	Soybeans	9,326	Hay	8,647	Fruit & nut	6,520

[1]*Includes logs, bolts, or other round sections cut from trees.*
[2]*Includes field crops, fruits and nuts, and vegetables of commercial significance.*
[3]*Data for the Pacific Northwest-West and Pacific Northwest-East subregions are not available.*
[4]*Less than $500,000.*
Source: See table 51.

areas of irrigated crop lands in Southern California account for the importance of these two agriculture crops over timber.

Timber values in the North and the Rocky Mountain regions are small compared to other agriculture crops, and to timber in other regions of the country. In both the Northeast and North Central subregions, timber production is valued at well below $1 billion (table 52). For the North region, timber ranks fourth at $1.6 billion. As expected, timber is not an important crop in the Great Plains subregion of the Rocky Mountains, but it ranks third in the Rockies below hay and wheat. For the Rocky Mountain region, timber's rank drops to fifth due to the large impact of Great Plains' field crop production.

From these comparisons, it is apparent that timber is an important, vital crop in the United States. It is the single most important agricultural commodity in many areas of the country, with changes in production levels or prices dramatically affecting local, state, and regional economies.

Contribution of All Forest Industries to Regional and National Economies

The volume and value of roundwood timber products are two indicators of the contribution to the economy made by roundwood timber. Roundwood production levels, stumpage payments made to landowners, and payments made to transport roundwood to processing sites represent both employment and income resulting from utilization of the Nation's forest resources at the harvesting stage. Every year, the sale of U.S. Forest Service timber generates a return of 25% of gross revenue to the counties where harvest occurred.[12] This money is allocated to roads and schools in these counties and represents a significant contribution to many counties throughout the Nation.

Scope of Forest Industry Manufacturing

The wood manufacturing industries rely on the roundwood forest resource for income and employment. Industries such as sawmills and paper mills process roundwood directly into lumber, newsprint, and other marketable primary wood products. Some industries purchase these products to manufacture more highly finished, secondary goods, such as cabinets, furniture, pallets, paper bags, and high-grade paper products. Producers of gum and wood chemicals also rely on timber for raw materials.[13]

The 1986 Annual Survey of Manufacturers (USDC BC 1988b) is used for information on employment, wages and salaries, value of shipments, and value added from manufacture. These measures serve as indicators of the effects the forest industries have on regional and national economies. Most are self explanatory but value added is a net measure of an industry's contribution to the economy because the value of materials received from other firms and used in the manufacturing process is subtracted from the value of the products shipped.

Contributions to the National Economy

The forest industries are a vital component of the Nation's economy. About 8% of all employment, wages and salaries, value added by manufacture, and value of shipments by all manufacturers were directly attributable to the forest industries in 1986 (table 53). This translates to a workforce of more than 1.6 million employees earning nearly $34.3 billion. Industry shipments were valued at $185.8 billion, with $83.4 billion being value added.

In terms of the gross national product, forest industries wages and salaries were less than 1% and the value of shipments was 4.4% of GNP in 1986. In total, over 5% of the gross national product is derived from the production of the forest industries, as measured by these indicators.

Contributions to Regional Economies

The contributions made by forest industries, in comparison to all manufacturing industries, to regional economies vary widely. The North, which is relatively more industrialized than other regions, is less dependent on the forest industries for economic stability than the South and Pacific Coast where the forest industries represent a larger proportion of all manufacturing. The Rocky Mountain region has about the same proportional contribution to manufacturing by the forest industries as does the North, but in absolute terms, is less than a tenth the size of the North.

Economies in the Northeast and North Central subregions of the North received nearly equal contributions from their forest industries. These are the two largest subregions in the United States in terms of both total manufacturing and forest industries manufacturing. Forest industries in the Northeast accounted for about 6% of all employment, wages and salaries, value added by manufacture, and value of shipments (table 53). Forest industries in the North Central subregion contributed 8% of employment, and about 7% each of wages and salaries, value added by manufacture, and value of shipments.

The South is the region most dependent on the forest industries for its economic well-being, even though its individual subregions rank only third and fourth among all subregions in the percentage contribution by forest industries to all manufacturing. The total size of the forest industries in the South is nearly equal to that in the North, but all other manufacturing is considerably

[12] *The sale of Bureau of Land Management timber returns 50% of gross revenues to the counties where harvest occurs.*

[13] *Using the two-digit Standard Industrial Classification (SIC) code (Office of Management and Budget 1972), the Forest Industries are defined here to be lumber and wood products (SIC 24), furniture and fixtures (SIC 25), paper and allied products (SIC 26), and Industry 2861—gum and wood chemicals.*

Table 53.—Employment, wages and salaries, value added by manufacture, and value of shipments for all manufacturing and for forest industries,[1] by region and subregion 1986.

Region and subregion	Employment[2] All industries	Employment[2] Forest industries		Wages and salaries[2] All industries	Wages and salaries[2] Forest industries	
	Thousands		*Percent*[3]	*Million dollars*		*Percent*[3]
North						
Northeast	4,739.4	307.9	6	119,205.1	6,629.2	6
North Central	5,036.4	381.6	8	135,744.3	8,630.9	6
Total	9,775.8	689.5	7	254,949.4	15,260.1	6
South						
Southeast	2,585.1	340.9	13	51,444.7	6,225.0	12
South Central	2,656.0	288.8	11	58,557.4	5,635.5	10
Total	5,241.1	629.7	12	110,002.1	11,860.5	11
Rocky Mountains						
Great Plains	315.7	16.3	5	6,985.8	302.0	4
Rockies	567.7	48.2	8	13,701.7	931.3	7
Total	883.4	64.5	7	20,687.5	1,233.3	6
Pacific Coast						
Pacific Southwest	1,996.7	143.0	7	52,719.5	3,025.1	6
Pacific Northwest[4]	474.4	116.0	24	12,447.7	2,842.9	23
Alaska	8.8	1.3	15	230.5	39.2	17
Total	2,479.9	260.3	10	65,397.7	5,907.2	9
United States	18,380.2	1,644.0	9	451,036.7	34,261.1	8

Region and subregion	Value added by manufacture[2]			Value of shipments[2]		
	Million dollars		*Percent*[3]	*Million dollars*		*Percent*[3]
North						
Northeast	256,713.5	15,787.0	6	495,877.2	33,743.1	7
North Central	302,304.0	21,193.2	7	682,008.4	44,756.9	7
Total	559,017.5	36,980.2	7	1,177,885.6	78,500.0	7
South						
Southeast	134,488.3	15,085.0	11	286,570.9	34,374.0	12
South Central	150,948.3	14,444.4	10	385,640.2	33,281.2	9
Total	285,436.6	29,529.4	10	672,211.1	67,655.2	10
Rocky Mountains						
Great Plains	19,272.9	740.7	4	51,668.6	1,681.7	3
Rockies	31,875.0	2,018.3	6	64,888.7	4,849.2	7
Total	51,147.9	2,759.0	5	116,557.3	6,530.9	6
Pacific Coast						
Pacific Southwest	114,142.3	7,080.9	6	227,603.4	15,602.1	7
Pacific Northwest[4]	26,076.7	6,995.6	27	66,057.3	17,389.7	26
Alaska	501.2	63.7	13	2,014.7	135.3	7
Total	140,720.2	14,140.2	10	295,675.4	33,127.1	11
United States	1,036,322.2	83,408.8	8	2,262,329.4	185,813.2	8

[1]*Includes logging contractors and manufacturers whose primary products include softwood and hardwood rough and dressed lumber, flooring, dimension stock, railroad ties, furniture frames, wood lath, wood chips, pulp, paper, paperboard, building paper and board, veneer, plywood, millwork, wood furniture and fixtures, wood containers, pallets, prefabricated wood structures and mobile homes, shingles, excelsior, particleboard, gums and wood chemicals, wood preserving, and converted paper and paperboard products.*

[2]*Data may have been withheld to avoid disclosure.*

[3]*Forest industries as a percent of all U.S. industries.*

[4]*Data for the Pacific Northwest-West and Pacific Northwest-East subregions are not available.*

Note: Data may not add to totals because of rounding.

Source: USDC BC 1988b.

smaller making the proportional contribution by the forest industries greater in the South. For example, forest industry employment in the North and South regions was nearly equal at .69 and .63 million, while employment in all industries was nearly twice as much in the North as in the South (table 53, fig. 33). Employment was 13 and 11% of all manufacturing; wages and salaries, value added by manufacture, and value of shipments were about 12% and 10%, respectively, in the Southeast and South Central subregions.

The Rocky Mountain region is a diverse mixture of geographical types, including primarily agricultural lands in the Great Plains subregion, and forest lands in the Rockies subregion. The makeup of the forest industries in the region reflect this diversity. Proportionally, the Great Plains subregion has the smallest forest industry. Just 5% of all manufacturing employees are in the forest industries, and about 4% of manufacturing wages and salaries, value added, and value of shipments originate in the forest industries. Manufacturing in the Rockies subregion is much more dependent on the forest industries. Eight percent of all employees, and about 7% of all wages and salaries, value added by manufacture, and value of shipments from manufacturing result from the forest industries.

The Pacific Coast is the second largest region in the proportional contribution of its forest industries to total manufacturing. Much of this is directly attributable to the Pacific Northwest subregion. The Pacific Northwest is a major timber producing area, with its economy being dependent on forest industries. This dependency is reflected in the four measures reported here. Forest industry accounts for 24% of all employment (table 53), 23% of the wages and salaries, 27% of the value added by manufacture, and 26% of the value of shipments. These last three measures are the highest shares in any region or subregion.

The percentage distribution in the Pacific Southwest is nearly identical to that in the Northeast. Seven percent of employment, and about 6% each of wages and salaries, value added by manufacture, and value of shipments are accounted for by forest industries in this subregion.

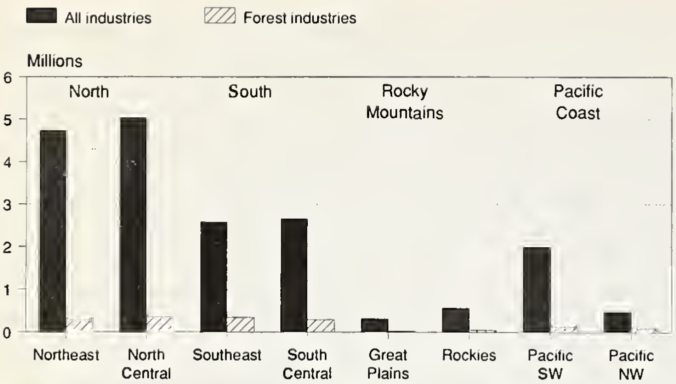
Although Alaska has the lowest measures for all industry and forest industry activity of all subregions, it ranks second only to the Pacific Northwest in contributions by forest industries to its manufacturing economy. Fifteen percent of all manufacturing employment in Alaska is in the forest industries, reflecting the importance of timber. Seventeen percent of total wages and salaries, 13% of the value added by manufacture, and 7% of the value of shipments are due to forest industry activity in Alaska.

CHARACTERISTICS OF THE PRIMARY TIMBER PROCESSING INDUSTRIES

The Nation's timber processing industries can be divided into seven primary industries based on the types of products produced. These primary timber processing industries include logging and harvesting operations; producers of solid-wood commodities such as softwood and hardwood lumber, structural and nonstructural panels, and a wide variety of other wooden products such as pallets, treated fence posts, ladders, and picture frames; as well as producers of fiber-based commodities such as pulp, paper and paperboard. Information for each of these groups was compiled, in part, from data reported in the periodic Census of Manufacturers and in the annual Survey of Manufacturers conducted by the U.S. Department of Commerce, Bureau of the Census. The most recent Census of Manufacturers was conducted in 1982; the most recent Survey of Manufacturers in 1986. The following list shows the composition of the timber processing categories used here, based on SIC industry and product groupings:

Primary timber processing industry	SIC code	SIC industry or product
Timber harvesting	2411	Logging camps and contractors
Lumber	2421	Sawmills and planing mills, general
	2426	Hardwood dimension and flooring
	2429	Special product sawmills, not elsewhere classified
	2448	Wood pallets and skids
Structural panels	2436	Softwood veneer and plywood
	24922	Waferboard and oriented strand board
Nonstructural panels	2435	Hardwood veneer and plywood
	24996	Hardboard
	26611	Insulating board
	24921	Particleboard
	24993	Medium-density fiberboard
Other primary timber	2441	Nailed wood boxes and shook
	2449	Wood containers, not elsewhere classified
	2491	Wood preserving
	2499	Wood products, not elsewhere classified, except hardboard and medium-density fiberboard
Wood pulp	2611	Pulpmills
Paper and paperboard	2621	Paper mills, except building paper
	2631	Paperboard mills
	2661	Building paper and board mills, except insulating board

Source: Office of Management and Budget 1972



Source: USDC Bureau of the Census 1988b

Figure 33.—Employment in all industries and forest industries, by region and subregion, 1986.

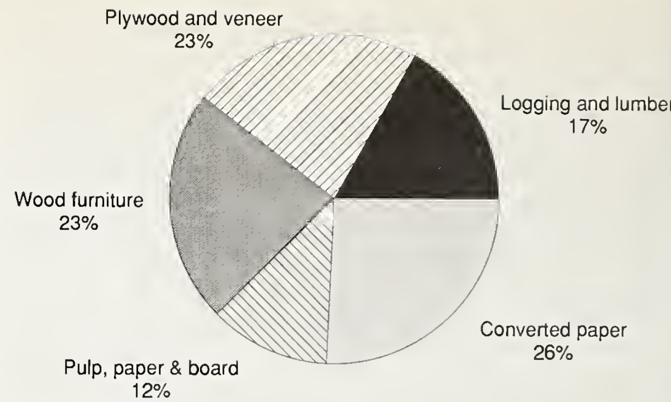


Figure 34.—Percentage employment in the timber processing industries, by industry, 1986.

Relative Importance of Various Industries

These seven industries can be grouped into five to better understand and compare them. These five timber processing industries are: the logging and lumber industry; plywood, veneer, and other wood products industry; wood furniture and fixtures industry; pulp, paper, and board industry; and the converted paper and paper board industry.

Four economic measures can be used to assess the relative importance between the timber processing industries. Employment in each of the 5 timber processing industries ranges from a high of more than 400 thousand (26% of total employment) in the converted paper and paperboard industry; to a low of under 200 thousand (12% of total employment) in the pulp, paper and board industry in 1986 (table 54, fig. 34). Employment levels reflect the nature of the end product, more than the number of establishments or extent of capitalization. For example, those industries producing largely secondary or consumer products such as furniture and fixtures, or paper products, tend to have more employees than those producing mostly primary or intermediate products such as lumber, plywood, containers, or woodpulp.

Total wages and salaries paid out in 1986 exceeded $32 billion (table 54). The converted paper and paperboard industry paid the highest total wages and salaries ($9.3 billion), followed by the pulp, paper, and board industry ($6.8 billion). Average compensation per employee, a measure of relative differences between industries, was higher in the two fiber-based industries than in the three solid-wood-based industries. Higher average compensation in the paper industries reflects many characteristics of the industry, including the need for better trained employees, the corporate nature of mill ownership, the degree of unionization of the labor force, and relatively stable levels of consumption for the end product.

Value added by manufacture in all timber processing industries totaled nearly $80 billion 1982 dollars in 1986; value of shipments was nearly $180 billion (table 54). The two paper industries accounted for over half of the value of all shipments, with more than half of these being converted paper and paperboard products. Value added per dollar of shipments measures the contribution of the industry to the end product. Industries which produce primary products or commodities tend to add less value to the product in manufacturing than those

Table 54.—Employment, wages and salaries, value added by manufacture, and value of shipments in the timber processing industries, 1986.

Industry	Employment	Wages and salaries	Value added by manufacture	Value of shipments
	Thousands	*Million 1982 dollars*		
Logging and lumber	263.3	4,485.5	9,994.8	26,130.8
Plywood, veneer, and other wood products	359.1	6,376.1	13,402.5	32,403.5
Wood furniture and fixtures	356.8	5,758.2	12,251.9	23,399.5
Pulp, paper, and board	197.5	6,760.4	18,668.8	40,932.8
Converted paper and paperboard	405.1	9,320.3	25,168.1	56,725.0
Total	1,581.8	32,700.5	79,486.0	179,591.6

Source: USDC BOL 1988.

producing secondary or consumer goods. Further, the value of an end product such as furniture, is more dependent on the manufacturing process than the value of the raw material used to produce it. In 1986, 52% of the value of wood furniture and fixtures shipments were a result of value added, as opposed to 38% in the logging and lumber industry. All industries averaged 44% of the value of industry shipments resulting from the manufacturing process.

National Characteristics

Industry Characteristics

The primary timber processing industries in the United States employed more than 600 thousand persons in 1986, and paid out nearly $14 billion in wages and salaries, measured in 1982 dollars (table 55). Total industry shipments were valued at nearly $81 billion, of which $34 billion was added by manufacture. Timber harvesting, lumber manufacturing and other primary timber processing accounted for 56% of all employment and 39% of the value of all shipments originated in 1986 (McKeever and Jackson 1990: table B-5). Structural and nonstructural panels, woodpulp, and paper and paperboard industry groups accounted for 44% of employment and 61% of the value of all primary timber products shipped.

During the 1980s, most industries experienced reductions in employees and constant-dollar value of shipments. The only increases were in the number of employees in the woodpulp industry. The solid-wood industries (lumber and structural panels) were most severely impacted. These declines cannot be completely blamed on the 1982 economic recession. Long-term trends in the primary timber processing industries have been towards larger mills with fewer employees producing goods with increasing real total value and value per employee (figs. 35 and 36). These long-term trends are evident in 1986 as total employment remained near the 1982 low, but constant dollar shipments and shipments per employee rose to record levels.

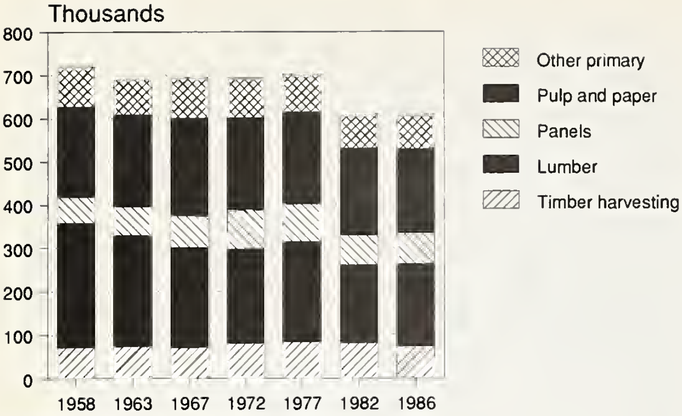
Organization

Overall, establishments in the primary timber processing industries tend to be small and to operate as single-unit companies. The timber harvesting, and lumber and other primary timber manufacturing dominate the primary timber processing industry. Overall industry trends in establishment types are largely determined by these three groups. The remaining primary processors, those producing structural panels, nonstructural panels, woodpulp, and paper and paperboard, tend to be large establishments operated by multi-unit companies.

Table 55.—Employment, wages and salaries, value added by manufacture, and value of shipments in the primary timber processing industries, 1986.

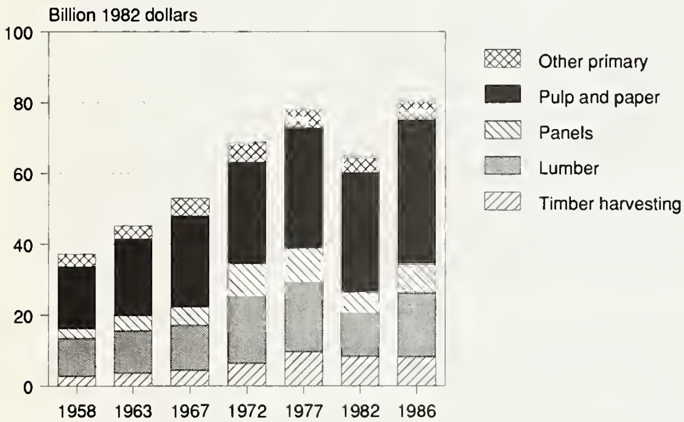
Industry	Employees	Wages and salaries	Value added by manufacture	Value of shipments
	Thousands	*Million 1982 dollars*		
Timber harvesting	72.3	1,247.5	2,886.5	8,219.3
Lumber manufacturing	191.0	3,238.0	7,108.3	17,911.6
Structural panel manufacturing				
Softwood veneer and plywood	35.9	824.5	1,675.0	4,392.3
OSB/waferboard	2.5	87.1	393.2	664.8
Total	38.4	911.6	2,068.3	5,057.1
Nonstructural panel manufacturing				
Hardwood veneer and plywood	17.0	268.2	630.7	1,582.0
Hardboard, insulating board, particleboard, and medium-density fiberboard	14.3	274.7	642.8	1,587.7
Total	31.3	542.8	1,273.6	3,169.8
Woodpulp manufacturing	15.3	592.5	1,587.6	3,829.6
Paper and paperboard manufacturing				
Newsprint	10.7	321.5	1,088.0	2,524.0
Other paper	118.6	4,100.0	10,949.7	23,202.0
Paperboard	51.0	1,710.5	4,937.3	11,138.0
Total	180.3	6,131.9	16,975.0	36,864.0
Other primary timber manufacturing	79.0	1,117.3	2,392.4	5,502.0
Total, primary timber processing	607.6	13,781.7	34,291.6	80,553.3

Note: Data may not add to totals because of rounding.
Source: USDC BC 1988b.



Source: USDC Bureau of the Census 1971, 1987.

Figure 35.—Employment in the primary timber processing industries, by industry, specified years 1958–1986.



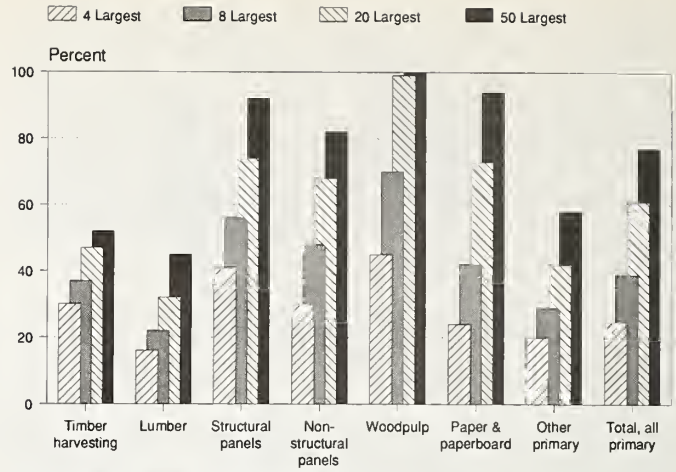
Source: USDC Bureau of the Census 1971, 1987.

Figure 36.—Value of shipments in the primary timber processing industries, by industry, specified years 1958–1986.

The most common legal form of organization in the primary timber processing industries is noncorporate, individual ownership. Again, overall trends are largely dependent on the timber harvesting, lumber, and other primary timber industries. Timber harvesting is the only industry where noncorporate ownership prevails. The level of incorporation in the other industries varies from about half for the lumber industry to complete incorporation for the woodpulp industry. Differences between the industries reflect, to some extent, the levels of capital needed to build, operate, and maintain equipment and production facilities.

Concentration

One way to view industry structure is to measure how much output is accounted for by some specified number of the largest companies. Using the average for all primary timber processing industries,[14] 25% of the value of shipments of all companies was accounted for



Source: USDC Bureau of the Census 1985.

Figure 37.—Percentage of value of shipments in the primary timber processing industries, by company size and industry, 1982.

by the 4 largest companies (fig. 37). In the structural panels and the woodpulp industries, the 4 largest companies accounted for 41 and 45%, respectively, of the value of shipments. The 4 largest companies in the lumber and the other primary timber products industries accounted for just 16 and 20%, respectively, of the value of industry shipments.

When looking at the proportions accounted for by the eight largest companies, these relative rankings remain the same. The average value of shipments of all primary timber processing industries accounted for by the 8 largest companies within each industry group in 1982 was 39%. In the structural panels and woodpulp industries, 56 and 70%, respectively, of the value of shipments were attributed to the 8 largest companies. The value of shipments by the 8 largest companies for lumber manufacturing and the other primary timber industries accounted for just 22 and 29%, respectively. These proportions reflect the more capital-intensive nature of the panel and pulp industries compared to the lumber and other primary timber industries.

In 1982, the 50 largest primary timber processing companies accounted for 77% of all industry shipments (fig. 37), compared to 70% in 1972. Patterns of shipments by company size within the individual industry groups are similar to the patterns stated above. Approximately one-half of the value of all shipments in the timber harvesting, lumber, and other primary timber industries were accounted for by the 50 largest companies. In contrast, over 80% of all shipments in the remaining industries—structural panels, nonstructural panels, and the paper and paperboard industries—were accounted for by the 50 largest companies (fig. 37). The 20 largest woodpulp-producing companies accounted for 99% of industry shipments.

Regional Capacity

Primary timber processing industries usually locate close to raw material supplies, thereby reducing acqui-

[14] *This section is based on data from the 1982 Census of Manufacturers (USDC BC 1985) which is the most recent source of this data.*

sition and transportation costs, and ensuring timber supply sources. Differences in roundwood supplies influence the types of industries located within each region. Timber species, size, and quality; ownership and size of timber tracts; accessibility and quality of transportation networks; and the general availability of timber are all influencing factors.

Information on the productive capacity of the primary timber processing industries for 1985 (table 56) was available for four industries: lumber, softwood plywood, woodpulp, and paper and paperboard manufacturing. By their nature, the remaining industries—timber harvesting, nonstructural panels, and other primary timber—do not lend themselves to aggregated measures of industry capacity. The South ranks first in capacity for woodpulp, and paper and paperboard production, and second in lumber manufacturing capacity. Structural panel capacity is nearly equal in the South and Pacific Coast regions. The Pacific Northwest subregion had more lumber manufacturing capacity than any other single region or subregion. Lumber manufacturing capacity in this region in 1985 exceeded that of the Southeast, the second largest subregion, by 50%. The North ranked second in both woodpulp, and paper and paperboard capacities in 1985.

Significant Changes in the Last Decade

Two distinct changes occurred in the primary timber processing industries in the last 10 years. The first was a change in raw material supplies, which has affected all industries and their products. Depletion of the old-growth timber and the removal of large tracts of national forest lands from timber production in the West have shifted production away from large diameter sawlogs and veneer logs to smaller diameter logs with different utilization characteristics in those regions. During the same period, the availability and utilization of Southern pine roundwood has increased. For both Southern subregions, this has altered harvest by landowner class, the quality of available roundwood, and in the extreme, location of individual firms. During the last decade, a few large, integrated firms physically moved their headquarters from the Pacific Northwest to the South in response to these changes in raw material supplies.

The second significant change in the last decade has been the increasing adoption of new technologies by all industries. These technologies usually focus on either increasing product recovery or reducing labor requirements, both of which result in improvements in efficiency. For solid-wood products, the economic recession

Table 56.—Annual production capacity for specified primary timber processing industries in the United States, by region and subregion, 1985–86.[1]

Region and subregion	Lumber	Softwood plywood	Woodpulp	Paper and paperboard
	Million board feet (lumber tally)	*Million square feet (3/8-inch basis)*	*Thousand tons*	
North				
Northeast	NA	NA	4,849	11,754
North Central[2]	NA	NA	4,614	14,100
Total	NA	NA	9,463	25,854
South				
Southeast	6,945	3,710	19,227	18,901
South Central	5,865	8,975	21,800	21,706
Total	12,810	12,685	41,027	40,607
Rocky Mountains[3]	5,075	1,240	736	1,512
Pacific Coast				
Pacific Southwest	4,900	325	1,182	2,501
Pacific Northwest	13,625	11,000	7,846	7,447
Pacific Northwest-West	10,440	10,150	NA	NA
Pacific Northwest-East	3,185	850	NA	NA
Alaska	377	NA	433	NA
Total	18,902	11,325	9,461	9,948
United States	36,410	25,250	60,686	77,921

NA—Not available.
[1]*Average annual capacity for the 2-year period.*
[2]*Includes the Great Plains subregion.*
[3]*Includes both the Rockies subregion and western South Dakota.*
Sources: Lumber and softwood plywood: Adams et al. 1987. Woodpulp, and paper and paperboard: American Paper Institute 1987a, Vance Publishing Corp. 1988. Alaska: USDA FS 1988d.

of the early 1980s accelerated this process by eliminating inefficient operations and forcing plant closures or renovations to remain competitive. Some plants that did close were sold, remodeled, and then reopened as more efficient operations. Examples of technological change include the adoption of lasers and computerized green chains in sawmills, the power back-up roll and spindleless lathe now in use in plywood plants, and new processes to produce woodpulp at higher recoveries and with less pollution. For several industries, the availability of new technologies has created opportunities for new products and new markets for old products. OSB/waferboard is one example of a new product that has matured during the last decade, reaching both new users and new markets.

The Timber Harvesting Industry

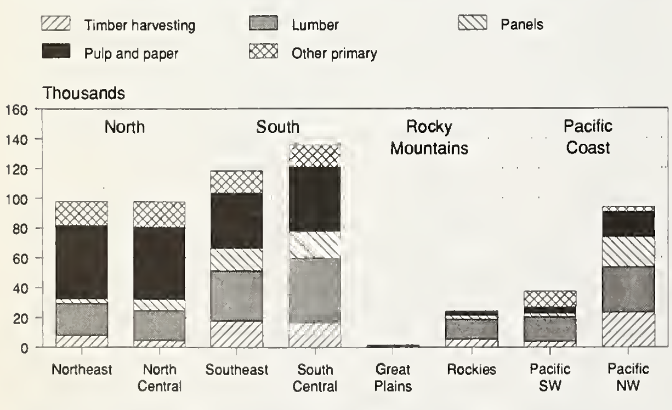
Industry Characteristics

Timber harvesting activities in the United States employed 72.3 thousand persons in 1986. Wages and salaries exceeded $1.2 billion, measured in 1982 dollars (table 55). Industry shipments were valued at $8.2 billion, with value added by manufacture accounting for 35% of industry shipments. The primary timber processing industries are value-added industries; timber harvesting provides the base for the remaining primary timber processing industries, accounting for about 10% of total economic activity of the primary timber processing industries.

Regional Characteristics

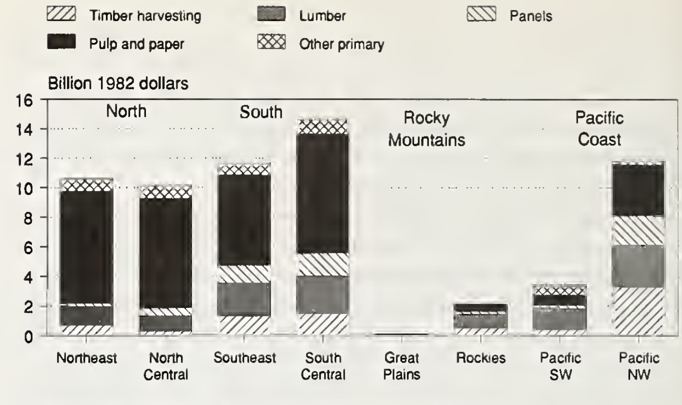
Regional characteristics of the timber harvesting industry reflect regional timber resource patterns and timber accessibility. In 1982, the South and North, with large acreages of readily accessible timber, employed 58% of the industry's work force (fig. 38), and had shipments valued at just 47% of the industry's total (fig. 39).

The Pacific Northwest-West subregion supports 58% of all timber harvesting employees and industry shipments within the Pacific Coast region. This subregion had 21% of all employees, and 29% of all industry shipments for the United States, underscoring its importance as a major timber supplier. Wages and salaries, and value added by manufacture were correspondingly high. Both the Pacific Southwest and the Pacific Northwest-East subregions had less than 10% each of the employees and value of shipments of this region. Timber harvesting in Alaska accounted for less than 2% of the total industry employees and the value of shipments in 1982. The two Rocky Mountain subregions each accounted for 7% or less of all industry totals in 1982 (McKeever and Jackson 1990: table B-6).



Source: USDC Bureau of the Census 1985, Adams et al. 1987.

Figure 38.—Employment in the primary timber processing industries, by region and subregion, 1982.



Source: USDC Bureau of the Census 1985, Adams et al. 1987.

Figure 39.—Value of shipments in the primary timber processing industries, by region and subregion, 1982.

Harvesting Costs, Production, and Innovations

Differences between the cost structure for the timber harvesting industry in the Pacific Northwest compared to that in the South reflect regional timber resource differences. In 1985, the average cost of harvesting timber in the Pacific Northwest was nearly two times higher than in the South (McKeever and Jackson 1990: table B-8). Harvesting costs throughout the West reflect these same factors, although Alaska consistently faces much higher harvesting costs. Cost estimates for the Northern regions are not available. Convergence of regional harvesting costs is slowly occurring as the physical differences between regional timber bases decrease.

Since 1958, timber harvesting in the United States increased 49%, mostly in the South (McKeever and Jackson 1990: table B-9). Harvest in the western regions peaked in 1986 reflecting general economic conditions. In the East, where more roundwood is used in the pulp, paper, and paperboard industries, harvest levels have either remained stable or increased.

Several trends in the automation of timber harvesting have developed as changes in the resource have occurred. Widespread use of the feller-buncher and other mechanized harvesting equipment over much of the South has helped reduce harvesting costs in this region. As more second-growth timber becomes available for harvesting, new, smaller equipment has been designed and is now in use. Smaller stems and more trees per acre

Tractor logging and mobile loaders are becoming more widespread in the West.

have also influenced this development. Overall, automation of timber harvesting has been widespread and influential in reducing operating costs.

The Lumber Manufacturing Industry

Industry Characteristics

The lumber manufacturing industry includes hardwood and softwood sawmills, planing mills, dimension mills, flooring mills, special product sawmills that produce lumber and other sawn products for sale, as well as pallet manufacturers. Pallet manufacturers are included because many produce pallet parts from logs, bolts, and cants, and as such, are "captive" sawmills. The U.S. lumber manufacturing industry employed 191 thousand in 1986, and paid out $3.2 billion 1982 dollars in wages and salaries (table 55). Industry shipments were valued at $17.9 billion, with value added by manufacture exceeding $7.1 billion. Employment in lumber manufacturing was about one-third of total employment in primary timber processing; while all other characteristics represented about one-fifth of all primary timber processing.

Reductions in 1972 and 1977 partially reflect the economic recessions experienced during the seventies. Between 1977 and 1982, employment fell 22% and value of industry shipments fell 38%, before increasing in 1986 (McKeever and Jackson 1990: table B-5). The industry is still operating well below levels achieved in 1977. The pallet manufacturing sector remained relatively unchanged during this period.

Regional Characteristics

Regional characteristics of the lumber manufacturing industry, like those of the timber harvesting industry, reflect regional timber resource patterns, but to a lesser degree. The North accounts for only about one-third of the employment and economic activity in the East; the South the remaining two-thirds.

Lumber Production, Costs, and Innovations

Total lumber production in 1986 was 42% above the 1958 level, and 16% above 1977, the previous peak year (McKeever and Jackson 1990: table B-9). All regions follow this trend. In 1986, the South led all regions in lumber production with 37%, the Pacific Northwest subregion was second at 24%, and the North third at 19% of the total.

In 1985, capacity of the two Southern subregions was 35% of the U.S. total, and capacity of the Pacific Northwest subregion was 37% of the total (table 56). Capacity data for the Northern regions was not available. Average lumber manufacturing costs varied from a low of $92.08 per thousand board feet (MBF), lumber tally, for the South to a high of $113.22 per MBF lumber tally, for the Pacific Southwest subregion (McKeever and Jackson 1990: table B-8). Product recovery factors, in MBF lumber tally, per MBF log scale, were highest in the Pacific Northwest subregion (1.579), about the same for the remaining Western regions and subregions (1.3–1.45), and 1.370 for Southern subregions in 1985 (Adams et al. 1988). Recovery factors have continued to increase since 1952, indicating continuing improvements in processing technologies and techniques.

Increasing computerization at all stages of processing is increasing lumber recovery. Some of these improvements focus on improving the handling of eccentrically shaped logs. Others, such as optimizing edgers and trimmers or using saws with thinner kerfs, apply new technologies to old practices. Application of Saw-Dry-Rip technology has succeeded in improving lumber grade recovery and in producing structural lumber from hardwoods and from Southern softwoods. Many of these technologies are being applied nation-wide as mills are renovated.

As new technologies are applied to changing timber resources, the potential for new lumber products increases. The use of molded 2 x 4's, hardwoods for structural lumber, and edge-glued or laminated lumber will soon challenge the traditional softwood lumber products for market share. Other new products, such as combination solid-wood/flakeboard I-beams are beginning to penetrate markets for competing products, notably steel and concrete.

The Structural Panels Manufacturing Industry

Industry Characteristics

The structural panels industry consists of manufacturers producing softwood plywood, waferboard, and oriented strandboard. In 1986 the industry employed 38.4 thousand, with more than 90% of these being in the softwood plywood sector of the industry (table 55). Wages and salaries totaled $911.6 million 1982 dollars. Industry shipments were valued at $5.1 billion, with value added being $2.1 billion. Structural panels manufacturing accounts for about 6% of employment, wages and salaries, value added by manufacture, and industry shipments in all primary timber processing industries.

Separate data for the softwood veneer and plywood component of the structural panels manufacturing industry are not available from the Census of Manufacturers prior to 1972; data on the OSB/waferboard component are not available prior to 1982. However, softwood plywood data are good indicators for the structural panel industry because of their continuing domination of the industry. Between 1977 and 1982, the number of employees and the value of shipments of softwood veneer and plywood fell. During this period the value of shipments of softwood veneer and plywood dropped nearly 30% when measured in 1982 dollars (McKeever and Jackson 1990: table B-5). Employment fell 24%. These reductions are largely a result of the economic recession of the early 1980s. Between 1982 and 1986, the structural panel industry rebounded from the recession, with both employment and industry shipments increasing. The OSB/waferboard component of the industry increased proportionally much faster than the softwood veneer and plywood component. Industry totals in 1986 were below levels set in 1977.

Regional Characteristics

Regional characteristics of the structural panel manufacturing industry, like the timber harvesting and lumber industries, reflect the forest resource base. Timber volumes, size, quality, and cost dictate the types of panels that can be economically produced. Top quality, large-diameter Douglas-fir peeler logs are the preferred species in the Pacific Northwest-West subregion where much of the Nation's high quality, sanded, and specialty softwood plywood grades are produced (McKeever and Meyer 1983). Softwood timber in the South is ideally suited to sheathing-grade plywood production. Peeler logs are generally small-diameter, and low quality. Few differences exist between southern pine peeler logs and southern pine sawlogs. The North Central subregion, with its abundant, mature aspen forests, is rapidly becoming the dominant OSB/waferboard producing region (Crows 1987). New capacity in the structural panels manufacturing industry is expected to come from OSB/waferboard mills located in the North and South.

Capacity

Capacity in the softwood plywood industry peaked in 1980, then dropped 9% to its current level in 1986 (25.3 billion square feet, 3/8-inch basis) (table 56). In addition, over 3 billion square feet of OSB/waferboard capacity has been added (McKeever and Meyer 1983). Between 1965 and 1975, softwood plywood industry capacity grew at a rate of 3.7% per year. The number of active plants also increased, but at a rate lower than capacity, resulting in an increase in average plant size. Between 1975 and 1982, net additions to capacity slowed and the number of active plants declined nearly 8%. These declines, and the decline in the industry's operating rate, are partially due to the economic recession in the early 1980s. The softwood plywood industry normally operates at around 95% of capacity; in 1982 it was operating at 65% of capacity. The 1986 operating rate was about 90% of capacity.

Panel Production, Costs, and Innovations

Total structural panel production in 1986 was a record 25.6 billion square feet, 3/8-inch basis (McKeever and Jackson 1990: table B-9). This is an increase of 32% over the previous high mark set in 1977. Production costs for softwood plywood in all regions have dropped in recent years as labor costs have fallen, especially in the West. Panel production costs in the West were still about 15% higher than in the South, reflecting higher labor costs and other factors (McKeever and Jackson 1990: table B-8). However, Western production costs are slowly converging towards the lower costs of the South as labor costs continue to drop. Recovery factors in the Pacific Coast regions were also higher than those in the Rocky Mountains or the South (McKeever and Jackson 1990: table B-10).

Several new technologies have been instrumental in improving product recoveries for softwood plywood. The spindleless lathe, in combination with powered back-up rollers, peels smaller logs down to a 2-inch core. Powered nosebars also peel to a smaller core, reduce spinouts, and improve both veneer quality and recovery. Improvements in gluing and drying have also improved product quality and recovery.

Many changes have occurred in this industry in the last decade. The most notable is the commercial acceptance of OSB/waferboard as a structural panel and a substitute for softwood plywood in some applications, particularly exterior sheathing applications. By 1986, OSB/waferboard had captured 19% of all structural panel consumption; this share has continuously increased. Revisions to building codes have been and are being accepted throughout the United States to accommodate this and other new products used by the construction industries.

The Nonstructural Panels Manufacturing Industry

The nonstructural panels manufacturing industry consists of an interesting assortment of panel producers. Hardwood veneer and plywood is made from logs that are either peeled or sliced. Hardboard, insulating board, and medium-density fiberboard (MDF) are produced from defibrated/exploded or groundwood woodpulp and other nonwood fibers. Particleboard is made from chipped roundwood and processing residues and sawdust (McKeever 1979, Dickerhoof and McKeever 1979).

Industry Characteristics

Employment at all establishments producing nonstructural panels totaled 31.3 thousand in 1986, with wages and salaries totaling $542.8 million 1982 dollars (table 55). Industry shipments were valued at $3.2 billion; value added by manufacture $1.3 billion. In terms of employment, wages and salaries, value added, and value of shipments, the industry is nearly equally divided between hardwood veneer and plywood manufacturers and manufacturers of all other nonstructural panels. In terms of establishments, however, the industry is dominated by hardwood veneer and plywood manufacturers. In 1982, 306 of 403 establishments were hardwood veneer and plywood producers.

Since 1972, the number of nonstructural panels manufacturing establishments has declined steadily. Data for the industry are incomplete prior to 1972, but during the 10-year period from 1972 to 1982, the number of hardwood veneer and plywood plants fell from 366 to 306, and the number of other nonstructural panel plants fell from 114 to 97 (McKeever and Jackson 1990: table B-5), representing an 18% loss. Employment by all nonstructural panel manufacturers fell 28%, while the value of industry shipments, measured in 1982 dollars, fell 18%. These declines resulted largely from a trend toward importing more domestic hardwood veneer and plywood. This trend is expected to continue as long as foreign suppliers, primarily those in the Far East, continue to supply low-cost, quality panels.

Regional Characteristics

The pine and mixed-hardwood forests in the South contain the favored tree species for producing nonstructural panels. In 1982, the two Southern subregions had a total of 17.4 thousand employees and $1.4 billion of shipments (McKeever and Jackson 1990: table B-6). This represents approximately half of the industry's employees and shipments.

Panel Production, Costs, and Innovations

The combined production of hardwood plywood, insulating board, hardboard, and particleboard (including medium-density fiberboard) has more than doubled since 1958 (McKeever and Jackson 1990: table B-11). The recession of the early 1980s severely impacted nonstructural panel production. Production levels have not returned to pre-recession levels for any individual product except particleboard. Since 1977, product substitution has played an important role in the overall decline in production of individual products. For example, hardwood veneer and plywood production has declined steadily since 1972, being replaced by overlayed nonveneered panels in furniture applications, and paper and paperboard in container and shipping applications. None of these panel products have been very successful in penetrating new markets, but some substitutions have occurred within the industry. More hardwood plywood, for example, is now being manufactured with a particleboard core and hardwood veneer faces. Similarly, particleboard with a decorative paper face is substituting for hardwood panels in some traditional uses.

Many of the same new technologies being applied in the lumber and the structural panels industries are being used for nonstructural panels as well. The spindleless lathe, laser technologies, and computerization of mills are all being implemented to increase product recovery and reduce production costs.

The Woodpulp Manufacturing Industry

Industry Characteristics

The market pulp industry in the United States is relatively small, accounting for about 15% of all pulpmills (McKeever 1987a). Employment in 1986 at market pulpmills was 15.3 thousand, with wages and salaries totaling $592.5 million 1982 dollars. Shipments of woodpulp were valued at $3.8 billion in 1986, with value added by manufacture being $1.6 billion. The woodpulp manufacturing industry is the smallest primary timber processing industry in terms of numbers of establishments, but exceeds the nonstructural panels industry in total value of products shipped, value added and wages and salaries. Employment declined in 1986 after increasing steadily since 1972. Industry shipments, however, were at a record $3.8 billion 1982 dollars in 1986. The economic recession which seriously impacted the solidwood industries (lumber, structural panel, nonstructural panel, and other primary timber) had less impact on the woodpulp industry. Pulp and paper products are used primarily for packaging and personal consumption, and are less responsive to economic cycles than are solidwood products.

Organization

Economies of scale dictate that woodpulp mills must be large to be competitive. They are second only to paper and paperboard mills. In 1982, one-fifth of the establishments in the woodpulp industry had fewer than 50 employees, while over half had 250 or more employees. Woodpulp mills are almost entirely operated by multiunit companies and are entirely corporately owned. The woodpulp industry is one of the most highly capital-intensive of the primary timber processing industries.

Regional Characteristics

The South is by far the largest woodpulp producing region. Nearly two-thirds of all employment, wages and salaries, value added by manufacture and value of industry shipments originated in the South in 1982 (figs. 38 and 39). The large volumes of southern pine, and the large paper and paperboard industry located there support the market pulp industry. Most of the pulp produced is kraft market pulp, but pulp using cotton linters is also common (Vance Publishing Corp. 1988).

Sulfite, groundwood, and deinked pulp are produced in addition to kraft pulp. Shipments from the North were below those from the Pacific Northwest-West subregion. Shipments of sulfite and kraft market pulp from the PNW-West subregion were valued at more than one-half billion dollars in 1982. Production of dissolving market pulp is one of the major industries in Alaska. Two pulpmills located in southeast Alaska provide 3% of all employees and industry shipments for this primary timber processing industry.

Production, Costs, and Innovations

In 1986, the woodpulp industry operated at full capacity. Total woodpulp production, which includes production by mills integrated with paper and board mills, increased steadily between 1958 and 1986, with a 24% increase since 1977. Table 57 lists the major pulp grades for all U.S. mills and production volumes in the United States from 1958 through 1986.

Regional production costs vary widely by product mix and were not available for 1986, but a national average of $371 per ton was estimated by the American Paper Institute (1988). Pulp yields for 1986, by region, were estimated and are listed in McKeever and Jackson 1990: table B-10.

Like the industries mentioned previously, the woodpulp industry has readily adopted computerization and other new technologies. Improvements in bleaching technologies and chemical recovery have also lowered costs and improved quality. Concerns about energy consumption and the environment in the last decade have generated changes in waste handling and financial expenses on control measures, usually increasing capital or operating costs.

Changes in the relative cost structures of hardwood and softwood roundwood supplies have generated shifts from exclusively softwood pulp production to the use of increasingly greater amounts of hardwoods. Concurrent with this shift has been the development and adoption of technologies to better utilize hardwoods in pulp and paper production. These shifts in roundwood utilization have had some impacts on the other primary timber processing industries as well.

The Paper and Paperboard Manufacturing Industry

Industry Characteristics

The paper and paperboard industry is the largest single component of the primary timber processing industries. Although the number of mills is low, employment, wages and salaries, value added by manufacture, and value of industry shipments far exceed all other industries. Nearly a third of all employment, and half of all wages and salaries, value added, and value of shipments in 1986 originated in the paper and paperboard manufacturing industry (table 55). The number of paper and paperboard mills has been declining since 1958. Older, pollution-intensive mills are being replaced, abandoned, or renovated with new papermaking technologies. These new technologies not only reduce pollution levels, but also increase average mill size. Also, some pollution-intensive pulping processes, such as caustic soda, have been virtually eliminated.

Employment in the paper and paperboard industries generally increased through 1967 and has since steadily declined (McKeever and Jackson 1990: table B-5). The capital-intensive technologies which were responsible for increasing average mill size and decreasing pollution levels are also responsible for declining employment. Total constant-dollar industry shipments, which increased steadily through 1977, declined slightly in 1982 as a result of the economic recession, and increased again in 1986 to a record $36.9 billion. Shipments of individual products followed the same general trend. Newsprint and other paper grade shipments increased dramatically over 1977 levels; paperboard shipments increased only modestly. Paperboard production is closely tied to levels of manufacturing activity; therefore it is more responsive to general economic shifts than are other paper grades.

Table 57.—Pulp, paper, and paperboard production in the United States, by product and grade, specified years 1958–86.

Product and grade	1958	1963	1967	1972	1977	1982	1986
	Thousand tons						
Woodpulp							
Sulfite	2,381	2,689	2,563	2,173	2,012	1,654	1,637
Sulfate							
Bleached[1]	5,099	7,829	10,326	14,218	15,728	19,660	23,982
Unbleached	7,647	10,502	13,894	17,792	18,436	17,995	21,559
Total	12,746	18,331	24,220	32,010	34,164	37,655	45,541
Mechanical							
Groundwood	2,890	3,468	3,885	4,639	4,268	3,751	3,092
Thermomechanical	NA	NA	NA	NA	583	1,459	2,498
Total	2,890	3,468	3,885	4,639	4,851	5,210	5,590
Semichemical	1,622	2,629	3,185	3,786	3,542	3,311	4,214
Dissolving and special alpha	929	1,371	1,448	1,656	1,533	1,115	1,249
Other	1,228	1,632	1,376	2,502	3,030	2,040	2,704
Total, woodpulp	21,796	30,121	36,677	46,767	49,132	50,986	60,935
Paper and paperboard							
Paper							
Printing & writing	6,230	8,174	10,131	12,221	14,014	15,554	19,821
Newsprint	1,771	2,215	2,711	3,670	3,926	5,042	5,693
Tissue	1,931	2,573	3,232	3,992	4,346	4,441	5,152
Packaging & industrial	3,656	4,337	4,870	5,553	5,811	5,197	5,174
Construction paper	1,298	1,453	1,503	1,915	1,852	798	302
Total, paper	14,887	18,752	22,447	27,351	29,948	31,033	36,143
Paperboard							
Unbleached kraft	5,055	6,621	9,180	13,277	13,676	14,535	17,708
Recycled	6,771	6,867	6,985	7,543	7,330	6,476	8,092
Semichemical	1,720	2,260	2,959	4,013	4,272	4,389	5,382
Solid bleached	1,939	2,491	2,962	3,689	3,728	3,665	4,276
Wet machine board	138	141	144	148	129	129	101
Total, paperboard	14,271	18,380	22,229	28,670	29,135	29,194	35,559
Total, paper and paperboard	29,158	37,132	44,676	56,021	59,083	60,227	71,702

NA – Not available.
[1]*Includes soda pulp.*
Note: Data may not add to totals because of rounding.
Sources: American Paper Institute 1987a, USDC BC 1987e, Ulrich 1988.

Organization

Paper and paperboard manufacturing establishments are large and virtually all are owned by multi-unit corporations. As in the woodpulp industry, mill size is largely determined by the economies of scale associated with capital investment. Mills processing in excess of 2,000 tons of woodpulp per day are common (McKeever 1987a). Nearly 90% of all mills are operated by multi-unit companies and nearly all companies are corporately owned.

Regional Characteristics

The North Region had more paper and paperboard employees than any other region in 1982, as well as the highest total wages and salaries, value added by manufacture and value of industry shipments (figs. 38 and 39). Many of the mills in the North are smaller than the national average, and produce higher-valued printing, writing, and sanitary papers from softwoods and mixed hardwoods (American Paper Institute 1987a). Establishments in the South numbered just slightly more than one-third those found in the North. However, the value of shipments from these mills was over 80% of the value of shipments from Northern mills. Southern mills are generally newer than mills in the North, and are much larger in terms of both employment and output. The largest mills in the United States are the kraft mills in the South. Southern mills produce about two-thirds paperboard, of which most is unbleached kraft, and one-third paper. Mills in the West are intermediate in size and output, and produce a fairly equal mix of paper and paperboard. Table 57 lists the major paper and paperboard grades and production volumes for U.S. mills between 1958 and 1986.

Production, Costs, and Innovations

The paper and paperboard industry operated at about 95% of capacity in 1986 and the four Eastern subregions hold over 85% total capacity and production. Production costs for the United States were estimated by the American Paper Institute (1988) at $364 per ton for all products in 1986 (McKeever and Jackson 1990: table B-8). Regional and national recovery factors are listed in McKeever and Jackson 1990: table B-10. A higher proportion of mechanical pulp is being used in newsprint production, improving yields and quality. Anthraquinone is now being used in kraft production, increasing yields and lowering bleaching and recovery costs.

A significant change has occurred in the type of raw material used in papermaking. Many firms are using a higher proportion of hardwoods in their paper production processes. This shift is continuing and new processing technologies are being utilized to support the greater use of hardwoods in the papermaking process.

New paper and paperboard products have successfully penetrated some traditional packaging markets. Most notable is the development and acceptance of aseptic packaging technologies, slowly replacing glass bottles and aluminum cans in the food industry. New absorbent and nonwoven products have entered personal hygiene markets. Demand for printing and writing papers has increased concurrent with the spread of personal computers, somewhat negating predictions of the "paperless office." Technologies that improve the preprinting quality of newsprint and fine papers have been widely accepted in the last decade.

The Other Primary Timber Manufacturing Industry

Industry Characteristics

The other primary timber manufacturing industry is a collection of manufacturers producing a wide variety of miscellaneous wooden products. Included are manufacturers of wooden boxes and box shook, barrels, baskets, cooperage and crates, dowels, lasts, ladders, picture frames, toothpicks, rolling pins, and many other turned and shaped wooden products. Wood preservation plants are also included in this category. Employment in 1986 was 79.0 thousand, with wages and salaries totaling $1.1 billion 1982 dollars (table 55). Value added by manufacture and value of industry shipments were $2.4 and $5.5 billion respectively.

Because the other primary timber industry is such a diverse collection of establishments, no distinct overall patterns of growth or decline are evident. Employment has averaged about 90 thousand (McKeever and Jackson 1990: table B-5). The constant-dollar value of shipments has tended to increase slowly over time.

Organization

The other primary timber manufacturing industry, like the timber harvesting and lumber manufacturing industries, is composed of small, single-unit companies. Most of these establishments were operated as single-unit companies, and two-thirds were corporately owned.

Regional Characteristics

Regional characteristics of the other primary timber manufacturing industry, like many of the other primary processors, largely reflects regional timber resource patterns. Since many of the manufactured products are made from hardwoods, much of the industry is located in the North. In 1982, about 40% of all industry characteristics were attributable to establishments located in the North (McKeever and Jackson 1990: table B-6). Southern pines are a favored species group for wood preserving; thus nearly one-third of the other primary timber industry is located in the Southeast and South Central subregions. Most of the remaining establishments are located in the Pacific Southwest subregion.

CHANGES IN THE STRUCTURE OF THE PRIMARY TIMBER PROCESSING INDUSTRIES

The primary timber processing industries are a dynamic sector of the United States' economy, and are affected by many different socioeconomic factors. These factors include, but are not limited to, changes in population, income, and the demand for forest products. Environmental and human concern factors affect, and are in turn affected by, these industries. Over the last decade, the timber harvesting, and the pulp, paper, and paperboard manufacturing industries have been particularly affected by environmental concerns, while the lumber manufacturing, and structural and nonstructural panels manufacturing industries have been more affected by economic factors. For convenience, the factors affecting timber industries can be classified as economic, physical, or technical. A discussion of each follows.

Economic Factors

Several economic factors have had major impacts on the primary timber processing industries. The economic recession in the early 1980s forced many of the more inefficient solid-wood processors to shut down, some permanently. Some of these closed mills were then sold, refurbished, and reopened under improving economic conditions. Other mills remained in operation, but modernized to improve product recovery and lower operating costs.

High stumpage prices bid during the late 1970s were no longer economic in the 80s when demand for solid-wood products and product prices dropped. This forced many timber harvesters to default on their timber sale contracts. Special legislation was required to prevent the shut-down of many operators in this industry. This has also prompted new rules for bidding on national forest timber.

Competition from Canadian lumber suppliers has taken an increasing share of U.S. softwood lumber markets over the last decade. A coalition of U.S. lumber producers claimed that Canadian producers were unfairly subsidized, and filed a formal complaint with the U.S.

Calibration of a continuous lumber testing machine is an important aspect of overall quality control. This MSR machine separates high strength material for use in engineered wood structures (i.e., trusses, laminated beams).

government. Subsequent negotiations between the United States and Canada resulted in Canada applying, in January 1987, a 15% export tax on certain softwood lumber exports to the United States. This tax may be replaced by appropriate actions in the forestry sector in Canada and such actions may offset all or some of the effects of this tax in British Columbia and Quebec.

Several interrelated phenomena have occurred since the recession in the early 1980s that have affected all of the primary timber processing industries. Long planning horizons, combined with lower rates of return, have made forest products companies more susceptible to takeovers, hostile or otherwise, by other interests. At the same time, greater concentration is occurring within the forest products industries as fewer companies control larger shares of their particular industry.

The last major economic factor has been the expansion of all primary timber processing industries into foreign markets. Increased competition for domestic markets by U.S. and Canadian suppliers has reduced shares for many producers. Traditionally, wood processors have viewed foreign markets as substitutes for domestic markets during poor economic conditions. More recently, this view has been changing and many firms now produce solely for foreign destinations, mostly Pacific Rim countries. The economic recession in the early 1980s forced many companies to seek new markets. These markets have required innovations in mill management and marketing to properly serve these new clients.

Physical Factors

Several changes have occurred in the physical characteristics of the timber resource supplying the primary timber processing industries. Of major concern to producers in the West and the South has been the reduction of available old-growth timber due to harvesting and changes in land classifications. This shift to processing second-growth timber has forced many mills to install new equipment designed for smaller logs. Problems with juvenile wood, quality, and fiber strength found in some second-growth timber have required innovations in processing and have often led to new products and markets. Timber inventories in many regions now contain an increasing share of hardwoods, offering the primary timber processing industries another set of utilization problems and opportunities.

Changes in the physical characteristics of the timber resources have had major effects on the location of the primary timber processing industries. The industry first located processing facilities in the Northeast, then the South, the North Central Region, and the West, always in search of timber. More recently, the industry has expanded processing capacities in the South. The industry has adapted equipment and operating procedures to process the available timber.

Technological Innovations

Changes in the resource have affected the economics of timber production in this country. Many companies now utilize the latest technology designed for smaller diameter logs, fast processing, and high recovery. The combination of changing resources, new technologies, increased competition, and shifts in production locations provide the opportunity for the primary timber processing industries to modernize their mills and improve their markets. The range of technological changes available to the industry in the 1980s will help the industry modernize and develop innovations necessary for the timber processing industry to meet the demands of the future.

CHAPTER 5. INTERNATIONAL TRADE IN FOREST PRODUCTS

The United States has engaged in trade in forest products since colonial times; timber was one of the first natural resources to be exploited and exported from the continent. After three centuries, international trade remains a critical component of the forest sector economy. U.S. producers rely on offshore markets to sell a small but valuable part of their output, while a substantial proportion of U.S. consumption is provided by foreign (especially Canadian) producers. Long-term developments in the U.S. forest sector will be linked inevitably to developments in forest products markets throughout the world. This chapter will present information on trends in U.S. imports and exports of forest products, and will review forest sector conditions in those countries or regions most likely to affect producers and consumers in the United States.

TRENDS IN U.S. TRADE IN FOREST PRODUCTS

National economies have become increasingly interdependent in the post-war period, linked through trade in merchandise and through the flow of capital. The constant-dollar value of U.S. trade in merchandise (imports plus exports) grew at an annual rate of more than 6% between 1950 and 1989. Over this same period, the U.S. economy (the gross national product, GNP) grew at an average (constant-dollar) rate of just over 3%. In 1989, total merchandise trade was 18% of GNP, and net imports were more than 2% of GNP. Trade is an essential part of the U.S. economy, and a source of economic growth throughout the world.

The constant-dollar value of U.S. trade in forest products grew at an annual rate of more than 4% over the period 1950–89 (fig. 40a). In dollar terms, forest products exports grew at a faster rate than all merchandise exports, but in the last decade (1980–89) accounted for roughly 4% of total exports (fig. 40b). In contrast, the forest products component of total imports dropped sharply between 1960 and 1975 (fig. 40b); forest products now account for roughly 4% of total imports.

The United States became a net importer (in terms of total merchandise trade) in the mid-1970s, and the expansion of the trade deficit in the 1980s fueled a continuing economic and political debate. However, for most of this century the United States has been a net importer of forest products. Since 1950 the United States has annually imported, on average, forest products costing approximately 3 billion (1982 $) more than those exported (fig. 40c). This deficit has been extremely volatile since 1970, falling (in absolute terms) to near zero in the recession years of 1975 and 1980, followed, in each case, by equally dramatic increases. In the mid-1980s the forest products trade deficit was unprecedented, approaching $6 billion (1982 $); in spite of this, forest products have accounted for less than 5% of the merchandise trade deficit in this decade. The balance of forest products trade began to improve in the latter part of the 1980s, returning to the long-term average of $3 billion (fig. 40c).

The United States is the world's leading producer and consumer of forest products. The United States is also

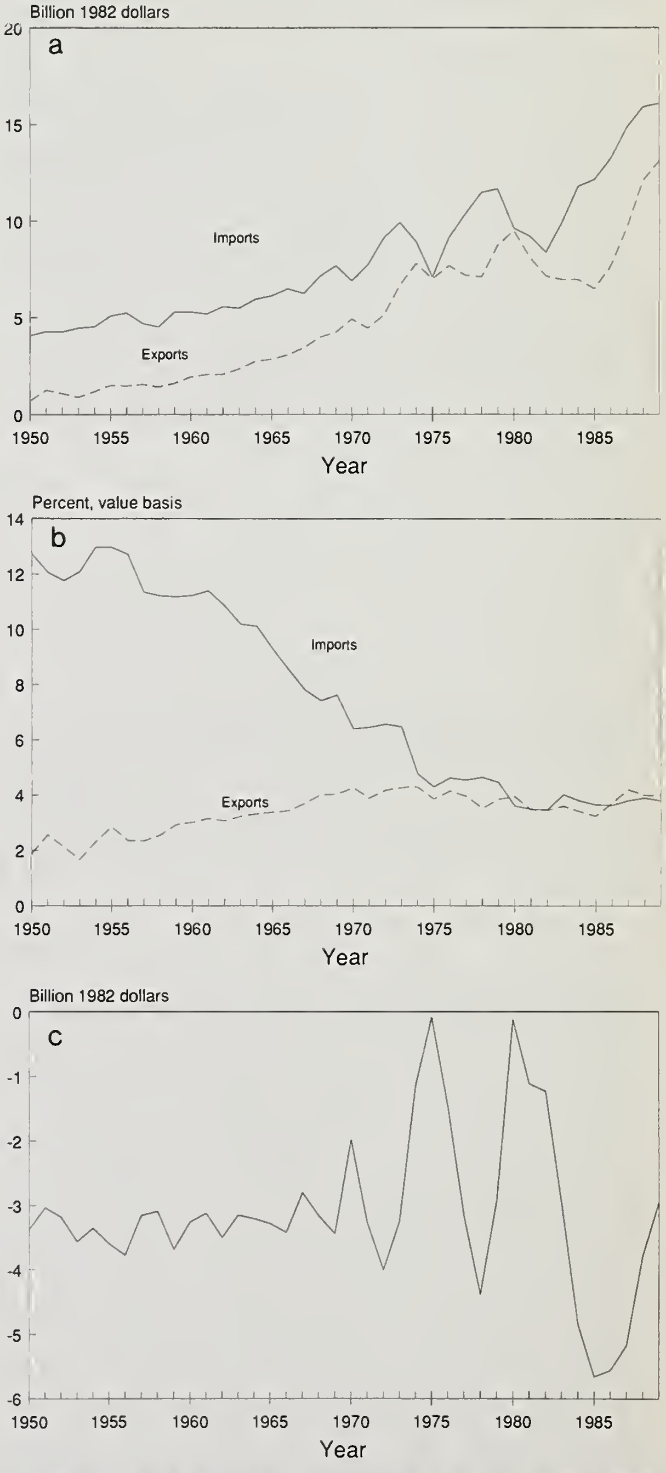


Figure 40.—Value of forest products trade in the United States 1950–1989: (a) imports and exports, (b) forest products share of total trade, and (c) forest products balance of trade.

the world's leading importer of forest products, and is second only to Canada as an exporter of forest products. In 1987 the United States accounted for approximately 16% of world imports of forest products (by value), and over 11% of world exports of forest products. The U.S. share of the volume of world forest products trade was similar. The total volume of U.S. forest products trade in 1987 (7.2 billion cubic feet, roundwood equivalent) was equal to nearly 13% of world production of timber for industrial products.

The volume of imports in 1987 was 4.6 billion cubic feet, roundwood equivalent, a three-fold increase from 1950 (fig. 41a). Imports increased to nearly 30% of U.S. consumption in 1985 (from 15% in 1950), and declined slightly to 28% of consumption in 1987 (fig. 41b). The volume of exports increased even more dramatically over this period, to 2.7 billion cubic feet, from 140 million cubic feet in 1950 (fig. 41a). In 1987, exports were 18% of U.S. production, up from 2% in 1950; in the 1980s the share of production exported remained higher than any other period (fig. 41b). Although forest products exports showed relatively greater gains over the 1950–87 period, net imports were the equivalent of 2 billion cubic feet of roundwood in 1987.

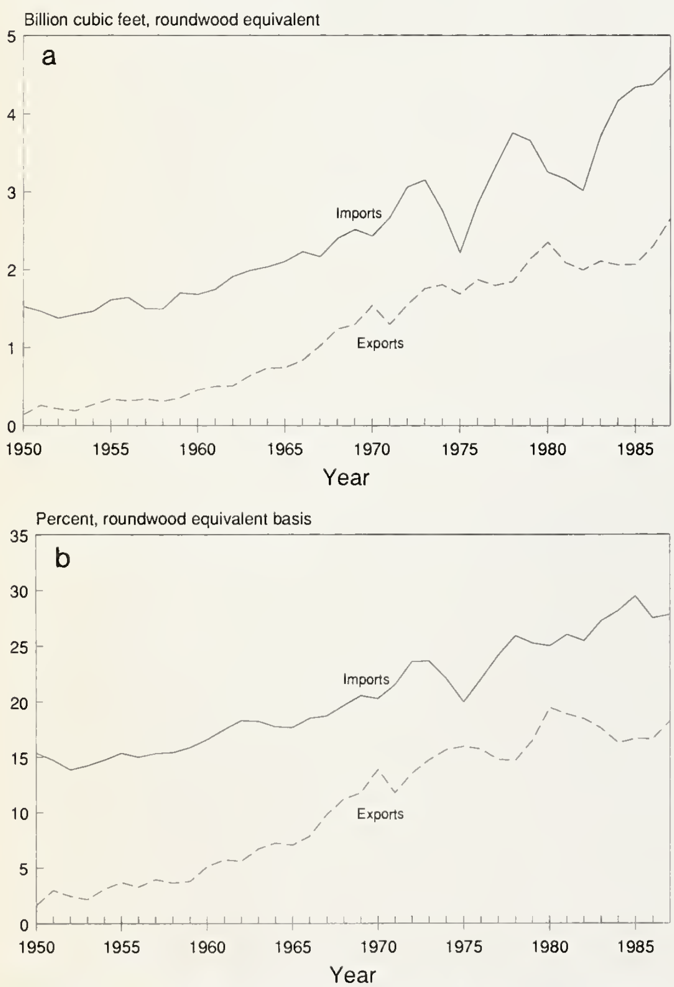


Figure 41.—Volume of forest products trade in the United States 1950–1987: (a) imports and exports and (b) export share of production and import share of consumption.

The general trend in both imports and exports of forest products trade has been upward, but not consistently smooth, especially in the past 20 years—in part as a consequence of business cycles in both the U.S. economy and in the economies of our trading partners. Troughs in the long-term trend of forest products imports coincide almost exactly with troughs in the U.S. business cycle; during the recovery period of the cycle, imports increase at a rate well above the long-term average (see figs. 40a and 41a). In the most recent phase (1982–89), imports increased at nearly 10% per year in constant-dollar terms.

The pattern of U.S. exports of forest products depends primarily on the business cycles of our trading partners, although there are indications of an "export push" during some domestic recessions (see fig. 40a). In the early 1980s, exports declined as a result of a prolonged recession in major markets and a strong U.S. currency. With a more broadly based economic recovery, and following adjustments in the value of the dollar (in 1985), the constant-dollar value of exports has grown at nearly 20% per year (1985–89).

Trends in Imports

The United States spends, in most years, about 50% more on imports of fiber products (pulp, paper, and board products) than on imports of solid-wood products (logs, lumber, panels, and other manufactured products). In 1986, solid-wood product imports were \$5.3 billion (1982 \$), while fiber product imports amounted to approximately \$8.0 billion (1982 \$) (table 58). In 1989 the constant-dollar value of solid-wood imports declined to \$4.4 billion, but the value of fiber products imports increased to \$9.7 billion. The majority of U.S. forest product imports, in both volume and value, originate in Canada. In 1989, Canada accounted for 80% of the value, and well over half of the volume of U.S. forest product imports. However, in the past decade, there have been substantial increases in imports from Western Europe and from Latin America.

More than half (52%) of the 4.6 billion cubic feet (roundwood equivalent) imported in 1987 was lumber; most of the remainder (43% of the total) was in pulp and paper products, primarily woodpulp and newsprint (table 59, fig. 42a). The United States imports relatively small quantities of panel products (plywood, veneer, and reconstituted boards), and an even smaller quantity of logs (all shown as "other" products in fig. 42a).

Imports of pulp and paper products have accounted for 30% to 40% of U.S. consumption, on a volume basis, for more than three decades (fig. 42b). In 1989, pulp products imports accounted for 35% of U.S. consumption, compared to 39% in 1950. The share of U.S. lumber consumption supplied by imports in 1989 was slightly lower than the share for pulp and paper products. However, the 28% market share held by foreign producers in 1989 was more than three times the share in 1950. The decline in the share of domestic markets held by domestic lumber producers contributed to the

Table 58.—Value of United States trade in forest products, 1986.

	Imports	Exports
	Million 1982 dollars	
Solid-wood products		
Logs	11.3	1,224.2
Of which: softwood logs	7.2	1,127.1
Lumber	3,128.2	986.0
Of which: softwood lumber	2,960.2	642.5
Panel products[1]	839.6	298.9
Of which:		
Hardwood plywood	483.5	13.4
Softwood plywood	34.1	131.1
Particleboard	136.3	34.3
Other solid-wood[2]	1,273.6	472.1
Total solid-wood	5,252.7	2,981.1
Fiber products		
Woodpulp	1,598.2	1,659.2
Printing and writing papers	5,292.6	569.1
Of which: newsprint	3,675.0	194.1
Industrial paper and board	961.9	1,919.9
Of which: industrial paperboard	80.7	1,158.6
Other fiber products[3]	131.7	547.5
Total fiber	7,984.4	4,695.7
Total forest products	13,237.1	7,676.8

[1]*Includes veneer, plywood, particleboard, and hardboard.*
[2]*Includes poles and piling, railroad ties, millwork, and other miscellaneous products.*
[3]*Includes pulpwood, chips, waste paper, and miscellaneous products.*
Sources: Ulrich 1989, U.S. International Trade Commission 1987.

Table 59.—U.S. timber product imports by product group, and specified years 1950–87.

Year	Total	Lumber	Veneer and plywood	Pulp products	Logs
		Billion cubic feet, roundwood equivalent			
1950	1.5	0.5	([1])	0.9	([1])
1955	1.6	.6	([1])	1.0	([1])
1960	1.7	.6	0.1	1.0	([1])
1965	2.1	.8	.1	1.2	([1])
1970	2.4	1.0	.2	1.3	([1])
1975	2.2	.9	.2	1.1	([1])
1976	2.8	1.3	.2	1.3	([1])
1977	3.3	1.7	.2	1.4	([1])
1978	3.8	1.9	.2	1.6	([1])
1979	3.7	1.8	.2	1.6	([1])
1980	3.3	1.5	.1	1.6	([1])
1981	3.2	1.5	.1	1.5	([1])
1982	3.0	1.5	.1	1.4	([1])
1983	3.7	1.9	.2	1.6	([1])
1984	4.2	2.1	.1	1.9	([1])
1985	4.3	2.3	.2	1.8	([1])
1986	4.4	2.3	.2	1.9	([1])
1987	4.6	2.4	.2	2.0	([1])

[1]*Less than 50 million cubic feet.*
Note: Data may not add to total because of rounding.
Source: Ulrich 1989.

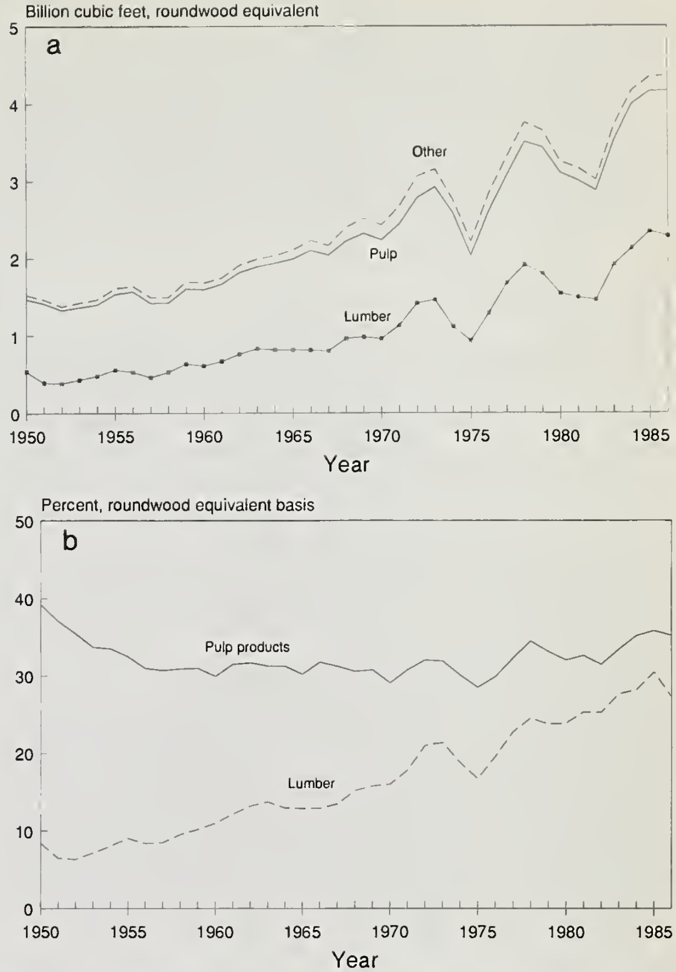


Figure 42.—Forest products imports 1950–1986: (a) volume of imports by commodity group and (b) share of consumption imported.

increased attention focused on lumber imports in the 1980s.

Lumber

Lumber is the primary solid-wood product import, and accounts for roughly half the volume, and 25% of the value of all forest product imports. In 1989 U.S. lumber imports were more than 2 billion cubic feet, roundwood equivalent (14 billion board feet), more than four times the volume imported in 1950. Most imported lumber is softwood, and over 90% of these shipments originate in Canada. Imported softwood lumber now accounts for nearly 29% of U.S. consumption (fig. 42b). The increase, since 1970, in the share of domestic softwood lumber markets held by imports resulted in strong pressure on the federal government for the protection of domestic producers. In late 1986 as a result of a finding of unfair trading practices, the United States imposed a countervailing duty on Canadian softwood lumber. This duty was subsequently removed, and replaced by fees collected in Canada. This process briefly disrupted lumber markets in 1986–87, and lead to a modest reduction in the share of U.S. lumber consumption that is imported (from a peak of 33% in 1985).

Hardwood lumber accounted for only 2% of the volume, but approximately 10% of the value of lumber imported in 1986. Latin America, Canada, and Asia are the primary sources of hardwood lumber imports. Imports of tropical species account for roughly two-thirds of hardwood lumber imports.

Pulp and Paper

The roundwood equivalent volume of imports of pulp and paper products more than doubled between 1950 and 1987. In 1987 the United States imported fiber products (and raw material) amounting to 2.0 billion cubic feet, roundwood equivalent, compared to 0.9 billion cubic feet in 1950. Imports of pulp and paper products are roughly 35% of total U.S. consumption, down only slightly from the level in 1950 (see fig. 42b). Pulp and paper products accounted for less than 45% of the volume, but nearly 70% of the value of all forest products imported in 1989.

Newsprint accounts for the majority of paper and board imports; over 95% of U.S. newsprint imports originate in Canada. Canada is also the primary source of U.S. woodpulp imports, although woodpulp imports from Scandinavia (primarily Sweden) and Latin America (primarily Brazil) have increased over the past decade and now account for roughly 12% of the U.S. total. Woodpulp accounts for 20% of the value of all pulp and paper products imports.

Panel Products

Imports of panel products increased substantially between 1950 and 1987 (from 5 million cubic feet, roundwood equivalent in 1950, to nearly 200 million cubic feet in 1987), but remain a minor component of total imports. Panel products accounted for roughly 5% of the volume, and 7% of the value of forest products imported in 1986. Hardwood veneer and plywood compose the majority of panel imports. Since the mid-1960s the United States has relied on imports for more than half the annual consumption of hardwood panels; in 1986 imports accounted for more than 75% of U.S. consumption.

Most hardwood veneer and plywood imports originate in Asia, primarily in South Korea, Taiwan, the Philippines, and Japan. The implementation of log export restrictions, imposed by Southeast Asian timber producers (Indonesia, Malaysia, and the Philippines) has shifted processing, and shares of the U.S. market to these countries, and away from the traditional Southeast Asian suppliers. However, in 1986 Canada supplied roughly 16% of U.S. hardwood veneer and plywood imports, and Latin America (primarily Brazil) and Western Europe (using, for the most part, tropical African logs) combined to supply an additional 10% of the U.S. import total.

Softwood veneer and plywood accounted for less than 1% of total forest product imports in 1986. Imports are also a minor share of U.S. consumption (roughly 1%). Until recently, Canada accounted for most softwood veneer and plywood imports; however, in 1986 Canada was the origin of just over 50% of U.S. imports. Western Europe, Latin America, and Asia (primarily South Korea, Taiwan, and Japan) have all increased their exports of softwood panel products to the United States.

Imports of other panel products, including particleboard, oriented strand board, and wafer board have increased significantly since the mid-1960s. Together these products accounted for nearly 15% of panel product imports in 1986, but as with softwood panels, imports are a relatively minor component of U.S. consumption. Canada supplies most U.S. imports of these products, although Latin America (primarily Mexico) now contributes 10% of U.S. imports.

Other Products

In addition to these commodities, the United States also imports a wide variety of miscellaneous solid-wood and fiber products. Other solid-wood imports include a small quantity of logs, posts and poles, fuelwood and charcoal, wooden containers, and miscellaneous manufactured products. Imports of these products in 1986 totaled more than 1.2 billion dollars. The majority of these imports originated in Canada (over 95%); Mexico accounted for roughly 2% of the total value of U.S. imports of miscellaneous solid-wood products. Miscellaneous fiber products imports include wallpaper, albums, books, and other printed material.

Trends in Exports

As is the case with imports, export trade in pulp and paper products is more valuable than solid-wood products. In most years, the value of exports of fiber products exceeds the value of solid-wood products by roughly 50%. On a volume basis, trade in the two commodity groups is nearly equal. In 1986, fiber products (pulp and paper) accounted for more than 60% of the value, and 50% of the total volume of forest products exported by the United States (tables 58 and 60, fig. 43a). Although fiber products account for nearly all the growth in imports between 1982 and 1989, the doubling of exports between 1985 and 1989 is a result of expansion in both solid-wood and fiber products shipments.

The total volume of forest products exported is nearly 17% of U.S. production, and exports are again approaching the level reached in 1980 (fig. 43b). The total value of forest products exports in 1986 was nearly $8 billion (table 58), but in each of the last 3 years (1987–89) exports (in constant-dollar terms) set a new record. Japan and Western Europe are the primary markets for U.S. forest products, accounting for 30% and 20% (respectively) of U.S. exports in 1986. Latin American and Asian countries (other than Japan) combined to purchase

Table 60.—U.S. timber product exports by product group, and specified years 1950–87.

Year	Total	Lumber	Veneer and plywood	Pulp products[1]	Logs
		Billion cubic feet, roundwood equivalent			
1950	0.1	0.1	(2)	0.1	(2)
1955	.3	.1	(2)	.2	(2)
1960	.5	.1	(2)	.3	(2)
1965	.7	.1	(2)	.4	.2
1970	1.5	.2	(2)	.9	.5
1975	1.7	.2	.1	.9	.5
1976	1.9	.3	.1	1.0	.6
1977	1.8	.3	(2)	1.0	.5
1978	1.8	.3	(2)	.9	.6
1979	2.1	.3	(2)	1.1	.7
1980	2.4	.4	(2)	1.3	.6
1981	2.1	.4	.1	1.2	.4
1982	2.0	.3	.1	1.1	.6
1983	2.1	.4	.1	1.1	.6
1984	2.1	.3	(2)	1.1	.6
1985	2.1	.3	(2)	1.1	.7
1986	2.3	.4	.1	1.2	.6
1987	2.7	.5	.1	1.4	.7

[1]*Includes pulpwood, wood chips, and the pulpwood equivalent of products.*
[2]*Less than 50 million cubic feet.*
Note: Data may not add to total because of rounding.
Source: Ulrich 1989.

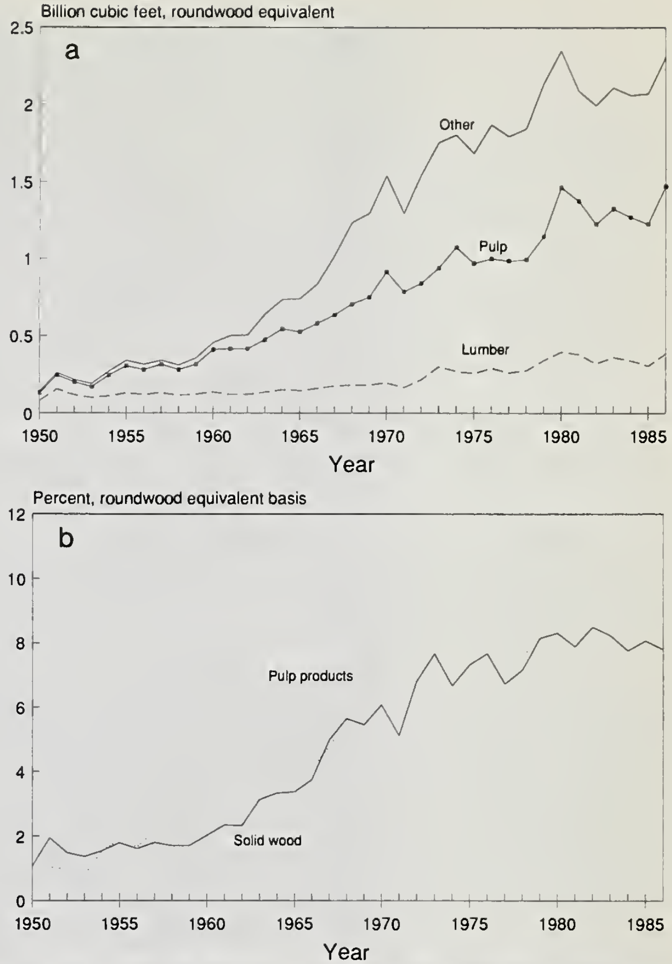


Figure 43.—Forest products exports 1950–1986: (a) volume of exports by commodity group (other includes logs, chips and panels) and (b) share of production exported.

roughly 30% of U.S. exports; Canada accounts for more than 10% (by value) of U.S exports of forest products.

Logs

Logs account for more than 25% of the volume, and roughly 17% of the value of U.S. forest products exports. Over 95% of these shipments are softwood logs, 60% of which go to Japan. The People's Republic of China, a customer since 1980, purchased more than 15% of U.S. softwood log exports in 1986, but less than 10% of exports in 1989. Other Asian countries (primarily South Korea and Taiwan) purchase roughly 10% of U.S. softwood log exports. Exports of softwood logs from the west coast to Pacific Basin countries comprise 90% of total U.S. log exports. Roughly 20% of roundwood production in the Northwest, and 7% of total U.S. roundwood production is exported as logs.

Exports of raw material, especially from the high-value end of the quality range (as is the case with both softwood and hardwood logs) have led to controversy. The volume of softwood log exports was minor prior to the early 1960s but expanded rapidly in the 1960s and 1970s, reaching a first peak in 1968, and a higher peak in 1979. Public debate over log exports policy, focused in the Pacific Northwest, has followed a similar cycle. Opponents of log exports, arguing that restricted exports would support domestic employment and reduce domestic raw material prices, were successful in placing restrictions (in 1968), and finally a ban (in 1973) on exports of logs harvested from federal lands west of the 100th meridian. Softwood logs currently exported from the Pacific Northwest are harvested from private land (predominantly forest industry) and from land managed by the states of Washington and Oregon.

Both the volume and total value of hardwood log exports are quite small in comparison to softwood logs. However, hardwood logs are, on average, two or three times the unit value of softwood logs. Although volumes are small in absolute terms, hardwood log exports also have significant impacts in regional stumpage markets. Most hardwood logs exported originate in the North (most of which are shipped to Canada), or in the South (most of which are shipped to Western Europe). In the past 10 years, however, shipments of hardwood logs to Canada have declined while shipments to Asia (including Japan) through west coast ports have increased.

Lumber

In 1986, U.S. lumber exports totaled 385 million cubic feet, roundwood equivalent (2.4 billion board feet). This is nearly four times the volume exported in 1950. Lumber exports in 1986 were valued at nearly 1 billion

Logs being loaded ror export to Pacific Rim countries.

dollars. Softwood species accounted for more than 75% of the volume (1.9 billion board feet) and 65% of the value of lumber exports in 1986. By 1989 softwood lumber exports increased to 3.4 billion board feet, an all-time high.

Japan is the largest market for U.S. exports of softwood lumber, purchasing 43% of the volume. Canada is the next largest market, although softwood lumber exports to Canada in 1986 (400 million board feet) were dwarfed by imports from Canada (14.1 billion board feet). Other major markets for U.S. softwood lumber are the European Economic Community (EEC) (especially Italy, the United Kingdom, and West Germany), Latin America (especially Mexico), and Australia. Roughly 70% of U.S. exports originate in western states and are shipped to the Pacific Basin.

In 1986 the United States exported 500 million board feet of hardwood lumber valued at 347 million dollars. This is more than six times the level of exports in 1950. By 1989, hardwood lumber exports increased to $574 million (1982 $). In spite of this growth in exports (most of which has occurred in this decade), hardwood lumber accounts for less than 5% of the value of U.S. forest products exports. Canada, Taiwan, Japan, and the EEC are the major markets for hardwood lumber.

Panel Products

Exports of panel products in 1986 were nearly 70 million cubic feet, roundwood equivalent. Softwood plywood accounts for roughly 80% of the volume, and just over 50% of the value of panel product exports. Softwood plywood exports increased sharply between 1986 and 1989, nearly tripling. Exports in 1989 were roughly 7% of U.S. softwood plywood production. The EEC is the primary market for U.S. softwood plywood exports; 70% of U.S exports go to these countries. A restrictive quota (with tariffs levied on quantities above the quota volume) limits U.S.-EEC trade in softwood plywood, and exporters in the United States and Canada compete vigorously for this market.

Europe is also the primary market for U.S. exports of hardwood plywood and veneer; more than half of the 13 billion cubic feet, roundwood equivalent (1 billion square feet) exported in 1986 went to the EEC, with a small quantity shipped to other Western European countries. However, European consumption of U.S. hardwood panels in 1986 was less than one-third the quantity consumed in 1978, and this decline accounted for the sharp reduction in U.S. total exports of hardwood veneer and plywood. Exports in 1986 were roughly half the volume exported in 1978. Canada purchases 15% of U.S. exports, and Asian countries (notably Taiwan, South Korea, and Japan) account for 17% of U.S. exports. Hardwood plywood and veneer exports to Asia in 1986 were six times greater than in 1978; growth in domestic economies, and the development of furniture manufacturing (for export) account for much of this increase.

The United States also exports a small quantity of other panel products (particleboard, fiberboard, oriented strand board, and wafer board). In 1986, 171 million square feet valued at 34 million dollars was exported, the highest volume to date. Asian countries (as a group) and Canada each consume roughly 40% of U.S. exports; 15% of the total volume was shipped to Latin America.

Pulp and Paper Products

Exports of pulp and paper products (including pulpwood chips) totaled 1.2 billion cubic feet, roundwood equivalent in 1986. This is nearly 25% of U.S. production, and over half of the volume of all forest product exports. Pulp and paper product exports in 1986 were valued at 4.5 billion dollars, roughly 60% of the value of all forest product exports. As was the case with exports of solid-wood products, exports of fiber products increased sharply after 1985, and in 1989 were at record levels.

Woodpulp accounts for half the quantity, and 40% of the value of pulp and paper exports. The European Economic Community (40%), Japan (20%), other Asian countries (16%), and Latin America (11%) are the major markets for U.S. woodpulp. Shipments to Canada have increased sharply since 1978, and now account for 6% of U.S. exports. Over 60% of U.S. woodpulp exports originate in the South (most of which are shipped to the EEC); most of the remainder are shipped from western states.

Exports of industrial packaging paper and paperboard were valued at 1.2 billion dollars in 1986 (28% of all fiber product exports). Kraft linerboard is the dominant product in this group, and is shipped to markets in Asia, Latin America, Europe, and Canada. Exports of other papers (newsprint, and printing and writing papers) were valued at 570 million dollars in 1986. Asia, Latin America, and Canada are the primary markets for U.S. paper exports. Exports of other paper and paperboard products were valued at 750 million dollars in 1986.

Exports of pulpwood chips were 150 million cubic feet, roundwood equivalent (2.4 million tons) in 1986, down from 280 million cubic feet in 1979. Exports in 1986 were valued at 170 million dollars. Most of the decline in chip exports was in shipments to Japan, the primary market for pulpwood chips. Exports to Japan in 1986 were down nearly 50% from the quantity exported in 1979; however, shipments of woodpulp to Japan doubled over the same period (949 thousand tons in 1986, compared to 557 thousand tons in 1979). Chip exports to Scandinavia also dropped sharply between 1981 and 1986, but here, too, the decline was offset by a modest increase in woodpulp exports.

Trends in Net Trade in Forest Products

Although well endowed with forest resources, the United States has been a net importer of forest products for most of this century. Imports exceed exports, whether expressed in terms of value, or expressed on a common volume basis. The total forest products trade deficit peaked (in absolute terms) in 1985 at nearly 5.6 billion dollars. In most years more than half of the deficit is attributable to trade in fiber products, but in recent years the deficit (in terms of value) in solid-wood products has shrunk to zero. In 1986, trade surpluses with Asia (2.2 billion dollars, most of which was accounted for by Japan), the EEC (900 million dollars), and Latin America (500 million dollars) were overwhelmed by deficits in forest products trade with Canada (8.6 billion dollars) and Scandinavia (550 million dollars). In 1989, the forest products trade surplus with Japan was \$3.7 billion (1982 \$), and the deficit with Canada was \$10.1 billion (1982 \$). Stronger demand overseas, combined with a weaker dollar, reduced the overall forest products trade deficit to \$2.4 billion (1982 \$) in 1989.

The United States is a net importer (on a volume basis) of all major forest product groups except logs (compare tables 59 and 60). Total net imports in 1987 were 2.0 billion cubic feet, roundwood equivalent, and were equal to 13% of U.S. consumption. Net imports in 1987 were down only slightly from the record level in 1985 (2.2 billion cubic feet, and 15% of consumption. Over the period 1980–87 net imports more than doubled, although net imports in 1987 were only slightly higher than those in 1979.

Softwood lumber and newsprint account for the majority of net imports (on a volume basis). In 1986 the trade deficit for these products in terms of value was 5.6 billion dollars, 60% of which is attributable to newsprint. The United States is also a net importer of panel products—net exports of softwood plywood being offset by net imports of hardwood plywood and particleboard. The deficit in panel trade was roughly 600 million dollars in 1986.

The United States was a net exporter of both softwood and hardwood logs in 1986; net receipts for log trade amounted to more than 1.2 billion dollars, most of which is accounted for by softwood log trade. Net exports of logs (600 million cubic feet in 1986) have been 4% to 5% of U.S. roundwood production since 1970. There is also a small (200 million dollar) surplus in hardwood lumber trade. Trade in woodpulp is roughly balanced in both quantity and value; however, the United States imports woodpulp from Canada, and exports woodpulp to Europe, Asia, and Latin America. The United States is a net exporter of industrial papers (roughly 6 million tons for a net gain of 1 billion dollars in 1986).

For more than four decades the United States has relied on other countries to supply as much as 30% of the volume of forest products consumed. However, at the same time, U.S. producers profit from opportunities to trade in foreign markets. The U.S. forest sector is clearly dependent on developments throughout the world.

WORLD FOREST RESOURCES AND TIMBER PRODUCTION

There are approximately 7.3 billion acres of closed forest in the world, roughly 20% of the total land area (table 61). "Closed" forests (those with continuous tree canopies) account for slightly less than two-thirds of the total area classified as forest land. There are substantial, but quite different forests in both the Northern and Southern Hemispheres. In the North, forests are located predominantly in the temperate zone, and coniferous species account for a majority of both the area and volume. Forests in the Southern Hemisphere are predominantly tropical, and composed largely of nonconiferous species. Four countries account for half of the world's closed forests: the Soviet Union, Canada, the United States, and Brazil.

Plantations are an increasingly important component of the world's forests. Although they account for a small proportion (less than 5%) of the total forest area in the world, plantations are important components of the economically viable forest, in terms of timber production, in nearly every region. For example, it has been estimated that more than 30% of industrial timber production in Latin America originated in plantation forests. (McGaughey and Gregerson 1982). Large areas of plantations have also been established for erosion control and for nontimber tree crops (nuts, oils, etc.). The total area of forest plantations in the world in 1975 was estimated at 220 million acres (Sedjo 1987). The rate of plantation establishment increased in the decade following 1975, but slowed in the 1980s. The reduction in the rate of plantation expansion has been the result of: (1) reforestation and afforestation programs nearing either established goals or natural limitations; and (2) economic recession-induced changes in long-term natural resource investment strategies.

Half of the forest plantations of the world are in developed countries in the northern temperate zone (North America, Europe, and the Soviet Union). A massive reforestation effort in the People's Republic of China, begun in the 1950s with the multiple objectives of environmental protection and commodity production, accounts for one-third of the world's forest plantations. Four decades of reforestation in Japan has resulted in the establishment of 27 million acres of plantations of native species. Australia, New Zealand, and Chile have established a total of nearly 7 million acres of exotic coniferous species, most of which are less than 20 years old. The remaining plantations are in developing countries in the tropics, and are composed of fast-growing, predominantly exotic species, both coniferous and nonconiferous.

World forests contained nearly 11 trillion cubic feet of growing stock in 1980; two-thirds of this volume was nonconiferous species, and the remainder was coniferous (table 61). Most of the nonconiferous growing stock (80%)—and half of all of the world's growing stock—is in the tropical forests of Latin America, Asia, and Africa. Over half of the world's growing stock of coniferous timber is in the Soviet Union, although two-thirds of this is in the remote Far East and Siberian regions. The United States and Canada, together, account for 25% of the world's coniferous growing stock, and 6% of the nonconiferous growing stock.

More than half (53%) of the 112 billion cubic feet of world production of timber in 1985 (table 62) was consumed as fuel. In the developing countries of Latin America, Asia, and Africa fuelwood accounts for as much as 90% of total timber removals. In the developed countries fuelwood accounts for roughly one-fourth of the total timber harvest. The United States, the Soviet Union, and Canada accounted for half of world production of industrial roundwood in 1985; the developed

Table 61.—Closed forest area and growing stock volume by species group, by country or region, 1980.

Country or region	Closed forest area	Growing stock: Coniferous	Growing stock: Nonconiferous	Growing stock: Total
	Million acres	*Billion cubic feet*		
United States	482.5	452	258	710
Soviet Union	1,956.0	2,306	728	3,034
Canada	652.6	547	145	692
Europe[1]	209.2	227	180	407
Nordic[2]	119.3	130	25	155
Asia	1,208.4	217	1,254	1,471
Africa	582.8	7	876	883
Latin America	1,826.7	99	3,327	3,426
Oceania[3]	215.8	20	63	83
World	7,275.2	4,005	6,855	10,860

[1]*Except Nordic countries.*
[2]*Finland, Norway, and Sweden.*
[3]*Australia, New Zealand, Papua New Guinea, and Pacific Islands.*
Sources: United Nations 1985, Canadian Forestry Service 1987.

Table 62.—World production of all timber products, and production, net trade, and apparent consumption of industrial timber, by country or region, 1985.

Country or region	All timber products production[1]	Industrial timber products: Production	Net imports	Net exports	Consumption
	Billion cubic feet, roundwood equivalent				
United States	15.9	12.2	2.5	—	14.7
Soviet Union	12.6	9.7	—	1.2	8.5
Canada	6.0	5.8	—	4.6	1.2
Europe[2]	8.6	6.9	3.9	—	10.8
Nordic[3]	3.7	3.4	—	3.1	.3
Asia	34.8	8.7	2.4	—	11.1
Africa	16.2	1.9	.2	—	2.1
Latin America	12.7	3.3	.1	—	3.4
Oceania[4]	1.3	1.0	—	.2	.8
World	111.8	53.0	9.1	9.1	53.0

[1]*Includes timber for industrial products, and fuelwood.*
[2]*Except Nordic countries.*
[3]*Finland, Norway, and Sweden.*
[4]*Australia, New Zealand, and South Pacific islands.*
Source: United Nations 1986b.
Note: Data for the United States differ slightly from those in tables 59 and 60 as a result of varying commodity definitions and conversion factors.

countries, as a whole, accounted for more than 75% of world industrial roundwood production.

One-third of the world's growing stock of timber is coniferous, but in 1985 coniferous species made up 39% of the total timber harvest, and 69% of the harvest of industrial roundwood. In the past two decades the relative importance in world production of temperate zone, coniferous forests has declined only slightly. An increase in the exploitation of tropical hardwood forests—for both fuel and industrial products—and a general stabilization of timber production in North America, Europe, and the Soviet Union has contributed to the modest reduction in world dependence on coniferous timber. However, coniferous forests are expected to remain the primary source of industrial timber for the foreseeable future. It is, in part, a reflection of this preference, that in spite of the fact that more than half of the world's growing stock of timber is in Latin America, Asia, and Africa, these regions produced only one-fourth of world industrial roundwood, and were net importers of industrial wood products in 1985 (table 62).

World timber removals in 1985 were 1% of world growing stock, ranging from a low of 0.4% in the Soviet Union and Latin America, to a high of 2.4% in the nordic countries and Asia. Aggregating across broad regions, timber growth exceeds timber removals; however, shortages of timber exist in a number of local areas. These conditions are most pronounced in the poorest developing countries where the need for food and fuel exceeds the short-run productive potential of the land. Population growth, fuelwood harvesting, and land clearing for agriculture combine to remove existing forests, and inhibit the establishment of new ones. Forest management, with long-term objectives, is foregone. In some developing countries with ample forest resources, the forest represents a stock of wealth that is deliberately liquidated to support both development and consumption.

In developed countries, most of which have a relatively long history of forest management, there are different, but no less significant pressures on forest resources. Atmospheric pollution originating in industrialized areas has had a significant, negative impact on the forests of Central Europe and, to a lesser extent, those in Scandinavia, and North America (Nilsson 1987). Increased mortality, and decreased growth on surviving trees will have both short- and long-run consequences on timber production and timber markets. In the short-run, efforts to salvage dead material may increase timber removals; however, in the long-run both productivity and production are likely to decline if damage is not abated.

WORLD ECONOMIC AND SOCIAL CHANGES AFFECTING FOREST PRODUCTS TRADE

Because wood products consumption and timber trade reflects and is a part of general economic welfare, it is significant that, in the 1980s, world output increased at an average rate of 2.7% per year through 1987; at the same time, world population grew 1.9% per year (International Monetary Fund 1987, World Bank 1987).

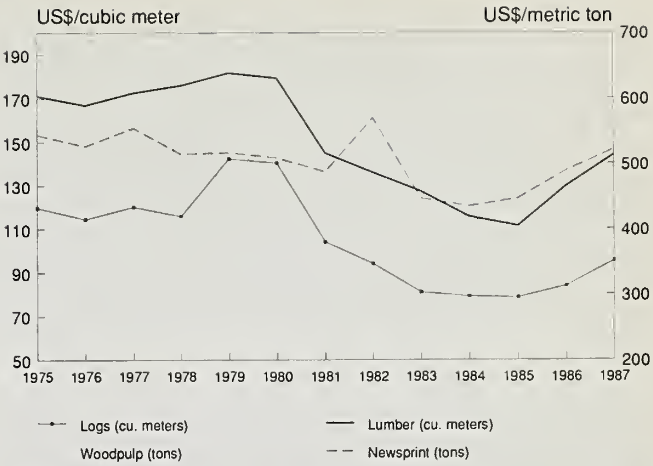


Figure 44.—Indexes of average world prices of wood products 1975–1987.

Thus, output per capita grew during this period despite a major economic recession. Industrial countries, whose consumption drives the bulk of world trade in wood products, increased their output at 7.8% per year on average, while their population grew at about 0.6% per year, indicating not only a growing capacity to buy wood products worldwide, but also a growing disparity between the per capita economic welfare and potential consumption of industrial versus developing countries.

In 1981 and 1982, world economic growth slowed markedly, then recovered in 1983. Trade in wood products reflected that trough, with annual exports of lumber declining 11% between 1979 and 1982 then climbing to record levels in 1985, 3% above the previous record year of 1979. Trade in woodpulp was similar. In 1982, woodpulp exports were 8% below the level in 1979; by 1985, exports were 8% above 1979. Paper exports followed a smoother path upward, declining in 1982 by only 5% relative to 1981, then turning upward toward a level in 1985 which was 14% above 1981 (United Nations 1986b).

Average world prices of wood products declined in the early 1980s and through the middle of the decade, recovering after 1985. Figure 44 shows the inflation-adjusted value of world imports of conifer logs, lumber, pulp, and newsprint. The downward trend in prices has been attributed to reduced housing activities in the industrialized countries for demographic and economic reasons—the latter related to the major recession of the 1980s. That recession carried forward a pattern of increasingly intense economic cycles that began in 1970, following a post-war period of relatively stable economic growth worldwide. In general, forest products prices have fluctuated more than trade volumes.

These worldwide averages obscure the influences of changes of intercountry monetary exchange rates; in fact, part of the increase in prices after 1985 is a result of the weakening of the U.S. dollar. For example, the rapid decline in the value of the dollar relative to the yen in 1985 instantly reduced the prices of existing contracts to be paid by the Japanese; contracts typically specify payment denominated in dollars. A 20% decline in the dollar yielded a 20% price reduction to importers. However, this windfall tended to be reduced in subsequent contracts as sellers negotiated to capture some of the gain. Thus, devaluation ultimately pressed upward the U.S. dollar prices of wood products exported, although not by the percentage amount of the devaluation. Eventually, such dollar price increases influence domestic prices. These market effects of the 1985–87 period of dollar devaluation are difficult to distinguish from the effects of a rising trend in demand associated with increased housing activity in the United States and Japan.

During the 1980s, timber-importing countries continued the staged reductions of tariffs agreed upon during the 1970s during the Tokyo Round of the GATT (General Agreement on Tariffs and Trade) negotiations. Examples of reductions especially pertinent to the United States are Canada's tariffs for panels and some paper items, which ranged from 7.5 to 15% and were reduced to a range of 0 to 9%, contingent on a North American agreement on plywood standards (Radcliffe 1981). The Unites States, too, reduced panel and certain paper tariffs from a range of 2.5–20% to 3–8%. Japan's tariffs, mostly in pulp- and chip-based products, formerly 5 to 12%, were scheduled for gradual reduction to 2 to 10%. Reductions were intended to be completed by 1990.

In the 1980s, several countries moved to make their economies more market oriented. Japan took several steps to free capital flows between that country and others, and expanded the ability of Japanese firms and individuals to invest overseas. In New Zealand, federal timber production and processing was moved into the private sector. China's steps toward developing a market economy have been numerous and substantial; they are described later. In addition, several countries made expatriation of foreigners' export earnings easier.

In supplying countries, trade consciousness appears to have been raised, perhaps because domestic markets were weak during the forepart of the decade. Particularly in the United States, but also in Chile, Brazil, and the Soviet Union among others, increasing efforts were made to understand, adapt to, expand, and influence the product demands and standards of consuming countries.

Compared with other commodities, most wood products are characterized as high in weight and volume relative to their value. To move freely in world trade, wood products must have access to inexpensive transportation. Long-distance materials moving became less costly during the 1980s, over many routes for several reasons. Economies of scale were achieved by using steadily larger and more specialized ships in shipping bulk cargoes such as logs. Rapid increase in the use of standardized 20- and 40-foot-long containers that fit on rail cars and trucks, and easily nest in ships, was a boon for U.S. wood products exporters. Many containers were returning empty to Asian countries that were supplying general merchandise in them to the United States; efforts to utilize the containers during the back-haul led to low shipping rates. Containers became a convenient way to handle orders; product packages (such as bundles of lumber and bales of pulp) can be kept together and intact in transit from producer to purchaser. Standard containers also led to "intermodal" transport systems, in which container-carrying trains meet ships at West Coast ports and move cargo directly across the country, offloading the containers onto trucks at a small number of destinations.

Another transient feature of ocean transport was a world surplus of shipping capacity, bringing ocean-transit costs down substantially. Deregulation of inland transport in North America permitted rail and shipping lines to adjust rates that generally declined on main haul routes from inland to coastal areas, while eliminating or raising costs on tributary routes. It also permitted shippers to negotiate lower rates for larger and more frequent shipments.

During the 1980s, there was a significant shift of timber-based manufacture into new wood products. Especially important to the United States were increased production in Canada of waferboard and increased output, within the United States, of medium-density fiberboard for export. High-speed lathes, forming machines, and dryers have lowered costs and increased the marketability of plywood and other panel products. Major pulp and paper capacity expansion was underway worldwide in the mid-1980s, based largely on new pulping processes combining chemical with thermal and mechanical pulp making. This development permitted greater use of hardwoods in printing and writing paper, particleboard, and other products formerly dominated by softwoods—a trend that has allowed the use of lower cost wood supplies.

In both Europe and North America, there has been an increasing recognition of the nontimber benefits of forests. This has resulted in pressures on both public and private forest owners to adjust management objectives to reduce timber production in favor of noncommodity outputs (recreation, wildlife, water). The United States and Europe already achieve the most intensive production of industrial timber products in the world; efforts to increase nontimber outputs of forests will require even more intensive management for timber production on fewer acres.

Economic development in Asia, Africa, and Latin America will bring greater pressure to bear on the forests of these regions, as well. It isn't clear that the developing countries will follow the resource use pattern of the developed countries; inevitably, however, the process of development has led to increased consumption of industrial timber products. Local and regional opportunities to expand production of timber for industrial products will depend, in part, on the ability to find (and afford) substitutes for wood fuel. The availability of capital, too, will determine whether some countries will remain commodity exporters and product importers. Governments in the developing countries face the considerable challenge of striking a balance between long- and short-run objectives; forests—or the lack of them—will be an important consideration. Continued economic growth in the industrialized countries will stimulate demands for timber products that will result in increased trade among these countries.

THE FOREST PRODUCTS SECTOR IN COMPETITOR AND CUSTOMER COUNTRIES

The widely varying economic factors, inside and beyond the wood products industries, that influence an individual country's commerce with the United States will be described in this section. Discussion will cover nations' changing timber resources, recent trends in their wood products manufacture, use, imports and exports, and their market partners. Each of these countries (or regions) is important to the United States as a market for U.S. producers, a supplier to U.S. consumers, or as both.

Japan

Propelled by a number of economic and social factors favoring growth in material well-being, Japan changed from an impoverished, resource- and energy-poor nation, stripped of its colonial empire at the end of World War II, and arrived 30 years later as one of the major industrial countries of the world. The Japanese economy benefitted from a pre-war legacy of emphasis on industrial development, an increasingly urbanized and literate work force, and a highly protected farm sector that made the country almost independent in food products while occupying a rapidly declining fraction of the work force. With close coordination between government and industry, Japan was aggressive in importing foreign technology and in appraising and penetrating foreign markets in targeted commodity areas. In addition, there has been a national willingness to forego consumption in favor of investment. Japan's rates of personal saving have been among the highest in the world despite relatively low rates of interest earned. Frugality permitted rates of growth and fixed capital formation (expenditures on dwellings, plants, and equipment) of about 15% per year into the 1970s—a rate 10 times that of the United States.

With increased industrialization and interaction with the world economy, a growing sensitivity to international economic cycles occurred. Japan benefitted from the rapid economic growth of industrial countries in the late 1970s, and suffered the subsequent decline into the mid-1980s. Figure 45a traces the annual changes in Japan's gross national product (GNP) in real (inflation-adjusted) terms, from 1975 to 1986. In 1975, capital formation (investment) accounted for one-third of Japan's GNP, roughly twice the proportion allocated to investment in the United States. By 1986, the investment share of GNP in Japan declined to about 28%, while in the United States it rose slightly to about 18%.

Japan's population and GNP per capita indicate the number of consumers, their average economic welfare, and ability to spend. Between 1975 and 1986, Japan's

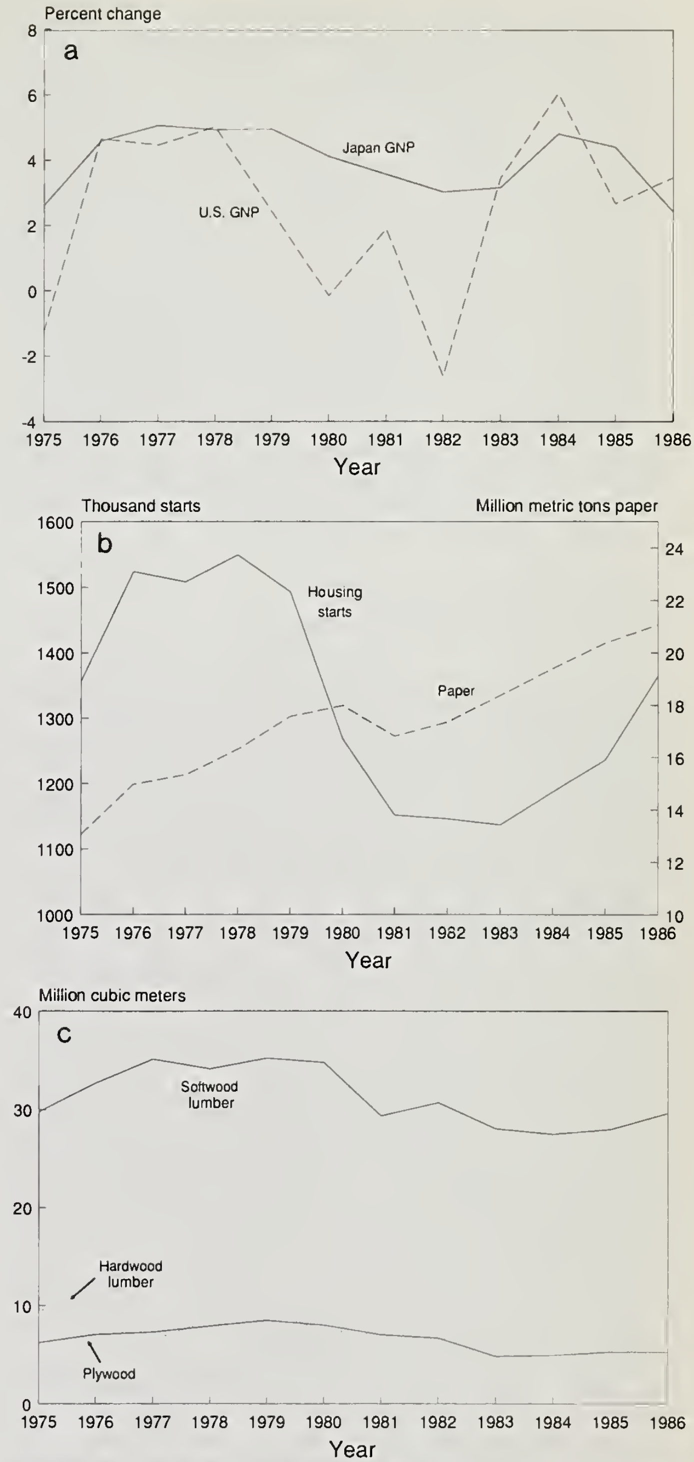


Figure 45.—Japan's demand stimulants for wood products 1975–1986: (a) gross national product compared with the United States, (b) housing trends and paper consumption, and (c) lumber and plywood consumption.

population grew a total of 9%, while per capita GNP grew almost 46%. Comparable figures for the United States were about 12 and 22%; per capita economic welfare in Japan increased almost twice as fast as that in the United States during the decade.

Figure 45b shows the trend of total housing starts in Japan from 1975 to 1986. Housing starts have generally followed economic cycles. The number of housing starts in Japan has rivaled the number in the United States—despite higher land prices, a population only half as large, and relatively high building costs in Japan. From 1977 to 1979, Japanese builders constructed about 1.5 million homes per year, declining to about 1.15 million in 1981. Comparable figures for the United States were 2.0 million and 1.1 million. Wooden houses, as a proportion of the total, declined steadily from about 65% to about 40% of the total. As predicted by Ueda and Darr (1980) at the time of the last Assessment, the average floor space of wooden houses, per structure, increased by about 13%. The trend away from wood houses can be explained by expansion of urban construction, where fire codes discourage the use of wood and land costs encourage high-rise structures that use relatively little structural wood. Rising Japanese affluence and a preference for wood is leading to an increase in the average size of single-family houses.

Wood Products Consumption

Japan is a major consumer of all wood products. In 1985, the Japanese consumed 370 pounds of paper and paperboard and about 10 cubic feet of lumber per capita (United Nations 1986a). Comparable figures for the United States are 625 pounds of paper and 32.2 cubic feet of lumber. The Japanese are especially appreciative of high quality in writing and wrapping papers. The important role of Japanese exports and growing domestic consumption of packaged goods accounts for the large volume of paperboard consumption. Consumption of paper in Japan has increased at an average rate of 2.5 to 3.0% per year; use of container board declined in the 1975–86 period by about 10% (Feng 1987). Although most of Japan's paper is produced domestically, about 20% of the pulp used comes from imports. There are about 600 paper and pulp plants in Japan, of which the top 10 produce about 70% of the paper and 40% of the paperboard manufactured (Nippon Mokuzai Bichiku Kiko 1986). Of the 20 million tons of paper and paperboard consumed in Japan in 1985, 50% was recovered for recycling. This proportion has risen steadily, as it has in the United States, where 26% is recovered (Kawake 1987). Figure 45b shows the trend of total consumption of paper and paperboard.

Figure 45c shows consumption of hardwood lumber, softwood lumber, and plywood. The decline of wood consumption in the early 1980s (most pronounced for softwood lumber) can be attributed in part to the general economic cycle, and in part to the previously mentioned fall in the proportion of wood-based houses. In addition, Nomura (1986) has cited a 50% decline in the number of new households between 1969 and 1982, and an excess supply of dwellings relative to the total number of households. In any case, the pattern of housing starts changed in mid-1986, driven at least partly by government efforts to stimulate the economy. By mid-1987, total housing starts reached an annual rate of 1.8 million.

With encouragement from U.S. trade associations, Japanese builders have experimented with platform frame construction, a departure from traditional building practices. It has been estimated that 300 to 400 basic sizes of lumber are used in Japan, with hundreds of local variations (Baskerville 1986). In addition, a variety of lumber grading systems are in use. Briggs and Dickens (1984) have estimated that only about 1% of Japan's lumber imports from North America fit Japanese size and grade standards. Although platform type housing is still at a low level (perhaps 3% of Japanese housing starts), the number is growing rapidly. With many of the structural members hidden, this North American approach to building lends itself to timber from young forests in Japan and elsewhere.

The Japanese wood products industry underwent major structural changes in the early 1980s. Declining demand, coupled with restrictions on supplies of tropical logs, sharply reduced the number of sawmills and plywood mills between 1977 and 1986. In both industries there were comparable decreases in employment. Between 1980 and 1985, Japanese annual plywood production declined about 20%. The economic recession in the furniture industry, for which much plywood is produced, was also a strong factor in the decline. By mid-1987, plywood production recovered two-thirds of the previous decline. Meanwhile, research in Japan on gluing thin hardwood face veneers to softwood plywood was successful (Japan Lumber Journal 1987), a development potentially favorable for U.S. exports of softwoods and higher grade hardwoods.

Timber Resources

Japan is about the size of California; 70% is mountainous. There has been an active program of afforestation throughout most of this century, with the forest area increasing from 45% to over 60% of the nation's land between 1920 and 1940 (Elchibegoff 1949). Japan depends on domestic forests for about 30% of its total wood consumption (Nippon Mokuzai Bichiku Kiko 1982). Of the 63 million acres of forest, 38 million acres are natural stands. Because of the country's great north-south orientation and large differences in altitude, the forests range from sub-tropical to sub-arctic in character. Of the forest area, 31% is in national forests; 11% is in other public ownership; and companies and individuals own 58%. About one-third of timber harvests come from the national forests; and of the 28 million acres of plantations, 26% are in national forests (Nippon Mokuzai Bichiku Kiko 1985). There are about 800 million cubic meters of growing stock in the country; 80% are in natural forests. Of logs harvested, two-thirds are sawn and one-third are chipped for pulpmills. About two-thirds of the trees harvested are conifers; of these, sawmills receive 80% (Nippon Mokuzai Bichiku Kiko 1986).

Heavy cutting during and soon after World War II led to intensive reforestation, with replanting of the existing cutover area accomplished by 1956. Thereafter, plantation activity emphasized conversion of natural hardwood forests to conifer stands. Plantation area by age class is as follows:

Age	Million acres
0–15 years	9.5
16–30	10.8
31–40	1.5
41–50	1.0
51 +	1.0

Intended harvest ages range from 35 to 80 years, depending on the planned end product (Fenton 1984, Nippon Mokuzai Bichiku Kiko 1985). Figure 46a shows the annual volume of saw logs arriving at sawmills from domestic forests. Because most plywood plants are supplied by logs from Southeast Asia, domestic log arrivals at plywood mills are negligible. The decline shown is attributable to reduced harvests in natural forests caused by the recession of the early 1980s and decreasing availability of mature timber. The economic recovery of the mid-1980s did not stimulate increased domestic log production, partly because plantations are not yet able to offset reductions in harvests from natural stands.

Wood Products Trade Patterns

Japan is the United States' largest export customer for wood products; in 1989, forest products exports to Japan were nearly $4 billion (1982 $). Changes in the pattern of Japan's wood products trade in the 1980s have particular significance to American producers. For example, Japanese imports of Canadian softwood logs grew significantly in the early 1980s; in 1986, Japan's log receipts from Canada equaled about 17% of those from the United States. A reduction in Canadian exports (discussed in the section on Canada) would widen American export opportunities. Imports of pulp chips from North America declined in the early 1980s, partly because of Japanese intentions to diversify their sources (Schreuder and Anderson 1987). Of a total of 6 million tons of chips imported, 34% came from the United States in 1986. The 1980–1986 decline in imports from the United States was 45%, but this was partially offset by an increase in imports of U.S. woodpulp.

Japan's softwood log and lumber imports have moved with economic cycles (fig. 46a). There has been a distinct upward trend in the ratio of lumber to logs. Plywood imports (fig. 46b) have been relatively small in volume and strongly cyclic.

Japanese imports of hardwood logs, used primarily in plywood and furniture manufacture, declined by 43% between 1979 and 1986, to about 450 million cubic feet per year. The change has had two principal effects on the United States. Japan (and other countries) have found that they can substitute hardwood logs from the U.S. Southeast and some from the West Coast, for Southeast Asian logs in some uses. In 1986, Japan imported 1/2 million cubic feet (about 3 million board feet) of hardwood logs from the United States. A second effect is through the substitution of particle and chip-based panels for the cores of furniture pieces that will be covered with paint, paper, plastic, or wood veneer. The United States competes with a number of countries in these expanding Japanese markets.

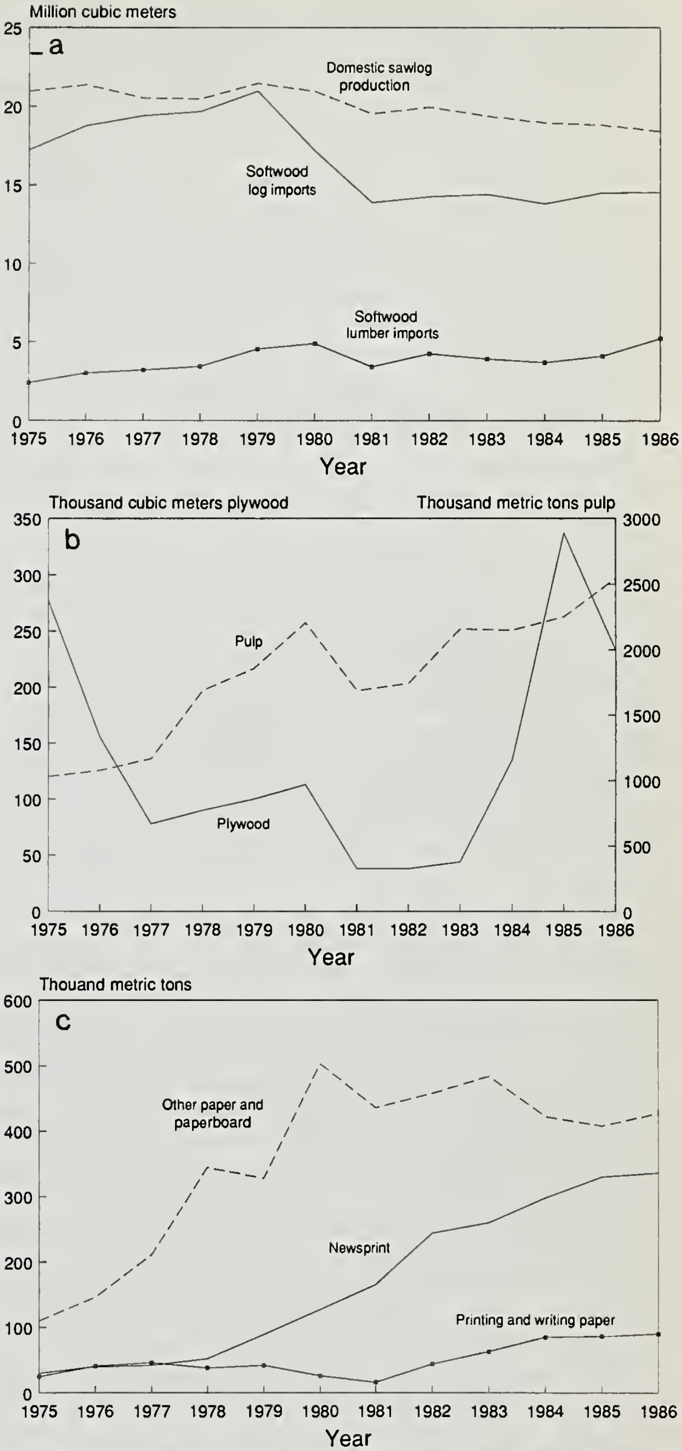


Figure 46.—Japan's domestic and imported timber supplies 1975–1986: (a) sawlogs and lumber, (b) plywood and pulp imports, and (c) paper and paperboard imports.

Japan's capacity to make pulp and paper expanded very little in the 1980s, in spite of steady growth in domestic demand. Chip imports increased to offset reduced availability of sawmill residues; however, most of the increase in consumption was supported through imports of pulp and paper products (fig. 46b and 46c). The United States has been a major supplier of the full array of fiber products in Japanese markets.

Between 1975 and 1980, the value of the yen relative to the U.S. dollar rose by 11%, then declined 21% by 1985, then rose again 32% by mid-1986; all in real (inflation-adjusted) terms. These changes coincided roughly with expansions and contractions of the business cycle, intensifying the cyclic price fluctuations that Japan confronted in dealing with the United States. Although viewed by some as an opportunity to speculate in currency, the Japanese have generally preferred long-term price stability.

For many reasons, including long-term price stability, long-term supply of raw materials, diversified sources of supply, and reducing labor costs, Japan has established joint ventures for processing forest products (and other goods) in many countries. This has been coupled with direct ownership of forest land in some cases. Countries involved include Canada, the Soviet Union, China, Southeast Asia, Oceania, several countries in Latin America, and the United States. In the United States, in particular, Japanese investors see an opportunity to acquire land with secure title, in a relatively stable economic and political environment, and at prices that in the 1980s were low relative to past values and Japanese domestic property costs. By the mid-1980s, Japanese offshore investments were a common feature of the world timber economy.

China

Although China has had hundreds of years of experience in international trade, political and military events of the Twentieth Century produced an insular social structure that discouraged foreign commerce until a major change in federal policies in 1979. Thereafter, brisk commercial interchange with a number of countries, in numerous commodities, occurred. However, the ease of purchasing relative to selling led to a near exhaustion of foreign exchange and downward pressure on the value of the yuan. The foreign exchange difficulty of 1984 and 1985 appears clearly in figure 47a. In 1986 and after, stricter discipline concerning imports, and expansion of exports of general merchandise, largely to Japan (the latter enhanced by Japan's strengthening currency), led to a gradual but steady increase in foreign exchange earnings.

Wood Products Consumption

China's low per capita income, about $300 per year, substantially offsets the market potential suggested by the size of the country's population—about 1.2 billion—5 times that of the United States. However, income averages obscure the somewhat higher incomes in coastal provinces, closer to offshore wood products sources, as well as the emergence of a relatively affluent segment of the population. Although income concentration has not been published, figure 47a shows the recent trend of per capita real income, which has risen sharply. These figures understate the economic welfare of the Chinese, especially in rural areas, where services are bartered and their values are unreported.

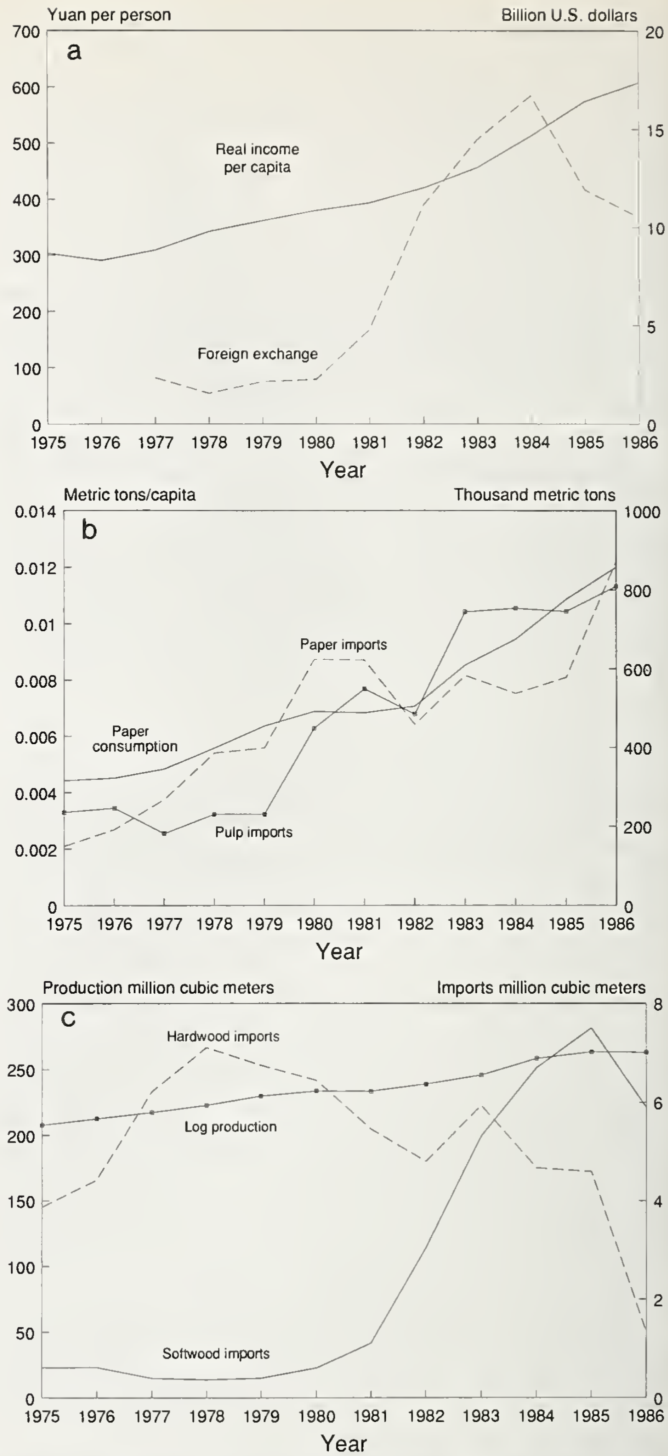


Figure 47.—China's wood products demand 1975–1986: (a) per capita real income and foreign exchange, (b) paper consumption per capita and pulp and paper imports, and (c) log production and imports.

As China develops, demand is great for newsprint and other papers used in communication, packaging materials for shipments to both domestic and foreign customers, hardwood plywood, and softwood building materials. Paper consumption per capita is about 15 pounds per year, only 5% of that in Japan. Figure 47b shows the recent trend of Chinese pulp and paper imports and per capita consumption.

Eight times as many houses are built each year in China as in the United States, but wood is used in few parts of the home. Windows, doors, roof beams, and occasionally floors, are typically made of wood; masonry housing uses wood concrete forms. Nonetheless, large volumes of wood are used in construction projects in China, both as lumber and plywood (Lovett and Dean-Lovett 1986). Of plywood produced, 60% goes into furniture and 20% into construction.

Domestic Timber Supplies

In the mid-1980s, China's forests provided almost 90% of China's roundwood consumption (USDA 1987a). However, the proportion of softwoods declined from 70% in 1965 to 60% in 1984. Figure 47c compares log production and timber imports. The largest reforestation program in the world's history increased China's forest land by 50% between 1949 and the mid-1980s. To preserve domestic timber supplies, China has imposed a wood substitution policy requiring that other materials be used in such conventional wood products as trusses, walls, railroad ties, mine props, and firewood. Despite these measures, China's estimated demand for timber other than firewood exceeded the growth of commercial roundwood by about 32% in the mid-1980s (Lovett and Dean-Lovett 1986). In 1985, Chinese consumption of lumber and plywood was about one billion cubic feet—about 20% of U.S. consumption (United Nations 1986a).

Wood Products Trade

Figures 47b and 47c show China's imports of pulp, paper, softwood logs, and hardwood logs in recent years. Pulp and paper imports have moved upward steadily, while log imports have responded to foreign exchange availability. Hardwood log imports have been affected strongly by supply constraints in Southeast Asia. China is one of the world's largest importers of solid-wood products (primarily softwood logs); the United States is the majority supplier, accounting for about 65% of Chinese imports. The Soviet Union and Canada supply, respectively, roughly 25% and 5% of Chinese imports. In paper and paperboard (excluding newsprint), the United States furnishes about one-third of China's imports. Most of the rest comes from Japan. Chinese tariffs are relatively high, ranging from 13% for softwood logs to 50% for finished softwood lumber and up to 100% for finished items such as window frames (including a 10% "product tax" on imported items). China's stated preference for logs over finished goods (e.g., Leland 1986) is attributed to conservation of foreign exchange and support of activity at China's 20,000 sawmills (Lovett and Dean-Lovett 1986). This objective is demonstrated plainly by the tariff schedule. In any case, in 1986, China accounted for about 18% of U. S softwood log exports; while softwood lumber and plywood percentages were nil.

South Korea

South Korea vies with China for third place, after Canada and Japan, in U.S. forest products trade. Most of that trade involves South Korea's imports of U.S. softwood logs. South Korea has also been one of several nations manufacturing hardwood plywood and furniture for export to the United States and elsewhere.

Domestic Markets

Although burdened with a significant fraction of the world's intercountry debt, South Korea's economic role has been enhanced by a rapid rate of economic growth as seen in figure 48a. GNP has regularly grown three to four times as fast as in the United States. The trend of individual economic welfare (per capita real income) in South Korea parallels that of Japan, although South Korea remains several years behind, and was impeded by the recession of the early 1980s.

South Korea's population is 34% that of Japan, but consumption of wood products is about 10% of Japanese wood use. This reflects lower per capita income and a different structure of wood-dependent economic sectors. Like China, South Korea's use of paper products is growing rapidly, including heavy demand for packaging materials for exported products. Also like China, South Korea uses little wood in residential construction and relies on reinforced concrete and other masonry products. Thus, solid-wood primarily goes into doors and window frames and interior decoration. The greatest use of softwoods is in construction, including concrete forms and scaffolding. South Korea makes extensive use of mine props in the production of coal. With Japan and Taiwan, South Korea has been a significant producer and user of hardwood plywood, primarily for export furniture production. Restraints on hardwood log exports in several Southeast Asian countries in the early 1980s sharply reduced plywood manufacture in South Korea. Furniture plants turned to imported plywood from countries formerly exporting logs, and to reconstituted wood panels from a number of countries. By the mid-1980s, half of South Korea's plywood capacity was idle (Schreuder et al. 1987).

Domestic Timber Supply

Two-thirds of South Korea is forested, but 90% of the stands are less than 20 years old; only 2% are older than 40 years (Schreuder et al. 1987). However, there has been an energetic reforestation program, and the 20-year trend of the domestic cut has been upward (fig. 48b). The in-

Figure 48.—South Korea's and Taiwan's wood products demand 1975–1986: (a) economic growth rates—annual change in gross domestic product, (b) domestic timber production, (c) South Korean pulp, paper, and log imports, and (d) U.S. hardwood log exports to Taiwan and softwood logs to South Korea.

crease, however, has been outstripped by domestic consumption. By the mid-1980s, harvests provided only about 15% of wood use; almost all of this was softwoods, and the majority was wood of low quality and value.

Wood Products Trade

The decline in South Korean plywood production coincided, in the early 1980s, with a drop in furniture exports, and a reduction in plywood exports to other furniture-producing countries in the Far East. By the mid-1980s, however, furniture production and export recovered rapidly, sustained by the fact that during a period of decline in the value of the U.S. dollar the South Korean won had roughly kept pace. As a result, South Korea could compete effectively with Japanese manufacturers in U.S. markets; in addition, South Korea was able to compete directly in Japanese markets (USDA 1987b).

Figure 48c portrays South Korea's pulp and paper and paperboard imports. In the mid-1980s, the United States accounted for one-third of South Korean pulp imports and two-thirds of South Korea's offshore paper and board purchases.

South Korea accounts for a minor share of U.S. lumber exports. Log exports to South Korea account for about 12% of U.S. offshore log shipments; the United States supplies about 66% of South Korea's softwood log imports. The balance of South Korean imports come primarily from Canada, New Zealand, and Chile. Figure 48d shows that real growth in U.S. log flows to South Korea came after 1975. South Korean orders are especially significant to the U.S. log industry because of South Korea's preference for lower grade logs than are commonly imported by the two other major log customers—Japan and China.

Taiwan and Southeast Asia

American forest products trade with Taiwan and other Southeast Asian countries has been mainly as a customer for hardwood plywood and furniture. Until the 1980s, the pertinent trade flows involved logs moving from the southerly countries into Taiwan, South Korea, and Japan for manufacture and export as higher valued products. By 1980, the Philippines had banned log exports, and export prohibitions were in place in Indonesia and

Peninsular Malaysia. By the mid-1980s, the principal sources of tropical hardwood logs for all markets were Thailand, Sarawak and Sabah in Malaysia, and Papua, New Guinea. These policy changes were accompanied by great expansion of the hardwood plywood industry in Indonesia, with more than 120 plants in operation by 1986 (Schreuder and Vlosky 1986). Major changes in wood product movements within the region have resulted, the most notable being the development of a market for U.S. hardwood lumber and logs. Idle plywood mills in Taiwan (as well as in South Korea and Japan, as mentioned earlier) have led to increases in shipments of temperate hardwood logs. However, U.S. hardwood log exports to Taiwan remain relatively small (fig. 48d).

Flows of wood chips within the region have also changed (Schreuder and Anderson 1987). Shipments from Indonesia have increased as domestic processing of logs has increased. The long-term effect on demand for U.S. chips is unclear, as these changes were taking place during the economic decline of the early 1980s.

The gross national product of the Southeast Asian countries grew at about 5% per year (in constant terms) in the early 1980s. Taiwan's economy expanded at a rate well above the regional average, more than 10% per year (fig. 48a). In spite of relatively strong economic growth, the U.S. dollar equivalent of average per capita income in the regions was only about $600 in 1985 (World Bank 1987). As a result, pulp and paper consumption in Southeast Asia was low in the 1975–1986 period. In addition, a significant amount of regional demand for materials for fiber products was met by local production from nearby materials, including bagasse (United Nations 1986b).

Because of its stronger economy and the ability to satisfy consumption through imports, Taiwan has been able to expand its forest sector while reducing demands on domestic forests. Taiwan's domestic supply of softwoods, for solid as well as fiber products, is in decline (fig. 48b).

The Soviet Union

Relative to other industrialized countries, economic growth in the Soviet Union was modest in the 1980s. It is not surprising, therefore, that per capita consumption of solid-wood products and paper and paperboard products (13 cubic feet and 77 pounds, respectively, in 1985) are well below consumption in the United States and Japan. Nevertheless, Soviet timber resources are vast, and the Soviet Union plays an important role in European and Pacific Rim markets.

The Soviet timber economy has two distinct segments—the area west of central Siberia (here called the "west") and eastern Siberia and the Far East (here termed the "east"). The west is characterized by relatively high population and pressure on declining forest resources. Economic interactions are primarily with European countries. In the east, population is low, forest resources are vast and largely untapped, and orientation of the timber economy is toward exports to Pacific Rim countries.

The West

Twenty-four percent of the country's population lives in the western portion of the Soviet Union (this is also referred to as the European portion of the country). Demands on Soviet forests in the west have been heavy, leading to diminished supplies and a longer reach for domestic timber (Blandon 1983, Braden 1983). The Ural Mountains, a north-south chain about 600 miles east of Moscow, have long been a natural barrier to eastward expansion of the forest industry. However, forests east of the Urals are now being tapped for shipment westward. Estimates of timber supplies remaining in the west range from 50 to 70 times recent harvest levels (Blandon 1983, Braden 1983, Rodgers 1983, Fenton and Maplesden 1986). The portion economically accessible is unknown and difficult to define given the centrally managed economy and the designated wages and prices. Figure 49 shows Soviet shipments of solid-wood products and fiber products (pulpwood, and paper and board) westward, to countries other than those in the Pacific Rim. These products are manufactured from timber harvested in the western forests. In addition to European countries, markets have included Cuba and several Middle Eastern countries. Most of these countries also trade in wood products with the United States.

The East

Declining oil prices after 1978 created significant foreign exchange problems for the Soviet Union because oil had accounted for 80% of the country's export income. During the same period, total Pacific Rim demand for wood products expanded, with the significant demands of South Korea and China more than offsetting relatively static Japanese consumption. Thus, Soviet development efforts in the east were heavily oriented to wood products complexes, supplemented by multipur-

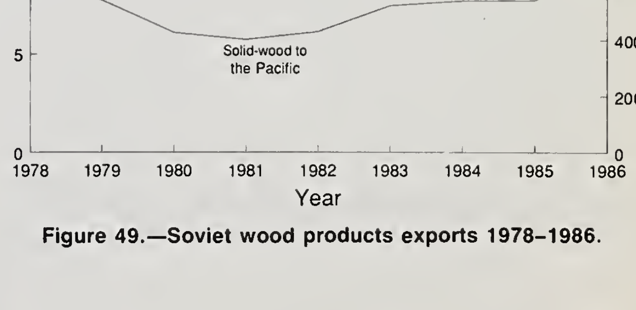


Figure 49.—Soviet wood products exports 1978–1986.

pose expansion of port facilities on the Pacific Coast and a new 2,000-mile railroad from the Pacific to the interior.

Exports from the Soviet east have primarily been softwood chips, pulpwood, logs, and lumber—mostly to China and Japan. Barter and joint ventures are common. Relative to U.S. exports to the Pacific Rim, Soviet shipments are equivalent to about 17% in chips, 52% in pulpwood and logs, and 7% in lumber. Soviet pulp and paper exports to the Pacific are negligible (Fenton and Maplesden 1986). Solid-wood exports to the Pacific region are shown in figure 49.

Soviet development of the east has proceeded throughout this century, primarily for strategic reasons (Mote 1983). Increased forest resource development in the 1980s faces the considerable problems of vast distances, low timber volumes per acre, a sparse transportation network, widely spaced communities, and a severely cold climate. Climatic conditions are comparable to those of far northern British Columbia and the southern part of the Yukon Territory, with timber-growing conditions generally declining as one moves westward from the Pacific Coast. Temperatures get progressively colder in the same direction, with more than three-fourths of the Soviet east having January temperatures lower than those of Fairbanks, Alaska; the 24-hour average temperature in January is about −12°F, and about 60°F in July. Of course, in a geographic zone extending more than 5,000 miles east-west and more than 2,000 miles north-south, with varied topography, there is significant climatic variation. For the same reasons, timber that is sparse on average, has significant concentrations of preferred species in high-quality stands. In expanse the Soviet eastern forest compensates for the severe climate. The Soviet east has about half of the world's softwood timber resource (Blandon 1983, Fenton and Maplesden 1986), and provides about 12% of the solid-wood products moving into Pacific Rim markets (excluding trade between Canada and the United States).

Canada

Merchandise trade between Canada and the United States is the largest bilateral exchange in the world; this is also the case in U.S.-Canadian forest products trade. Canada imports modest quantities of lumber and logs, and significant amounts of pulp and paper from the United States. Americans buy large quantities of Canadian softwood lumber, newsprint, publishing papers, and structural panels. As major participants in world trade, Canada and the United States compete to supply chips, logs, lumber, pulp, and most paper and board products to European and Pacific Rim markets. Major policy changes in the 1980s concerning wood products in particular, and U.S.-Canada trade generally, may materially affect the economics of trade between the two countries.

Canada's Timberland

Summaries of Canada's timber situation (Reed and Associates 1978, Bonnor 1982, Nilsson 1983, Honer and Bickerstaff 1985) indicate that Canada is second only to the Soviet Union in the extent of its total forest land. Although only half is judged suitable for timber production, the "productive" portion is about 10% larger than the comparable area in the United States. Of that area, about 550 million acres, half is in the eastern provinces, a quarter is in British Columbia, and the balance is in the prairie provinces and the northern territories. Only about 8% of the suitable forest land is privately owned.

Comparative aggregate timber inventory data is available for Canada and the United States as of about 1980. At that time, Canada had about 500 billion cubic feet of gross merchantable volume in mature forests (Honer and Bickerstaff 1985). Even after adjustments for decay and other defects, Canada's inventory exceeded the U.S. commercial saw timber volume of about 413 billion cubic feet.

About 80% of Canada's timber inventory is softwood. Hardwood, an increasingly significant part of the resource economically, is about two-fifths of the timber resource in the prairie provinces, one-third in Ontario, one-quarter in Quebec and the Atlantic provinces, and less than 5% in British Columbia and the territories.

Honer and Bickerstaff (1985) estimated that about 55% of Canada's stocked productive forest lands are recently regenerated or immature, with 45% mature or overmature. Some of the mature timber is the product of centuries of natural forest recycling; some is the result of harvesting and regeneration within the past 100 years. The analysts estimated that half of the remaining volume of mature and overmature timber is in British Columbia, with about one-quarter in Quebec and Ontario. Honer and Bickerstaff also estimated that the annual depletion of the growing stock is about 1.3%, of which about one-half is attributable to harvesting and one-half to fire, insects, and disease.

They estimated that, of the depleted area, 8% has been replanted, 72% has regenerated naturally, and 20% has gone out of production. The latter statistic was a matter of great technical and public interest in the early 1980s, leading to a major Federal-Provincial joint venture aimed at forest renewal (Environment Canada 1981, O'Hara 1985, Reed 1986). In connection with this program, over 700,000 acres received forestry treatments, including one-half million acres of site preparation and regeneration in 1985 (Canadian Forestry Service 1987).

Domestic Consumption and Production

Figure 50 compares Canada's per capita gross national product with that of the United States. Per capita real income in Canada increased at about 2% a year between 1975 and 1986, less rapidly than that in the United States, and significantly slower than the developed economies of Asia. Thus, Canadian markets for wood products have expanded less briskly than have those in the Pacific Basin. In forest products, Canada's consumption of all commodities, including wood products, is about one-tenth that of the United States. Between 1975 and 1985, Canada's per capita consumption of paper and paperboard increased 34%, while in Japan consumption increased 44%.

Figure 51 shows log production, including pulpwood, by region between 1975 and 1986. The prairie provinces are included with the interior West. The effect of economic cycles is clearly seen, as is the large role played by the interior West. The trend of lumber production (not shown) is similar. Again, the position of the interior West is significant, as is the increasing participation of the eastern provinces. Plywood production is not displayed because little is involved in trade with the United States. However, waferboard, a product developed in the 1960s and produced commercially since 1976 in Canada, is important. Canadian production of waferboard doubled between 1983 and 1985, and exports to the United States account for 40% of Canadian production (about 70 million cubic feet).

Pulp production grew 40% in Canada between 1975 and 1986. Notable is the Canadian trend toward new pulping processes (chemical-thermal-mechanical pulping), with new plants totaling more than 700,000 tons per year either under construction or planned in the mid-1980s (Young 1987). Newsprint production has been flat, while manufacture of other paper and paperboard doubled over the 11 years.

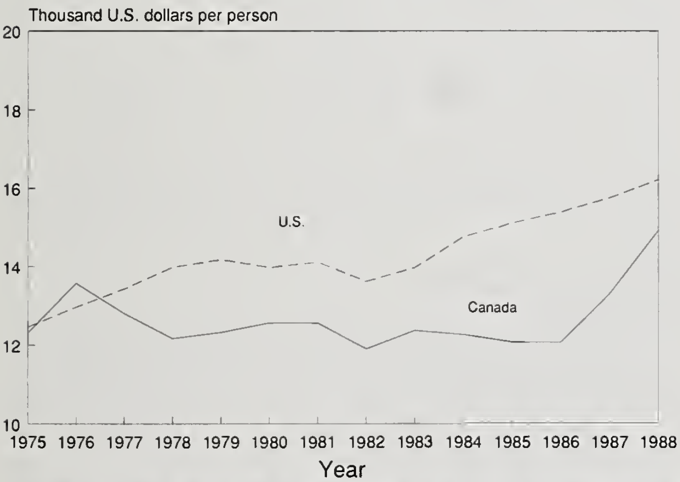


Figure 50.—Per capita real income in Canada and the United States 1975–1988.

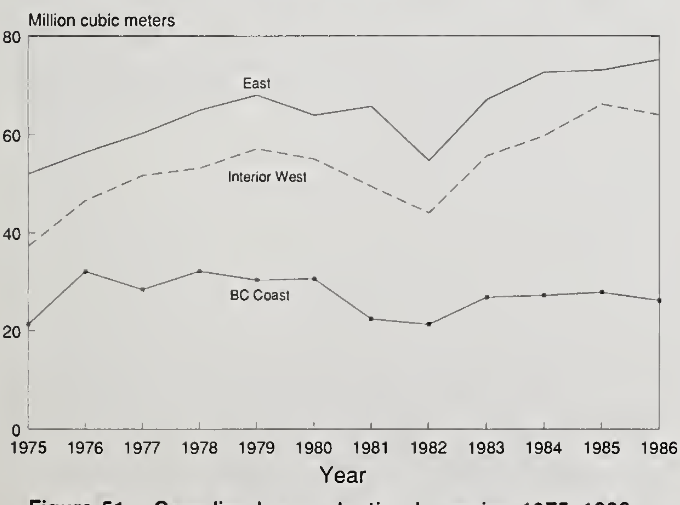


Figure 51.—Canadian log production by region 1975–1986.

Imports and Exports

Like the United States, Canadian imports of forest products from outside North America are limited to veneer and plywood from tropical-hardwood producers, and finished products such as furniture. Relative to other U.S. forest products trade (and U.S. imports from Canada), U.S. forest products exports to Canada have been small. Nevertheless, in 1989 U.S. forest products exports to Canada were roughly $1 billion (1982 $)

Export trade dominates the Canadian forest sector. Figure 52a shows Canadian pulp exports to the world and to the United States. In 1986, the United States accounted for 48% of Canadian pulp exports, with 21% going to the Pacific Rim and most of the balance to Europe. There has been a shift toward hardwood woodpulp in Canada, the result of significant hardwood resources and new pulp and paper technology. In the mid-1980s, there was substantial installation of chemical-thermal-mechanical pulping (CTMP), a change reflected in the character of pulp and paper exports. Between 1980 and 1986, U.S. imports of Canadian paper containing more than 10% mechanical woodpulp increased 70%. During this period, imports of standard newsprint grew 16%.

Canada has long been a major exporter of newsprint, primarily to the United States. Canada accounts for 60% of the world's newsprint exports. As shown in figure 52b, almost 85% of Canadian newsprint exports move southward; newsprint accounts for about 85% of all Canadian paper exports. Canadian exports of other paper and paperboard are shown in figure 52c. More than 70% of Canada's nonnewsprint paper exports go the United States.

Partly because of a long-standing 20% U.S. tariff on softwood plywood, little of that commodity moves between Canada and the United States. A rising trend in shake and shingle shipments from Canada to the United States led to a 1985 complaint by the U.S. industry that U.S. purchases from Canada were increasing at the expense of U.S. production. In 1986, the International Trade Commission imposed a 35% tariff to last 30 months, to be followed by 30 months at 20%, and 6 months at 8%. As a result, U.S. shake and shingle imports declined sharply.

U.S. purchases of Canadian lumber are shown in figure 52d. U.S. imports of Canadian lumber have followed a steady upward trend since 1932, interrupted by peaks and troughs attributable to economic cycles. Between 1975 and 1986, Canadian shipments to U.S. markets tripled, while U.S. lumber production increased about one-third. The U.S. industry appeal for relief, based on the premise that Canada was subsidizing its industry by charging artificially low stumpage prices, failed in 1983 but succeeded in 1986. As a result of negotiations between Canada and the United States, Canada imposed in January 1987 a 15% export fee on exports of certain softwood lumber exports to the United States. This fee may be replaced by forestry-related expenditures in Canada; some polices have been implemented and negotiations between the two countries are continuing.

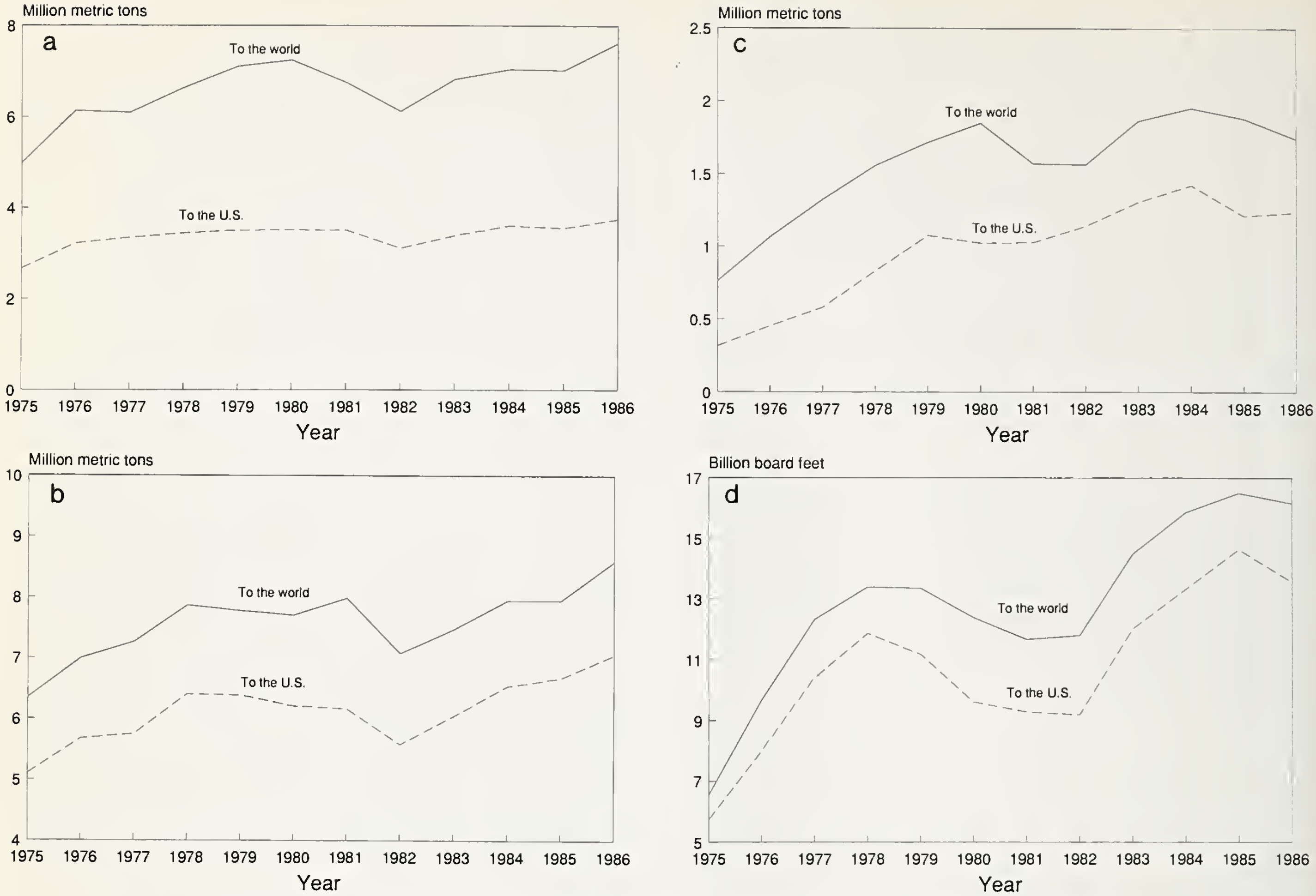


Figure 52.—Canadian wood products exports 1975–1986: (a) pulp, (b) newsprint, (c) all paper and paperboard, and (d) lumber.

Canadian softwood lumber competes with U.S. supplies in markets worldwide; Canada's lumber exports to destinations offshore have been significant for more than a century. Exports beyond North America are shown in figure 52d. In 1986, Canada exported to offshore markets 37% more softwood lumber than did the United States.

Unlike the United States, where tariffs and other trade limitations are federal matters, Canada has delegated control of timber exports to the provinces. British Columbia, the principal source of Canada's log exports, has had a statutory prohibition of roundwood exports from Crown lands since 1906. Provision has been made for exemptions when timber cannot be processed economically in domestic mills, or where timber is surplus to domestic needs. These provisions led to substantial log exports during recent recession years. Exports in 1986 were equal to about 16% of those from the United States, moving to the same countries as were served by U.S. shipments.

Canada's role as competitor in world markets is influenced by the relative values of United States and Canadian currencies. The inflation-adjusted value of the Canadian dollar declined by 14% relative to the U.S. dollar between 1975 and 1985; making Canadian lumber progressively cheaper for American buyers. It has been estimated that the decline accounted for 40% to 50% of the increase in Canada's share of the U.S. softwood lumber market (Flora 1985, Adams et al. 1986). Relative to currencies of other trading partners, Canada's currency declined about 25% from 1976 to 1979, giving Canada a trade advantage that continued into the mid-1980s. As Canada's dollar remained flat in world terms the U.S. dollar rose almost 40% (OECD 1986a, 1986b). After 1985, Canada's currency rebounded, rising in real terms almost 8% relative to the U.S. dollar by late 1987.

The Middle East

Along the eastern shores of the Mediterranean and Aegean Oceans and eastward through India, 18 countries import wood products. Sixteen rely on the United States for part of their supplies. With 25% of the world's population and 5.4% of western nations' economic output, Middle East countries account for 7.5% of world imports of sawn wood and 3.5% of world newsprint imports. Within the region, there are great differences in per capita income. In 1985, in the four lowest-income countries, per capita income was $239, while in the highest four it was $8,947; in the ten mid-income nations, it averaged $957 (World Bank 1987). Imports of sawn wood in cubic feet per capita were .01 for the low-income countries, .76 for the mid-income countries, and 3.32 for the high-income (oil-exporting) countries; a 300-fold differential between high and low. Similarly, newsprint imports per capita were .6, 2.2, and 4.1 pounds in low-, mid-, and high-income countries, respectively, in 1985. Worldwide, average per capita imports of these bench mark commodities were .68 cubic feet of sawn wood and 7 pounds of newsprint.

Faced generally with a dearth of timberland, Middle Eastern countries have emphasized domestic production of fuelwood and charcoal; in none of the countries have imports been a significant source (United Nations 1986b). India is unique in having a large forest area, equal to about 20% of that in the United States (United Nations 1976). However, those forests must support a population three times that of the United States. India has been a negligible importer of wood products except for newsprint, with a minor fraction coming from the United States.

In company with the rest of the world, the Middle East imports only small amounts of plywood. In contrast with much of the world, only small amounts of woodpulp move into this region. Turkey's imports of pulp are notable, however, because they doubled during the early 1980s. Eight countries import some pulp from the United States, accounting for about 4% of U.S. pulp exports. Most Middle East countries import paper from the United States, with particular emphasis on linerboard, which went to 13 countries, accounting for about 9.4% of U.S. linerboard exports.

The region's capacity to expand wood products imports drew attention in the early 1980s despite the relatively flat economic growth of the oil exporting countries. While real economic growth in the United States was about 2.5% per year between 1980 and 1985, the mid- and low-income countries of the Middle East (except for Israel, Syria, and Lebanon) grew at rates between 4 and 6% per year. The United Nations (1986a) noted that between 1970 and 1982 consumption of sawn wood grew more than 10% per year in Egypt, Iraq, Jordan, and Saudi Arabia. During the same period, consumption growth rates for paper and paperboard grew faster than 10% per year in Jordan, Kuwait, and Saudi Arabia. Evidence of the potential for expanding markets emerged in 1986, when Turkey began importing softwood logs, although the shipments also reflected a ban on Turkish timber harvesting (Random Lengths Export 1987).

Europe

Individually, the countries of Europe are more dependent on international trade than is the United States. This is, in part, a function of the fact that no single economy in Europe is as large as that of the United States; it is also a consequence of the fact that the countries of Europe are joined in three major economic and trade alliances. The 12 countries of the European Economic Community (EEC) form the largest group in terms of collective economic power and trade activity.[15] The Nordic countries, along with the nonaligned countries of Western Europe (Austria and Switzerland) form the European Free Trade Association (EFTA).[16] The centrally planned economies of Central and Eastern Europe are members of the Council for Mutual Economic Cooperation (COMECON).[17] The existence of these groupings discourages the imposition of trade barriers (directed at members of the group), and encourages specialization and trade (within the group). It is interesting to note, in passing, that the economic diversity, specialization, and trade dependence of the countries of Europe would be echoed if U.S. trade were to be viewed at the state and regional level.

The importance of trade to the economies of Europe, and the relative importance of Europe in world trade is not simply a product of exchange among members of economic associations. For example, trade between the EEC and nonmember countries is greater than U.S. trade (both imports and exports); members of the EEC ship half of all exports to nonmembers, and nonmembers are the source of half of all EEC imports. This form of trade dependence is even greater for EFTA. The members of COMECON form a more closed group, but one for which external, as well as internal trade is nevertheless important.

Periodic assessments of the current condition and prospective future of European forests are prepared jointly by the United Nations Economic Commission for Europe (ECE) and the Food and Agriculture Organization of the United Nations (FAO). The fourth in this series of studies—a European equivalent to the RPA process—was published in 1986 (ECE/FAO 1986). This review of the situation in Europe relies heavily on the data collected and the analyses prepared in the most recent European timber trends study (ETTS IV).

Forest Products Trade

Producers and consumers of forest products in Europe depend to a far greater extent on trade than do their counterparts in the United States. Forest products imports by all countries in Europe were 8.4 billion cubic feet in 1985 (roundwood equivalent, and including intra-European trade). This was 74% of regional consumption, and 80% of regional production of industrial roundwood. More than 1.4 billion cubic feet (17% of the total volume of imports) originated in countries outside Europe.

The Soviet Union, Canada, and the United States are the primary external sources of European imports. The

[15] *The current members of the EEC are: Belgium, Denmark, France, Germany, Greece, Italy, Luxemburg, Netherlands, Portugal, Spain, and the United Kingdom.*

[16] *Members of EFTA are: Austria, Finland, Iceland, Norway, Sweden, and Switzerland.*

[17] *Members of COMECON are: Albania, Bulgaria, Cuba, Czechoslovakia, the Democratic Republic of Germany, Hungary, Mongolia, Poland, Romania, the Soviet Union, and Vietnam.*

Soviet Union supplies pulpwood, logs, and sawn wood to both Eastern and Western Europe, and accounts for 30% of Europe's external supply. Canada accounts for 25%, and the United States accounts for roughly 20% of the volume of European "external" imports. European imports from North America include sawn wood, wood-based panels, woodpulp, and paper products. Most of the remaining (external) imports came from tropical countries in Africa, Asia, and Latin America. Unprocessed forest products (pulpwood and logs) accounted for more than one-fourth of imports from countries outside Europe, but only 15% of total imports.

Total European imports of forest products were valued at 25.7 billion dollars (U.S.) in 1985; the EEC accounted for 80% of this total. The Federal Republic of Germany and the United Kingdom are the leading importers in the EEC, together accounting for half of the group's total imports of forest products in 1985. France and Italy each account for roughly 13% of total EEC imports of forest products.

European exports of all forest products totaled 7.6 billion cubic feet, roundwood equivalent, 70% of regional roundwood production in 1985. The equivalent of more than 1.1 billion cubic feet of roundwood was exported to countries outside Europe; this was 15% of the total export volume. Pulp and paper products accounted for nearly 80% of the volume of exports to destinations outside the region; coniferous sawn wood (most of which originates in the Nordic countries) accounted for most of the rest. Major markets for European exports are the Middle East and Northern Africa (coniferous sawn wood), North and South America, and Japan (woodpulp, and paper products). Sweden and Finland are Europe's largest exporters of forest products; together they accounted for 40% of total exports (by value) in 1985. The Federal Republic of Germany, and France are the largest forest products exporters in the EEC, accounting for 50% of that group's exports, and 20% of the European total in 1985. However, both countries are net importers of forest products.

In 1985, Europe as a whole was a net importer of roughly 800 million cubic feet of forest products (roundwood equivalent). However, this was the result of 3.1 billion cubic feet of net exports by the nordic countries being offset by nearly 4 billion cubic feet of net imports by the rest of Europe (table 62). The European deficit with countries outside the region was roughly 300 million cubic feet. Net imports for all of Europe were valued at 3 billion dollars (U.S.), and amounted to 9% of industrial roundwood production, and 8% of regional consumption. The United Kingdom was the largest net importer in 1985 (4.4 billion dollars, U.S.), followed by the Federal Republic of Germany, and Italy. Together the countries of the EEC were net importers of 12 billion dollars (U.S.) in forest products. The members of EFTA were net exporters of 9 billion dollars (U.S.) in forest products in 1985.

In 1986 the United States imported 1.2 billion dollars of forest products from Western Europe (11% of total U.S. forest products imports, and 6% of European exports). Over 90% of these imports were fiber products (woodpulp and paper products); half of the total, by value, was printing and writing paper (other than newsprint). In the same year the United States exported to Europe forest products valued at 1.7 billion dollars (23% of U.S. forest products exports, and 5% of European imports). U.S. purchases of European forest products were equally divided between the EEC and EFTA. However, U.S. exports go primarily to countries in the EEC. The nordic countries in EFTA are the source of most U.S. imports from this association.

Forest Resources and Production

Detailed information on the forests of Europe was published in 1985; some of these data are summarized in table 63 (ECE/FAO 1986). There are 328 million acres of closed forest in Europe, less than 5% of the world total. Half of the European forests are privately owned. Nearly half of the forests of Western Europe (45%) are in the nordic countries, where private owners control 75% of the forests, and forest industry owns 15% of the forests. Private ownership of forests is lowest in the centrally planned economies of Eastern Europe. Only in the nordic countries is the forest industry share of forest land ownership comparable to that in the United States; forest industry owns roughly 18 million acres of the commercial forests in the nordic region. In all of Europe the forest industry owns approximately 6% of all commercial forest land.

Total growing stock of European forests in 1980 was 561.5 billion cubic feet, roughly two-thirds of which was coniferous (table 63). Total annual growth in 1980 (both coniferous and nonconiferous) was nearly 18 billion cubic feet, 3.2% of growing stock. Annual growth rates for coniferous species are highest in the EEC (nearly 5% of growing stock) as a result of extensive plantations in a number of countries, including France, Ireland, the United Kingdom, Portugal, and Spain.

Total roundwood removals in Europe were 12.7 billion cubic feet in 1985, having increased by nearly one-fourth (2.3 billion cubic feet) between 1950 and 1985 (table 64). Almost all of this growth was in coniferous removals. Nonconiferous timber production in Europe actually declined between 1970 and 1980; production in 1985 was roughly comparable to that in 1970. Total timber production for industrial products increased by more than 70% over the 1950–85 period; fuelwood production declined to less than 20% of total roundwood production in 1985, from more than 30% in 1950. Timber removals for pulpwood showed both the greatest relative growth, as well as the greatest absolute growth over the 35-year period. Roundwood removals in 1980 were 70% of growth for coniferous species, and 63% of growth for nonconiferous species.

Consumption of Forest Products

In 1985, European countries consumed roughly 41 billion board feet of sawn wood, 39 billion square feet of

Table 63.—European forest resources, 1980.

Region	Commercial forest[1]	Growing stock: Coniferous	Growing stock: Nonconiferous	Annual growth: Coniferous	Annual growth: Nonconiferous
	Million acres	*Billion cubic feet*			
Nordic[2]	119.3	130.1	24.7	4.1	1.0
EEC[3]	95.6	77.7	74.2	3.7	2.4
Other[4]	49.9	56.5	45.9	1.4	1.2
Total Western	264.8	264.9	144.8	9.2	4.6
Eastern[5]	63.7	88.3	60.0	2.4	1.6
Total Europe	328.4	356.7	204.8	11.6	6.3

[1]*Exploitable closed forests.*
[2]*Finland, Norway, and Sweden.*
[3]*European Economic Community (12 countries).*
[4]*Includes Austria, Switzerland, Turkey, Yugoslavia, Albania, Cyprus, and Israel.*
[5]*Communist block countries, excluding the Soviet Union.*
Source: ECE/FAO 1986: tables 3.2 and 3.6.
Note: Individual items may not add to totals due to rounding.

Table 64.—Roundwood removals and industrial wood production in Europe, by species group, and product group, for selected years 1950 to 1985.

Year[2]	Roundwood removals[1]: Total	Roundwood removals[1]: Coniferous	Roundwood removals[1]: Nonconiferous	Industrial wood: Sawlogs	Industrial wood: Pulpwood	Industrial wood: Other[3]
	Million cubic feet					
1950	10,379	6,028	4,351	3,454	1,317	1,310
1960	10,799	6,569	4,230	4,157	2,115	1,225
1970	11,891	7,459	4,432	5,074	3,309	1,088
1980	12,032	8,048	3,984	5,665	3,655	823
1985	12,723	8,256	4,467	5,618	3,869	968

[1]*Total removals, industrial wood and fuelwood.*
[2]*Data are a three year average, centered on the year shown; data reported for 1985 contain estimates for some countries.*
[3]*Other industrial wood products.*
Source: ECE/FAO 1986: tables 3.15 and 3.18.
Note: Data for Europe in 1985 differ slightly from those shown for Europe and the Nordic countries in table 62.

panels, and 59 million tons of paper and paperboard. Sawn wood consumption increased nearly 60% between 1950 and 1985; more than three-quarters of sawn wood consumption in 1985 was coniferous, and more than one-third was imported. Consumption of panel products showed the most dramatic change between 1950 and 1985, increasing by 1,200% (from 3 billion square feet in 1950). Most of the increase in panel consumption is attributable to particleboard; this group of panels accounted for two thirds of total wood-based panel consumption in 1985. Plywood accounted for roughly 15% of wood-based panel consumption in 1985.

Consumption of paper and paperboard in Europe increased by more than 400% between 1950 and 1985. Printing and writing papers (including newsprint) account for 40% of consumption in this product group, but growth in consumption of other paper and paperboard products accounted for most of the increase in total consumption.

Per capita consumption of all forests products (except fuelwood) also grew over the 1950 to 1985 period. Per capita consumption of wood-based panels increased most rapidly, followed by paper and paperboard. Per capita consumption of sawn wood increased only slightly (if at all) in most European countries. Per capita consumption (of all products) is highest in the more heavily forested nordic countries, and in central Western Europe (Austria and Switzerland). With the exception of paper and paperboard, per capita consumption in the nordic countries equals, or exceeds that in the United States. Paper and paperboard consumption in this region is comparable to Canada (roughly two-thirds of U.S. consumption).

Although the EEC accounts for half of European sawn wood consumption, 60% of wood-based panel consumption, and two-thirds of paper and paperboard consumption, this economic grouping has relatively low per capita consumption figures. In all three product groups, per capita consumption in the EEC is less than half that in the United States. In the EEC, the United Kingdom, the Federal Republic of Germany, Italy, and France are the major consumers of forest products.

Latin America

Latin America includes all countries in the Western Hemisphere south of the United States; diversity rather than similarity characterizes the countries in this region. In statistical terms, two countries are dominant in their respective subregions: Brazil in South America, and Mexico in Central America. Brazil has emerged as a major force, in economic terms, in all of Latin America, and is increasingly influential in the world economy (The Economist 1987a).

Most countries in Latin America are middle-income, developing economies (World Bank 1987). A few countries have average (per capita) incomes well above the regional average, even exceeding average income in some industrial market economies; at the other extreme, however, Haiti is among the poorest countries in the world. Regional average per capita income is 10% that of the United States.

Most Latin American economies experienced strong growth over the period 1965–80, and a sharp and deep recession during 1981–83. National incomes grew at an average annual rate of 5% for the period 1965–80; in 1981 regional income fell by 2% (World Bank 1987). During this recession most countries in Latin America experienced rising interest rates, high rates of monetary inflation, falling (export) commodity prices, and reduced foreign investment. The result was falling national incomes, sharply reduced imports, and substantial foreign debt. Regional external debt totaled over 350 billion dollars in 1986, nearly two-thirds of which was owed by Mexico and Brazil (The Economist 1987b).

Forest Resources

More than one-third of Latin America is forested; one-fourth of the world's closed forests are in this region. The forest resources of Latin America are extensive and diverse, but are not evenly distributed. The countries in the tropical region of South America are heavily forested (well over 50% of the land area is forest); countries in the southern temperate zone are less than 30% forested (United Nations 1985). Countries in Central America and the Caribbean region have significant areas of forest, but a much lower proportion of these forests is productive, closed forest. In 1980 a little over one-half (550 million hectares) of the nearly one billion hectares of forest in Latin America were classified as productive (United Nations 1981, 1985).

Although Latin America contains over one-fourth of the world's growing stock of timber, the region's indigenous forests, composed primarily of tropical hardwood species, have been long exploited and, in some areas, seriously depleted. Deforestation in the world's tropical forest regions has raised concerns among scientists and in the popular press, for local as well as global environmental reasons. There is no consensus, however, on the extent or severity of this problem (Lanly 1982). The island nations of the Caribbean, with the smallest relative forest area, have been most significantly affected; some face severe shortages of forest-based fuel and raw material (Lugo et al. 1981).

At the same time, other countries in Latin America—Brazil and Chile, for example—are noteworthy for programs establishing forest plantations composed of fast-growing, nonnative species. These plantations now account for a far greater proportion of national timber harvests than their share of either forest area or growing stock volume. Over 60% of the region's plantations are in Brazil, and roughly 15% are in Chile. More than half of the Brazilian plantations are fast-growing hardwood species; almost all of the plantations in Chile are fast-growing softwood species.

Forest Products Production and Consumption

In the two decades ending in 1985, forest products production and consumption in Latin America increased significantly. Total roundwood production increased by nearly 50%; production of industrial roundwood (timber used for manufactured products) increased by 150% over this period (United Nations 1986b). Production of roundwood for pulp in Latin America increased by nearly 500% between 1965 and 1985; over the same period world pulpwood production increased by only 63% (United Nations 1986b). Latin America now accounts for more than 8% of world pulpwood production, up from 2% in 1965.

This industrial development has been a response to regional demand for industrial wood products (driven by rising incomes and urbanization of the population) and the need to utilize abundant resources to support economic development. However, fuelwood remains the primary use of timber in Latin America; nearly three-fourths of the region's timber harvest was used for fuel (United Nations 1986b). Even when adjustment is made for the fact that as much as 15% of Brazil's fuelwood production may be used for industrial fuel (Sedjo 1980) the fuelwood share of total wood production in Latin America is well above the world average of 50%.

Brazil, Chile, and Mexico are the major timber-producing countries in Latin America; Argentina, Paraguay, Ecuador, and Colombia are smaller producers, but are nevertheless important. Brazil produces well over 60% of the region's roundwood (both total roundwood, and roundwood used for industrial products); in 1986 Chile produced more than 10% of the region's industrial roundwood, Mexico produced 8%, and Argentina, Paraguay, Ecuador, and Colombia together produced roughly equal shares of another 14% of the total (United Nations 1986b).

Brazil is the region's leading producer of manufactured forest products, accounting for over half of Latin American sawn wood and panel output, and nearly half of the region's paper and paperboard production (United Nations 1986b). Regional production, however, is less than one-third of U.S. production. Unlike production in the United States, the majority of forest products in Latin America utilize nonconiferous species; in contrast, the United States is largely a coniferous species-based forest economy.

As a result of its share of the region's population (roughly one-third), and its industrializing economy, Brazil is also the largest single consumer of forest products in Latin America. Most of the growth in forest products consumption in Brazil, as well as that in the rest of Latin America, occurred over the period 1965–80. Total forest products consumption remained roughly constant between 1980 and 1985; in some countries consumption declined. The 1981–83 recession had a more pronounced impact on forest products consumption (and imports) than on forest products production (and exports) because many countries pursued policies that controlled domestic consumption through import restrictions, while expanding the production and export of domestic resource-based industries.

Forest Products Trade

Latin America is a net importer of forest products in terms of value. Only in Brazil and Chile, and to a much smaller extent in Paraguay and Honduras, does the value of forest products exports exceed the value of forest products imports. All Caribbean countries are net importers of forest products, as are all Central American countries other than Honduras. Mexico, Venezuela, Argentina, Ecuador, and Trinidad and Tobago are now the region's major net importers of forest products. A number of countries—among them Mexico, Argentina, and Ecuador—are noteworthy as both exporters and importers of forest products. For many of these countries the mix of forest products exports is composed of products of relatively low unit value (logs, veneers); their forest products imports, however, are primarily high-value manufactured products (panels, paper and board products).

The United States annually exports over one billion dollars worth of forest products to countries in Latin America. Exports to Latin America account for approximately 14% of total U.S. forest products exports; the United States is the major extraregional supplier of forest products to Latin American markets. The United States supplies over 40% of the value of forest products imported by all Latin American countries; intraregional trade accounts for most of the rest of this trade.

The value of forest products exported to individual countries in Latin America is modest compared to, for example, the value of U.S. forest products exports to Japan; in 1986 forest products exports to Japan were valued at over 2 billion dollars. Exports to Mexico, the largest single market in Latin America, were 446 million dollars in 1986. The Latin American market is considerable in total, however, and is significant to U.S. exporters of particular commodities. Over 20% of all U.S. fiber products exports go to this region; fiber products (pulp, paper, paperboard and related products) are approximately 90% of total forest products exports to the region. Latin American countries have purchased over 50% of U.S. newsprint exports in recent years, and 40% of U.S. paper and board products exports.

Latin America is also the destination of 40% of hardwood plywood exports, and 30% of U.S. particleboard exports. The Caribbean Basin (including Mexico) is the primary export market for southern pine lumber; Mexico is the third largest importer of softwood lumber from the United States.

Although Latin America accounts for less than 5% of total U.S. forest products imports, imports from Latin America more than doubled over the period 1980–87. Almost all of this increase is the consequence of a 500% increase in the value of imports of fiber products. This broad commodity group that accounts for most of our exports to Latin America is now our most rapidly growing import from that region. Most of the recent increase in fiber product imports from Latin America is pulp from Brazil, and paper products (especially newsprint) from Mexico.

The United States is a net exporter of forest products to Latin America. The U.S. forest products trade surplus with this region, nearly one billion dollars in 1980, dropped to less than 500 million dollars in 1986, however. The United States is a net importer of forest products from Brazil; the deficit in this bilateral trade has been increasing as Brazil substitutes domestic production for imported products and realizes greater success in penetrating U.S. markets. The U.S. forest products trade surplus with Mexico decreased by nearly 50% over the period 1980–86 as a result of a combination of a weak Mexican economy (reducing Mexican imports of U.S. goods) and a dramatic decline in the value of the peso (doubling U.S. imports from Mexico).

Recent trends in trade with Latin America may be misleading, however. As a result of the recession of 1981–83, domestic demand for forest products in Latin American dropped sharply and, in some countries, had not recovered by the end of the decade. The decline in imports of all products, including forest products, is largely attributable to weak domestic demand rather than to import substitution. At the same time, many countries in the region have made an effort to maintain (or increase) export earnings in order to make payments on external debt, and support the consumption of other goods. The forest sector has been targeted by some countries (Brazil and Chile, in particular) as a potential source of valuable foreign exchange.

CHAPTER 6. MAJOR DEMAND AND SUPPLY ASSUMPTIONS

All projections are consequences of assumptions and in this assessment these assumptions concern the major determinants of the supply and the demand for various forest products. These assumptions are required as inputs in the model of the forest sector[18] used in this Assessment. The primary forest sector model (The Timber Assessment Market Model—TAMM[19]) was originally developed for the 1979 RPA Assessment. It is based on systems analysis and quantitative techniques and has been extensively revised for this Assessment. This chapter provides a summary of the major assumptions employed in the model.

BASIC ASSUMPTIONS

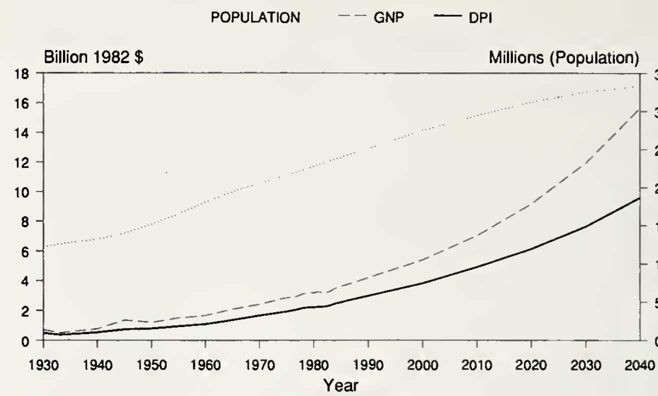
In the future, as in the past, demand for and supplies of forest products will be largely determined by such things as growth in population, income, and economic activity; technological and institutional changes; energy costs; capital availability; and investments in management, utilization, assistance, and research programs for forest, range, and water resources.

Past trends in these determinants have resulted from social, political, technological, and institutional forces that are not easily or quickly changed. The following assumptions are based on these trends, current knowledge about developments affecting these trends, and present expectations about future changes generally accepted as reasonable at this time.

Population

Over the last five decades, the population of the United States increased by more than 100 million people, to about 242 million in 1986 (fig. 53, table 65). Projections by the WEFA Group using Bureau of the Census (USDC 1984, The WEFA Group 1987) assumptions about future demographic developments indicate that population will continue to grow (although at declining rates) and should reach 333 million in 2040. The Bureau of the Census assumptions are the "middle series" projections developed by the agency. The sole exception is that net immigration is assumed to be 750,000 people per year in an attempt to account for net illegal immigration.

Although the population continues to expand, the annual rate of growth declines from about 1% currently to .2% by 2040. This decline in the growth rate depends, in part, on fertility rates that are assumed to remain roughly constant (around 1.8 births per woman) throughout the projection period. This is consistent with recent levels of fertility, expected number of births per woman's lifetime, and social and economic trends that tend to maintain low fertility; increases in female labor force participation, educational attainment and age at first marriage.



Source: Council of Economic Advisors 1987, WEFA 1987.

Figure 53.—Historical and projected gross national product, disposable personal income and population.

Fertility rates have fluctuated widely since World War II but fell from the late 1950s when they peaked at more than 3.6 births per woman through the mid-1970s when they ranged between 1.7 and 1.8 births per woman. In 1986, the fertility rate was 1.9 births per woman. This fertility rate is below the replacement rate (2.1 births per woman) and eventually in the late 2020s the crude death rate is expected to exceed the birthrate (Bureau of Census 1989). Growth in population after that time will be due to net immigration.

Under these conditions, the population (and the labor force derived from it) gradually ages with significant increases in the fraction of the population over retirement age (65–70+). This has important implications for the composition of aggregate demand in the economy (larger increases in demand for services, particularly health and retirement related, and slower growth in demand for both durable and nondurable goods), the composition of governmental expenditures (with large shifts into health and retirement), and ultimately the demand for housing and its composition in terms of types of dwellings.

The geographic distribution of the population has a strong influence on state and regional demands for renewable resources. State projections prepared by the Bureau of Economic Analysis (USDEA 1985) are used as the basis for regional projections of demands.

Economic Activity and Income

Perhaps the most commonly used measure of aggregate activity in the economy is gross national product (GNP) expressed in constant dollars (1982 dollars, net of inflation and deflation). Forecasts of future potential

[18]*A forest sector model, in general, combines activities related to the use of wood: forest growth and harvest; the manufacture of pulp, paper, and solid-wood products; and international trade and intermediate and final consumption of these products (Kallio et al. 1987).*

[19]*The original model is described in Adams and Haynes (1980) and Haynes and Adams (1985).*

Table 65.—Population, gross national product, and disposable personal income in the United States, selected years, 1929–86, with projections to 2040.

Year	Population		Gross national product		Disposable personal income		Per capita disposable personal income	
	Millions	*Annual rate of change*	*Billion 1982 dollars*	*Annual rate of change*	*Billion 1982 dollars*	*Annual rate of change*	*1982 dollars*	*Annual rate of change*
1929	121.8	—	709.6	—	498.6	—	4,091	—
1933	125.7	0.8	498.5	–8.4	370.8	–7.3	2,950	–7.8
1940	132.1	0.8	772.9	7.9	530.7	6.2	4,017	5.4
1945	139.9	1.1	1,354.8	–1.9	739.5	–1.3	5,285	–2.4
1950	151.7	1.7	1,203.7	8.5	791.8	7.1	5,220	6.2
1955	165.3	1.8	1,494.9	5.6	944.5	5.6	5,714	3.8
1960	180.8	2.1	1,665.3	2.2	1,091.1	2.2	6,036	.1
1965	194.3	1.3	2,087.6	5.8	1,365.7	5.8	7,027	4.5
1970	205.1	1.2	2,416.2	–.3	1,668.1	4.3	8,134	3.1
1975	216.0	1.0	2,865.0	–1.3	1,931.7	1.9	8,944	.9
1976	218.0	0.9	2,826.7	5.3	2,001.0	3.6	9,175	2.6
1977	220.3	1.0	2,958.6	4.7	2,066.6	3.3	9,381	2.2
1978	222.6	1.1	3,115.2	5.3	2,167.1	4.9	9,735	3.8
1979	225.1	1.1	3,192.4	2.5	2,202.6	2.1	9,829	1.0
1980	227.7	1.2	3,187.1	–0.2	2,214.3	0.1	9,723	1.1
1981	230.1	1.0	3,248.8	1.9	2,248.6	1.5	9,773	0.5
1982	232.4	1.0	3,166.0	–2.5	2,261.5	0.6	9,732	–.4
1983	234.8	1.0	3,279.1	3.6	2,331.9	3.1	9,930	2.0
1984	237.1	0.9	3,501.4	6.8	2,469.8	5.9	10,419	4.9
1985	239.3	1.0	3,607.5	3.0	2,542.2	2.9	10,622	1.9
1986	241.6	1.0	3,713.3	2.9	2,645.1	4.0	10,947	3.1
PROJECTIONS								
2000	274.9	0.7	5,402	2.8	3,827	2.4	13,920	1.6
2010	294.3	0.6	7,031	2.6	4,922	2.3	16,730	1.6
2020	312.1	0.5	9,166	2.8	6,136	2.4	19,660	1.8
2030	325.5	0.3	11,957	2.7	7,660	2.2	23,530	1.9
2040	333.4	0.2	15,627	2.7	9,599	2.3	28,790	2.1

Sources: Historical Data—Council of Economic Advisors 1987. Projections—WEFA 1987.

GNP are derived from assumptions about the size of the work force (number of workers) and its productivity (GNP per employed worker). The number of workers, in turn, depends on the size of the population and the fraction of individuals seeking employment (called the labor force participation rate). Growth in potential GNP is the sum of growth in the work force and growth in productivity. Historical data and projections for these concepts are shown in table 66.

Projected labor force participation rates continue to rise in the future, though less rapidly than in the past. Resulting growth in the labor force exceeds that for the population as a whole (compare rates for population in table 65). Female participation shows the strongest increase. The rate for males, which dropped steadily over the past 30 years, is nearly stable. The age structure of the population is also important. Increasing numbers of persons in the 65 + age classes, with traditionally lower participation rates, acts to retard growth in the labor force.

Over the past two decades growth in worker productivity (GNP per worker) has fallen sharply to levels well below 1% per year. The projections envision a rebound in the productivity growth to levels more nearly comparable to those observed in the 1950s and 1960s. As labor force growth slows in the future, competition for available workers will increase and wages will rise. To parti-

Table 66.—Labor force and gross national product (GNP).

Year	Labor force participation rate	Labor force	Labor force growth	GNP per worker	Growth in GNP per worker	Potential GNP growth
	Fraction	*Mill*	*%/year*	*M$ 1982/ worker*	*%/year*	*%/year*
1952	.39	61.5		22.9		
1960	.39	70.5	1.73	27.4	2.27	3.29
1970	.40	82.0	1.38	30.7	1.14	2.52
1976	.44	95.9	2.64	32.3	0.85	3.49
1986	.49	118.4	2.13	33.5	0.36	2.49
2000	.50	142.9	1.35	40.6	1.38	2.73
2020	.56	174.8	1.01	55.5	1.58	2.59
2040	.64	213.4	1.00	77.9	1.71	2.71

Source: WEFA 1987.

ally offset these increased costs, industry is expected to invest in capital equipment, thereby expanding worker productivity. An aging, but more experienced and better trained work force will also boost productivity.

Potential GNP growth during the 1950s and 1960s averaged roughly 4% per year, falling to 3% in the 1980s. The result of assumed growth in labor force and worker productivity in the present projections is potential GNP growth which averages roughly 2.7% per year by 2040.

Assumptions about future price levels, interest rates, and wage rates are shown in table 67. Inflation is projected to average roughly 4.5% per year until 2000, but in the longer term, aggregate demand moderates with the aging population and inflation gradually declines to an average of 4% in the period to 2040. Wage rates rise slightly faster than the inflation rate given the expected increases in per capita GNP.

These projections assume that a gradual tightening of federal spending and relatively modest tax increases lead to a net aggregate government budget surplus by 1995 and a balanced federal budget by 2005. With a gradual lessening of U.S. needs for off-shore financing and assuming no significant intervention to shore up the dollar, interest rates drop somewhat faster than inflation. Consequently, real interest rates fall to the 3% range by 2040.

Adjusting potential GNP for government monetary and fiscal actions, actual investment, foreign trade, unemployment and inflation, projections of observed real GNP are as tabulated in table 65. Growth is expected to range between 2% and 3% over the next 50 years, in contrast to the 3–4% range characteristic of the past three decades. This leads to an approximate quadrupling of GNP in the next five decades as opposed to a five-fold increase over the past 50 years. Paralleling expansion in GNP, total disposable personal income increases more than three times (see table 65) and some 2.5 times on a per capita basis. Though anticipated economic growth is somewhat slower than in the past, this projection still portrays a strong and resilient future economy, with a larger and increasingly affluent population.

Technological and Institutional Change

Past changes in demands and supplies have reflected the interactions of the influences of institutional and technological changes. It is assumed that the stream of institutional and technological changes will continue at similar rates in the future. Assumptions on important technological changes affecting product yields and other uses of the renewable resources are specified in the Assessment documents as appropriate.

Institutional changes that lead to the reservation of forest and range lands for designated uses such as wilderness, parks, and wildlife refuges have occurred for a long time. This development is specifically taken into account in the projections of forest and rangeland areas.

Table 67.—Inflation rate, interest rate, and wage rate projections.

Year	Inflation[1]	Interest rate[2]	Growth in Wage rate
		Percent	
1986	2.6	9.7	3.1
2000	4.5	9.5	5.7
2010	4.7	9.3	5.7
2020	3.6	8.8	3.8
2030	4.8	7.9	5.4
2040	4.0	7.9	4.5

[1]*Rate of growth in the implicit GNP deflator.*
[2]*Interest rate on long-term bonds.*
Source: WFEA 1987.

Energy Costs

The long-term outlook for energy costs is for a resumption in growth despite sharp price drops in the 1980s. Projections by the U.S. Department of Energy (in press) provide a rough view of trends through 2010. These projections show world crude oil prices increasing from $12.22 in 1986 to $47.27 per barrel in 2010:

Year	Dollars per barrel
1986	12.22
2000	29.68
2010	47.27
2020	50.00
2030	50.00
2040	50.00

Prices are in 1982 dollars, net of inflation or deflation. If the Department of Energy projections were extrapolated to 2040, the price per barrel would be near $100 in 2040. This price was judged so high as to be unreasonable in that conservation and development of alternative energy sources would act to slow the rate of increases in energy prices. As a result, the price per barrel was assumed to level off at $50 in 2020 and stay at this price through 2040. Rising energy prices are assumed to induce various technological changes that would partly offset these price increases. These price increases have also been used to project demands for fuelwood.

Capital Availability and Investments

Capital availability for plant expansion has occasionally been raised as an issue in making judgments about the likelihood of realizing future output levels. Over the years, there have been little analyses of this question but scant results have been supportive of the assumption that capital would not be a limiting factor for future production levels. Indeed, the WEFA projections of growth in gross national product are suggestive of a growing economy with sufficient capital generation to realize the capacity expansion and improvements called for in the assessment projections.

With regard to the timberland base, future timber supplies will be determined in large measure by the level of investments. In the base assessment projection the levels of future management intensities are assumed to be at levels consistent with trends of the last two decades.

DEMAND ASSUMPTIONS FOR SOLID-WOOD

Projections of demand for lumber, structural panels, and nonstructural panels were based on the end-use approach employed by the Forest Service in previous Assessments. The projection method for lumber and structural panels was modified to explicitly incorporate prices of products and their substitutes in making projections. The end-use approach depends on isolating markets by individual end-use categories selected to represent specific applications of the products, such as framing or sheathing of floors. Where lack of data precludes such specific breakdowns, more general categories were selected, such as combined use of lumber in shipping and manufacturing.

In this approach, the consumption of a market in a particular end-use is estimated by multiplying the level of an end-use activity times the consumption per unit of end-use. This requires assumptions about the levels of activity in each end-use category and the consumption of various forest products per unit of end-use activity. Both of these sets of assumptions are discussed in this section.

Determinants of End-Use Activity

Projections of end-use activity derive directly from the population, economic activity, income, and energy cost assumptions described above. Key end-use activity concepts include the number of housing starts and house size, levels of expenditures on residential upkeep and improvement, levels of expenditures for nonresidential construction, the index of manufacturing production and measures of activity in shipping and transportation.

Housing

In terms of volumes consumed, residential construction has been the dominant market for most timber products. Analyses based on projections of the factors that determine long-term demands for new housing units—household formations, replacement of units lost from the housing stock, and maintenance of an inventory of vacant units—indicate continued high levels of demand in the late 1980s, resulting in an average of nearly 2.0 million units for the last half of the decade (table 1). Housing demand remains at about 2.0 million units in the early 1990s, and subsequently drops to roughly 1.7 million starts by 2010, and declines to 1.5 million starts by 2040. After 2010 a larger fraction of the starts are for houses that replace individual units in the housing stock that are being retired (table 68).

The type of housing units demanded (single-family, multifamily, mobile home) is important in projecting demands for timber products because of the large differences in the average amounts and types of timber products used in each type.

Table 68.—Projections of number of households, housing starts, and replacement assumptions.

Year	Number of households	Total starts	Discards	Net additions	Net replacements
		Millions			
1986	88.6	2.111	.68	.480	.200
2000	109.9	1.868	.772	.344	.428
2010	121.0	1.640	.815	.199	.616
2020	132.4	1.850	.846	.313	.533
2030	142.3	1.691	.887	.283	.604
2040	150.3	1.545	.920	.301	.619

	Total starts	Single family	Multiple	Mobile
		Millions		
1986	2.111	1.191	.640	.280
2000	1.868	1.253	.268	.347
2010	1.640	.980	.380	.280
2020	1.850	1.141	.409	.300
2030	1.691	1.023	.368	.300
2040	1.545	.916	.329	.300

Single-family houses are typically occupied by households whose heads are in the middle-age classes, while occupancy of units in multifamily buildings and mobile homes is highest among households headed by younger and older persons. As a result of prospective shifts in the age distribution of the population, and the associated changes in household types and income, the numbers of conventional single-family units demanded are projected to fluctuate but generally remain near 1.1 million through most of the projection period. The exception is the decade of 2000–2010 when the number of new household formations is low. The numbers of multifamily units demanded show the same trend. Demand for mobile homes—most of which will be produced for primary residential use and are expected to become larger and more houselike—remains constant at 300,000 units a year through the projection period. This is just slightly larger than the number of mobile units discarded each year.

In addition to the numbers of new units demanded, their size is also an important determinant of the amount of timber products used in housing. The average size of single-family housing units, though showing some fluctuation, has grown fairly steadily over the past 35 years, rising from nearly 1,150 square feet in the early 1950s to about 1,825 square feet in 1986. This increase in floor area has offset a declining trend in wood use per square foot of floor area and resulted in roughly constant average lumber use per single-family unit. The size for units in multifamily structures has also increased; however, the rise has been somewhat smaller and more erratic. For example, the size of average new multifamily units in 1986 was about 911 square feet, 15% above the average in the early 1950s, but down 10% from the mid-1970s. Average floor area in new mobile homes, which more than doubled between 1950 and the mid-1970s, has continued to rise because of the increasing share of double-wide and expandable units.

Rising incomes and consumer preference for more space are assumed to lead to continued future growth in average size of all types of units. However, because of rising land costs and decreasing household size with an aging and less fecund population, such increases are expected to be slower than in the past. For example, the average floor area of single-family houses is projected to reach 2,010 square feet by 2040, an increase of less than 0.25% per year. Growth between 1950 and 1986 averaged about 1.4% a year. The size of units in multifamily structures is expected to rise to 1,110 square feet, about 75 square feet above the average in the mid-1970s.

Residential Upkeep and Repair

In addition to the timber products consumed in the production of new housing units, substantial and growing volumes—about 20% of lumber and structural panel products and 15% of nonstructural panel products—are used each year for the upkeep and improvement of existing units. Expenditures for residential upkeep and repair have in the last several years averaged nearly $600 (1982 dollars) per household. This is almost twice the level observed in the early 1970s. Such growth is expected to continue in the future as the Nation's inventory and average age of housing units increase. The housing stock is expected to increase from 98.1 million units in 1986 to 166.3 million units in 2040. The average age of this stock is expected to increase from roughly 50 years to 90 years during the same period.

Projections of expenditures for residential upkeep and repair are shown in table 69. These projections assumed a fixed level of expenditures per household (expressed in 1977 dollars). Assuming a stable vacancy rate, this projection is equivalent to a constant upkeep and repair expenditure per housing unit. As the housing inventory grows and ages so does the aggregate expenditure on upkeep and repair.

New Nonresidential Construction

In recent years about 10% of lumber, plywood, and other structural and nonstructural panel products have been used in the construction of offices, stores, churches, and a wide variety of other nonresidential buildings, and in other types of construction such as roads, dams, and water and sewer systems. Although expenditures for the various classes of construction have fluctuated widely in response to changing economic conditions, the long-run trend for all types combined has been strongly upward.

Projections based on the close historical relationship between changes in gross national product and changes in expenditures for nonresidential building and nonbuilding construction indicate substantial additional

Table 69.—Projections of major determinants of solid-wood products demand.

Year	Residential repair and remodeling expenditures	Value of non-residential construction	Index of manufacturing	Pallets
	Billion 1977 dollars		*1967 = 100*	*Millions*
1986	48.5	123.6	178.6	373
2000	57.7	145.8	272.4	397
2010	64.4	160.4	361.3	472
2020	70.2	176.8	477.9	525
2030	73.9	194.7	621.6	575
2040	76.7	214.7	815.3	600

expenditures over the next five decades (table 69). However, the rates of growth underlying these projections drop throughout the projection period. New nonresidential construction expenditures also decline as a percentage of gross national product. This is consistent with trends since the late 1960s, and with estimates that the service industries will account for a growing share of gross national product in the years ahead.

Manufacturing

Since the mid-1970s about 10% of the lumber, 5% of the structural panel products, and nearly 25% of the nonstructural panel products have been used for the manufacture of a wide range of products such as household furniture—the largest manufacturing use of timber products—sports equipment, games and toys, and commercial and industrial equipment.

Since World War II, U.S. demands for manufactured products have increased markedly reflecting increased population and incomes. Projections based on the close correlations between the values of shipments of certain groups of manufactured products, the index of industrial production for other groups of manufactured products, and projected changes in the economic and demographic variables discussed earlier, indicate continued growth in the years ahead (table 69). However, as in the case of nonresidential construction, the rates of increase in the value of shipments for all groups of products, including household furniture, drop significantly over the projection period.

Shipping

In recent years, nearly 18% of the lumber and about 3% of the structural and nonstructural panel products consumed have been used in the production of wooden pallets, containers, and for dunnage, blocking, and bracing of goods for shipping. Pallets account for about three-fourths of the lumber and nearly two-thirds of the panel products consumed in shipping.

During the past three decades, pallet production rose rapidly with the introduction of new methods of materials handling, the construction of facilities geared to the use of pallets, and increases in the volumes of manufactured and agricultural goods shipped. The rate of increase in the post-1982 recession period has been especially rapid. Projections of pallet output are based on the relationship of pallet use to the value of manufacturing shipments and the assumed growth in shipments as the gross national product rises (table 69). These projections indicate gradual increases mirroring the increase in gross national product.

Although increased demand for pallets is expected over the entire projection period, the rate of growth drops rapidly. This decline reflects competition from alternate systems and materials, and means that growth in pallet demand for use in new materials-handling systems gradually ends. Future expansion thus depends to a large degree on growth in industrial and agricultural production.

The other timber products shipping markets—wood containers, and dunnage, blocking, and bracing—are likely to decline slowly over the projection period in response to continued displacement by metal and fiber barrels and pails, and other fiber and plastic containers, and due to the rising use of palletized, containerized, and other bulk shipment systems.

Trends in Unit Use

Projected demand also depends on changes in product unit-use factors—the volume of timber products used per square foot of housing unit floor area, per dollar of construction expenditure, per pallet, or other measure of market activity. Assumptions regarding the trends in use factors are derived in two ways. For nonstructural products, projections of product-use factors for the major markets have been based on current trends, modified to be consistent with expected future movements of relative prices and associated changes in the various nonprice factors. In general, this procedure has resulted in a continuation of recent trends in the various unit-use factors. For example, additional decreases in the factor for particleboard use in housing and other light building construction are projected because of the likely penetration of oriented strand board/waferboard products in these uses caused by price and environmental factors.

After 2000, the projected rates of increase or decrease for the various product unit-use factors have been reduced, recognizing that continued change becomes more difficult as markets are saturated or as market share approaches zero. This phenomenon, which can be due to price or other factors, has apparently taken place in the case of insulation board used in residential construction where there has been displacement by other products.

For lumber and structural panels, projected use factors were based on two calculations. First, upper and lower limits for each factor were calculated. The upper limit calculated the potential levels that use factors may reach if only the wood product in question were used. Similarly, the lower limit estimated potential levels to which use factors may fall if completely displaced by competing products. This need not be zero. Nonzero lower limits imply some end-use elements where there are no technically or economically feasible substitutes foreseen over the projection. These limits define the range of possible use-factor variation through time.

Second, the actual path of the use factors within these limits was projected based on the relative in-place costs of key competing products. In-place cost projections are based on calculations regarding the amount of inputs required to install each competing system and the prices of these inputs. The change in use factors depends on which product's position is favored by the in-place cost comparison. When the wood product is less expensive, then the use factor is raised. When the competing product is less expensive, then the use factor is reduced. The amount of change is partly determined by functional relationships derived from numerical analysis of past use-factor trends (Spelter 1984, 1985b), and varies with the product and proximity of the use factor in relation to its limits.

The projections of demand contained in this assessment depend on these estimated relationships and on assumptions regarding relative in-place costs and end-use activities.

Demand for Pulpwood

The method used to project demand for pulpwood was based on projected demand for paper and paperboard products. The pulp and paper sector model (the Forest Products Laboratory (FPL) Pulpwood Model) was used to project technological change in fiber requirements and to project the allocation of production among supply regions, given projected North American demand for principal paper and paperboard grades. Paper and paperboard demand formulas for each product grade were derived by statistical regression of historical consumption data on historical per capita GNP, population, and price data. Demand coefficients for per capita GNP and population were then adjusted downward subjectively based on such considerations as the advancing age structure of population in North America, improvements in the efficiency of paper and paperboard use, and substitution of plastics and electronics technology for paper and paperboard products. The downward adjustments to demand coefficients result in substantially slower projected growth rates for paper and paperboard demand in future decades than was experienced in recent decades. However, demand continues to grow among almost all grades, and projections are consistent with recent industry forecasts.

TIMBER SUPPLY ASSUMPTIONS

In this assessment, the supply of timber at any point in time is modeled as a function of the private timber inventory levels, stumpage prices, and the amount of public harvest available at that time. The method used to project timber supplies requires assumptions relating to timberland area change, the efficiency of harvest utilization, and harvest flows from public timberlands.

Inventory Projection System

The aggregate timberland assessment system (ATLAS) was used to make inventory projections for the private ownerships (Mills and Kincaid, in press). The ATLAS model evolved from earlier systems developed to answer timber supply questions in the context of policy analysis (Beuter et al. 1976, Tedder et al. 1987). Previous timber assessments were made using TAMM and the timber resource analysis system (TRAS) (Larson and Goforth 1974); the new combined model is referred to as TAMM90/ATLAS.

Whereas TRAS is a diameter class model, ATLAS is age-based. Yield tables project acres by detailed strata for periods consistent with inventory stand-age classes. A major attribute of the model is that it can simulate shifts in management intensities and consequent changes in yields based upon alternative assumptions about the future.

The inventory in ATLAS is represented by acre-volume cells classified by region, ownership, management type, management intensity, and age class. The strata were also identified by three site productivity classes in the South and in the Pacific Northwest Douglas-fir region. A total of 18 age classes were used; 5-year classes were used in the South, and 10-year classes were used in all other regions. In each simulation period, inventory volume change is the result of growth, area change, and timber harvest. Growth is the result of an interaction between the current stocking, the base yield table, and the stocking change function (approach-to-normal assumption). Generally, a cell volume follows an upward sloping net yield trajectory. Each cell in the starting inventory may have an independent yield function, whereas, all regenerated acres in the same strata follow identical yield trajectories.

Inputs to the model include estimates of harvest, acreage shifts, and growth parameters. The ATLAS model is not, in principle, an even age model because it can simulate growth and removal processes across several age classes and it can account for both partial harvests and commercial thinning. The levels of harvest are derived through interaction with TAMM. Final harvested acres may be regenerated in alternative management levels, assumed to change timber type, or leave the timberland base entirely. Area change information by forest ownership and forest management type is provided as an input (see next section). Yield tables and approach-to-normal parameters were derived from the timberland inventory plot data collected by the various USDA Forest Service Forest Inventory and Analysis Units, parameters developed for use in previous studies, and yield tables developed from other models and from published sources. (The inventory data inputs and assumptions are summarized in Mills 1989.)

Projected Area Changes for Forest Ownerships and Forest Management Types

Projections of timber supply and corresponding prices are sensitive to the assumptions made regarding future forest area (Alig et al. 1983). These assumptions include changes in area by ownership, forest management type, and site.

In addition to changes in the area of total timberland, area changes for ownerships and forest management types may not only impact prospective timber supplies, but supplies of water, wildlife, forage, and outdoor recreation. Change in total timberland area is the net result of the conversion of timberland to nonforest and the shifting of nonforest to timberland by natural reversion or afforestation. Ownership changes in the timberland base may result in different land management objectives or new owners with different available resources to invest in forest management. Changes in the areas of forest types often reflect differences in land management objectives among owners, and indicate the differential influence of natural and management forces.

Projections of area changes for the timberland base were made for the North, South, Rocky Mountains and Great Plains, and the Pacific Coast. Within sections, projections were made for two private forest ownership classes—forest industry, and farmer and other private—and public timberland projections were provided by public agency personnel. The area projection methods and results are described in more detail in a supporting technical document (USDA FS 1989b) and state level projections are discussed by Alig and others (in press).

Trends in Timberland Area

Area of timberland in the United States steadily declined as the country was settled. This trend persisted until around 1920. Starting then, and continuing until the early 1960s, the acreage of timberland increased by about 50 million acres as the worked-out cotton lands in the South, cleared areas on hill farms in the East, and marginal farms in other regions reverted back to forests. By 1962, the timberland area in the United States reached 515 million acres (table 70).

During the 1960s, the upward trend in timberland area was reversed and by the 1970s, the rate of acreage loss begin to accelerate. As a result, timberland area declined 5% between 1962 and 1977 to 491 million acres. Between 1977 and 1987, timberland area dropped to 483 million acres; however, the rate of decline in timberland area lessened to about 2%, partly because of surplus crop production in the agricultural sector.

Area changes in timberland reflect the interaction of a number of forces. Timberland conversion takes place as the result of land clearing for highways, powerlines, and reservoirs, along with urban development. Public lands have been withdrawn, largely in the West, for parks, wilderness, and other recreation uses. Private lands have been acquired for second homes or recreation use. At the same time, additions to the timberland base from idle crop and pasture land have recently been increasing.

Projecting area change requires the consideration of complex economic and social factors. Thus, a mixture

Table 70.—Area of timberland in the United States, by ownership and region, specified years 1952–1987, with projections to 2040.

Ownership and region	1952	1962	1970	1977	1987	Projections 2000	2010	2020	2030	2040
	Million acres									
Ownership										
Public	152.8	152.5	150.2	144.2	136.3	134.3	134.3	134.3	134.3	134.1
Forest industry	59.0	61.4	67.6	68.9	70.6	71.5	71.5	71.4	71.3	71.0
Farmer and other pvt.	297.0	301.2	286.3	278.0	276.4	270.0	266.9	262.9	259.7	257.5
Total	508.8	515.1	504.1	491.1	483.2	475.8	472.7	468.6	465.2	462.6
Region										
North	154.3	156.6	154.4	153.4	154.6	154.4	153.6	151.7	150.5	149.5
South	204.5	208.7	203.3	198.4	195.4	191.3	190.0	188.6	187.4	186.8
Rocky Mountain	66.6	66.9	64.5	60.2	61.1	59.9	59.7	59.5	59.4	59.2
Pacific Coast	83.4	82.9	81.8	79.1	72.1	70.2	69.5	68.7	68.0	67.1
Total	508.8	515.1	504.1	491.1	483.2	475.8	472.7	468.6	465.2	462.6

Note: Data for 1952 and 1962 are as of December 31; all other years are as of January 1.
Source: Waddell et al. 1989.

of judgement and quantitative models was used to make projections of timberland area.[20]

Timberland by forest ownership was stratified into three site quality classes. The distribution across these classes was assumed to be constant given the general lack of data indicating otherwise. This was consistent with historical trends in the South, the section with perhaps the most frequent landscape changes affecting timberland (e.g., Alig et al. 1986).

Private Lands

The assumptions required to project the diverse set of variables that influence land use changes on private lands are described here. These assumptions were made based on historical trends, developments that affect those trends, and expectations regarding future changes. Assumptions used in making projections for population, personal income, and inflation rates are those shown in tables 65 and 67.

Many of the forces that have caused the recent changes in area of timberland will likely continue to influence changes in the future. Thus, in making projections of area changes, it has been assumed that determinants such as population, income, agricultural productivity, agriculture exports, and prices of agricultural crops and timber products would continue to influence land use changes (e.g., Alig 1985).

The amount of land used for agricultural purposes has a great impact on the amount of timberland available. Assumptions on the future rate of change in agricultural productivity and associated land incomes were derived from the 1986 RCA Appraisal (USDA SCS 1987). Assumptions on the annual rates of increase in yield vary by crop, but the rate of increase up to the year 2000 is higher than the 2001–2030 rate of increase in all cases. For example, productivity for field crops was assumed to increase by 1.9% annually up to the year 2000 and then slow down to 1.2% annually. Real product prices for agricultural products are assumed to remain constant over the projection period. Slow increases in the export of agricultural products are projected. Livestock incomes were projected assuming constant real prices and forage yields are assumed to increase at 0.7% per year.

Timber product prices rise in line with stumpage price projections from this assessment (see Chapter 7). Interaction with these price projections allows acreage trends to respond to economic forecasts.

Public Lands

Timberland area projections for the national forest ownership were made by the National Forest System and reflect the ongoing forest planning process (Alig et al., in press). Projections for each region include any withdrawals for roads, powerlines, reservoirs, wilderness areas, and other related uses. Similar methodology was used across all regions to project other public land. Area change projections were obtained from state, BLM, and other public agency personnel.

[20]*Major research studies by region which supported development of these models were: South—Alig (1986) and Alig et al. (1988) analyses of pooled cross-sectional and time series data using seemingly unrelated regression estimation (SURE); West—Park's (1986, 1988a) linear proportions analysis of the allocation of land among forestry, agriculture, and other uses; North Central—Plantinga and others' (1989) cross-sectional analysis of relationships between forest area changes and economic and demographic factors for the Lake States; and Northeast—Howard and Lutz's (1989) SURE analysis of forest area changes for four subregions.*

Relationships from these studies, which had land uses and/or forest ownership areas as the dependent variables, were incorporated into a projection system similar to that described by Alig (1985). If a research-based equation for a particular nonforest use was not available, projections of area changes for those uses—crops, pasture/range, urban and other lands—were constructed from expert opinion or existing studies (e.g., urban area projections by the Economic Research Service 1987 and Alig and Healy 1987).

Area Changes in Forest Types

Changes in area among forest types affect both the nature and volume of timber available from forests. For example, decreases in timber production can occur when commercial species are crowded out by noncommercial species. Area change projections by forest management type were based on assumptions about the probability that a particular acre will receive a certain type of management and the associated probabilities that an acre so managed will remain in the same forest type or will make the transition to other forest types.[21]

Projections

The total area of timberland is projected to decrease about 4% between 1987 and 2040 (table 70). During the 1970s, a significant portion of the decline in forest area resulted from conversion of forest to cropland, particularly on southern river bottoms and deltas. However, after 1990, reduction in forest land area will mainly result from conversion to other land uses such as reservoirs, urban expansion, highway and airport construction, and surface mining. Increased reclamation of mined lands in the future will limit the long-run impacts of surface mining on the total area of forest land.

There is always uncertainty associated with projections of land use and, at the present time, the outlook for cropland needs seems especially uncertain. Part of the uncertainty associated with the projections of land use include the implementation of provisions of the Food Security Act of 1985 (Farm Bill). Three major provisions of the 1985 Farm Bill may significantly impact timberland area: (1) the Conservation Reserve Program, (2) the swampbuster and sodbuster provisions, and (3) the conservation compliance provision (Moulton and Dicks 1987).

Over 8 million acres of highly erodible land, primarily in the South, are suitable for afforestation. Under the Conservation Reserve Program of the 1985 Farm Bill, it is assumed that over 3 million acres, mostly in the South, would be planted to trees by 1995. There are 22 million acres of marginal cropland and pasture in the South, including the highly erodible land, that would yield higher rates of return to the owners if they planted pine (USDA FS 1988b). This land, distributed in fairly large acreages across most southern states, would be another source of land for Conservation Reserve or other programs.

Impacts of the "buster" and compliance provisions are more difficult to project because of possible changes in government commodity subsidy and loan programs that would alter the attractiveness of converting erodible land. Next to the Conservation Reserve Program, the conservation compliance provision could have the largest impact on timberland area. Existing cropland identified as highly erodible will be subject to conservation compliance, some of which will be treated under the Conservation Reserve Program.[22] If farmers do not comply, they could lose government subsidies on all acres. However, full implementation and enforcement of provisions of the Farm Bill, such as conservation compliance, will not occur for several years and are difficult to predict. The maximum addition to timberland under the Farm Bill provision would amount to less than 5% of the existing timberland area in the South.

Because of the uncertainty pertaining to future changes in excess agricultural production capacity, it is difficult to project, for example, how timberland with potential for use as cropland or pasture, or the marginal cropland and pasture suitable for pine plantations will be used in the future. In Chapter 8 of this Assessment, alternative futures are simulated to show impacts on the timber resource situation from alternative assumptions about future changes in timberland area.

North.—Projections (table 71) show a slow declining trend in timberland area. The total timberland area in the North drops from about 155 million acres in 1987 to 149 million acres in 2040. The projections show a downward trend in both subregions, but the percentage drop is largest in some northeastern states where substantial relative increases in population and economic activity are expected. In most of the other states the projected changes are small, and in some states the area of timberland is rising or essentially constant in the latter part of the period (Alig et al., in press).

Most of the reduction in timberland area is projected to occur on farms and other private lands, with a slight projected decrease in industry ownership. Public timberland area is projected to increase slightly, by 2%.

Projected area changes for forest types in the North are largely based on a continuation of recent trends. The climax type of maple-beech is projected to increase because of successional forces. Conversely, the area of spruce-fir, oak-hickory, and aspen-birch is projected to drop.

South.—Projections of changes in area shown in table 72 are consistent with those for the recent comprehensive study of the timber supply situation in the South (USDA FS 1988b), except that Kentucky has been added to the 12 Southern states. The resulting projections show a slowly declining trend in total timberland area. The total timberland area in the South declines from about 195 million acres in 1987 to 187 million acres in 2040. The projected reduction is about evenly split between the South Central and Southeast regions.

[21]Alig (1985) and Alig and Wyant (1985) describe a Markov model for forest types in the Southeast that projects forest types that will result from custodial, harvesting, and other miscellaneous forest management activities. Separate models are constructed for farm, miscellaneous private and industry owner groups. The Markov approaches (e.g., Brooks 1985) are feasible if remeasurement data are available that can be stratified into forest type classes. Probabilities of forest type change are summarized in matrix form. Projections of future forest type areas are calculated by multiplying an initial vector of acres by forest type by the transition probability matrix. If no data on disturbances are available and plots have been remeasured at least once, probabilities are used which represent an average over all disturbance regimes (including no disturbance) and owner groups.

[22]The sodbuster and swampbuster provisions of the 1985 Farm Bill alter the attractiveness of converting highly erodible native vegetative rangeland and forest land to crop production and of converting forested wetlands to crop production. If persons break out highly erodible land or convert wetlands for the production of agricultural commodities after December 23, 1985, they lose USDA program benefits on all acres farmed.

Table 71.—Area of timberland in the North, by ownership and region, specified years 1952–1987, with projections to 2040.

Ownership and region	1952	1962	1970	1977	1987	Projections 2000	2010	2020	2030	2040
					Million acres					
Northeast										
Public	7.3	7.5	7.8	8.2	9.8	10.0	10.1	10.2	10.2	10.2
Forest industry	10.1	10.1	12.2	12.8	12.6	12.5	12.4	12.4	12.3	12.3
Farmer and other pvt.	55.6	60.3	58.0	57.5	57.7	57.6	57.1	55.7	54.6	53.8
Total	73.0	77.9	78.0	78.6	80.1	80.1	79.6	78.2	77.1	76.3
North Central										
Public	23.0	21.9	21.7	21.2	21.2	21.2	21.2	21.2	21.3	21.3
Forest industry	3.6	3.6	5.0	4.7	4.4	4.4	4.4	4.5	4.5	4.5
Farmer and other pvt.	54.7	53.3	49.7	49.0	49.0	48.7	48.3	47.8	47.6	47.4
Total	81.2	78.7	76.3	74.9	74.6	74.3	73.9	73.5	73.3	73.2
Total North										
Public	30.2	29.4	29.5	29.4	30.9	31.1	31.3	31.4	31.5	31.5
Forest industry	13.7	13.7	17.2	17.5	17.0	16.9	16.9	16.8	16.8	16.7
Farmer and other pvt.	110.3	113.5	107.7	106.6	106.7	106.3	105.4	103.5	102.2	101.2
Total	154.3	156.6	154.4	153.4	154.6	154.4	153.6	151.7	150.5	149.5

Note: Data for 1952 and 1962 are as of December 31; all other years are as of January 1. The same regions as in Chapter 3 are used. Data may not add to totals because of rounding.
Source: Waddell et al. 1989.

Table 72.—Area of timberland in the South, by ownership and region, specified years 1952–1987, with projections to 2040.

Ownership and region	1952	1962	1970	1977	1987	Projections 2000	2010	2020	2030	2040
					Million acres					
Southeast										
Public	8.0	8.3	8.2	8.5	8.8	8.8	8.9	8.9	8.9	8.9
Forest industry	13.9	14.8	15.6	15.3	16.8	17.0	17.0	17.0	17.0	17.0
Farmer and other pvt.	67.1	67.9	66.2	64.0	59.0	56.4	55.9	55.2	54.7	54.4
Total	89.1	91.0	90.0	87.8	84.6	82.2	81.7	81.1	80.6	80.3
South Central										
Public	9.7	9.7	10.2	10.1	10.9	11.2	11.4	11.5	11.6	11.7
Forest industry	17.9	18.8	20.3	21.5	21.4	21.7	21.9	22.0	22.1	22.2
Farmer and other pvt.	87.9	89.1	82.8	78.9	78.4	76.1	75.0	74.0	73.2	72.7
Total	115.5	117.7	113.3	110.6	110.8	109.1	108.2	107.5	106.9	106.6
Total South										
Public	17.7	18.0	18.4	18.6	19.7	20.1	20.3	20.4	20.5	20.5
Forest industry	31.8	33.6	35.9	36.9	38.2	38.8	38.9	39.0	39.1	39.2
Farmer and other pvt.	155.1	157.0	149.0	142.9	137.5	132.4	130.9	129.2	127.8	127.1
Total	204.5	208.7	203.3	198.4	195.4	191.3	190.0	188.6	187.4	186.8

Note: Data for 1952 and 1962 are as of December 31; all other years are as of January 1. Includes Kentucky in addition to the 12 states examined in the South's Fourth Forest Report (USDA FS 1988b). Data may not add to totals because of rounding.
Source: Waddell et al. 1989.

In some states, particularly in the east Gulf area, where substantial relative increases in population and economic activity are expected, the drop is fairly large. In most of the other states the projected changes are small, and in some states the area of timberland is rising or essentially constant in the latter part of the period.

The projected net area changes reflect the direct conversion of timberland to urban and developed uses, and other timberland acres converted to replace cropland lost to urban and developed uses. A small reduction for crop area is projected, while urban and related uses go up about 25%. Pasture and range area is projected to drop slightly.

Private owners control approximately 90% of the South's timberland and this is projected to continue. Area changes among the major groups of private owners have been substantial. Around 18 million acres or 11% of the area in farmer and other private ownership has been converted to other uses or transferred to other owners since 1952. Most of this area reduction has occurred on farmer ownerships.

Farmer ownership of timberland has declined because of several reasons. Many owners of timberland who were farm operators sold or passed on their holdings to new owners, who were classified as other private owners since they did not secure their primary source of income from farming. In addition, many farmers increasingly secured their livelihood off farms and were subsequently classified as other private owners. Conversion to other uses, primarily agriculture, has also contributed to a reduction in farm forest area.

Timberland area in farmer ownership is projected to continue declining. This trend is consistent across the South and in line with historical trends. However, over 3 million acres of highly erodible cropland under the Conservation Reserve Program of the 1985 Farm Bill could be planted to trees on farm ownerships by 1995, but this would still not be enough overall to offset forest area reductions.

Other individual and corporate private owners have acquired many of the timberland acres that were once owned by farmers. Corporate ownership is projected to increase in size, partly due to investment in southern pine timberland (USDA FS 1988b). It is uncertain how these corporate lands will be managed in the future. It remains to be seen whether some corporate owners will divest of timberland after harvest of the current rotation's crop, or if they will invest in long-run timberland management. Individual owners, the other component of the miscellaneous private ownership group, are the largest ownership class. This diverse set of owners holds over one-third of the southern timberland base—almost four times as much as corporate owners. Unlike the corporate owners, individuals in the other private owner group are projected to reduce their holdings of timberland in the future.

Forest industry has steadily acquired timberland in the South since 1952. In 1987, industry owned 38 million acres of timberland in the South, 6 million acres more than in 1952. The trend in forest industry area has been upward across all the southern states. In the past, many forest products companies have found it advantageous to own large amounts of timberland (Clephane 1978). Some of the recognized advantages include an assured wood supply for mills that represent large investments, augmentation of supplies of low-cost timber, an inflationary hedge, and certain tax advantages. In addition, some banks have required certain levels of timberland to be owned as one condition for loans.

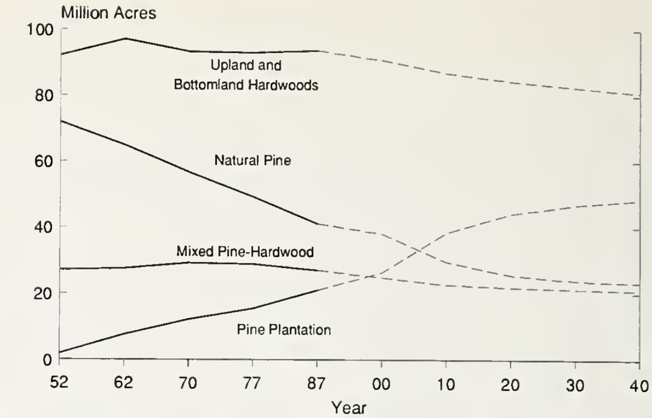


Figure 54.—Timberland area in the South, by forest management type, 1952–1987, with projections to 2040.

Although recent data do not show a significant slackening in the acquisition of timberland by industry, several factors now seem to be operating that reduce the attractiveness of industrial ownership of timberland. These include cash flow considerations, other investment opportunities, opportunities for land leasing and long-term harvesting rights, and the increased substitution of more intensive forestry practices in place of land acquisition.

Given this current setting, it has been assumed that the area in forest industry ownership will increase at a slower rate than in the past. Forest industries are projected to add around one million acres over the next 45 years. This represents a 3% increase. Most of the acquired land is expected to be in the South Central Region.

Public ownership of timberland in the South represents only about 10% of the total timberland base. Public ownership of timberland is projected to increase slightly, by 0.8 million acres or 4%, by 2040. Not included in the other public timberland expansion is some bottomland hardwood acreage that is likely to be acquired by state agencies and withdrawn from the timberland base to protect nontimber forest resources.

Projected changes in the area of the forest management types are consistent with recent historical trends. The largest area changes are projected for the pine types in the South (fig. 54). The area in pine plantations is projected to increase by over 25 million acres, thereby doubling by 2040 (USDA FS 1988b).

In contrast, natural pine area is projected to drop by nearly half. The net change in southern pine area is an increase of approximately 10 million acres by 2040. The projected doubling of planted pine area is largely due to the addition of pine plantations on forest industry lands. With management intensification on these industrial lands, many harvested natural pine stands are being artificially regenerated. This conversion to planted pine allows genetically improved stock to be introduced on many acres and trees to be spaced so as to reduce future management costs.

The projected drop in natural pine area is also due to an assumed continuation of trends in substantial hardwood encroachment after harvest of pine stands on the lands in farmer and other private ownerships. The farmer and other private ownerships contain the bulk of the natural pine area, and the projections assume that current trends in reforestation (Fecso et al. 1982) will largely continue.

The Rocky Mountains and Great Plains.—Projections show a slowly declining trend (table 73) as total timberland area in the Rocky Mountains and Great Plains drops from about 61 million acres in 1987 to 59 million acres in 2040. The projected decrease occurs largely on public lands and on farmer and other private ownerships. Overall, area changes among uses are relatively small compared to other regions.

The projected net area changes largely reflect withdrawals of public timberland, the direct conversion of timberland to urban and developed uses, and other acres converted to replace cropland lost to urban and developed uses. The area of cropland is projected to drop by several million acres, while urban and related uses go up slightly. The pasture and range area is projected to increase by several million acres, as a result of the conversion of erodible cropland to grassland through the Conservation Reserve Program.

Only small relative changes in area of softwood and hardwood forest types are projected for this region by 2040. Softwood types cover most of the timberland base and are projected to maintain that dominance.

Pacific Coast.—Timberland area in the Pacific Coast is projected to drop by 5 million acres, or 7%, by 2040 (table 74). As in the Rocky Mountains and Great Plains, most of the projected reduction is for the public and farmer and other private ownerships. Much of the current timberland in the Pacific Coast Region is located on lands where forestry has a comparative advantage or is a residual use due to physiography, and projected changes are smaller than historical ones.

The projected net area changes largely reflect withdrawals on public lands and direct conversion of timberland to urban and developed uses and other acres converted to replace cropland lost to urban and developed uses. Public timberland area is projected to drop 6%, largely due to withdrawals.

Currently, industry owns approximately 17% of the Pacific Coast timberland, up from the 13% share in 1952. This share is projected to change little, rising to 18% by 2040.

Around 3 million acres or 17% of the area in farmer and other private ownership was converted to other uses or transferred to other owners between 1952 and 1977. Most of this area reduction occurred on farmer ownerships. Since 1977, around 6 million acres of timberland were transferred from public ownership to the farmer and other private ownership in Alaska, resulting in an overall increase of over 4 million acres for the farmer and other private class in the Pacific Coast section between 1977 and 1987. Future acreage transfers between ownerships are expected to be much smaller, with total timberland area on the farmer and other private ownership projected to drop 11% by 2040.

Alaska contains 119 million acres of forest land, about one-sixth of that in the United States. However, only 15.8 million acres, some 13% of the state total, is classified as timberland. Of this area, some 10.1 million acres is in coastal Alaska. The remaining 5.7 million

Table 73.—Area of timberland in the Rocky Mountains and Great Plains, by ownership and region, specified years 1952–1987, with projections to 2040.

						Projections				
Ownership and region	1952	1962	1970	1977	1987	2000	2010	2020	2030	2040
					Million acres					
Great Plains										
Public	1.4	1.3	1.3	1.3	1.2	1.2	1.2	1.2	1.2	1.2
Forest industry	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
Farmer and other pvt.	2.6	2.5	2.4	2.3	2.3	2.3	2.3	2.3	2.3	2.2
Total	4.1	3.8	3.8	3.7	3.5	3.4	3.5	3.5	3.5	3.5
Rocky Mountains										
Public	48.1	48.7	46.4	42.1	42.9	41.9	41.9	41.9	41.9	41.9
Forest industry	2.2	2.2	2.2	2.1	2.9	2.9	2.9	2.9	2.9	2.9
Farmer and other pvt.	12.3	12.2	12.2	12.3	11.8	11.5	11.4	11.2	11.1	10.9
Total	62.6	63.1	60.8	56.5	57.6	56.4	56.2	56.1	55.9	55.7
Total Great Plains & Rocky Mountains										
Public	49.5	50.0	47.7	43.5	44.1	43.1	43.1	43.1	43.1	43.1
Forest industry	2.2	2.2	2.2	2.1	3.0	3.0	3.0	3.0	3.0	3.0
Farmer and other pvt.	14.9	14.7	14.6	14.6	14.0	13.8	13.6	13.5	13.3	13.2
Total	66.6	66.9	64.5	60.2	61.1	59.9	59.7	59.5	59.4	59.3

Note: Data for 1952 and 1962 are as of December 31; all other years are as of January 1. Includes the States of North Dakota, South Dakota, Nebraska, and Kansas, in addition to the Rocky Mountain States, as in Chapter 3. Data may not add to totals because of rounding.

Source: Waddell et al. 1989.

Table 74.—Area of timberland in the Pacific Coast, by ownership and region, specified years 1952–1987, with projections to 2040.

Ownership and region	1952	1962	1970	1977	1987	Projections 2000	2010	2020	2030	2040
					Million acres					
Pacific Northwest										
Douglas-fir subregion										
Public	12.1	12.1	11.9	11.4	11.3	11.0	11.0	10.9	10.9	10.8
Forest industry	6.9	7.2	7.2	7.5	7.3	7.6	7.7	7.7	7.7	7.6
Farmer and other pvt.	6.3	5.8	5.5	4.5	4.6	4.1	3.9	3.8	3.6	3.6
Total	25.2	25.1	24.6	23.4	23.1	22.8	22.6	22.4	22.2	22.0
Ponderosa pine subregion										
Public	13.6	13.2	13.1	12.9	11.1	10.6	10.6	10.5	10.4	10.2
Forest industry	2.2	2.2	2.4	2.4	2.4	2.4	2.4	2.3	2.3	2.3
Farmer and other pvt.	3.9	4.0	3.6	3.4	2.3	2.3	2.2	2.2	2.2	2.2
Total	19.6	19.4	19.1	18.7	15.8	15.3	15.1	15.0	14.9	14.7
Alaska										
Public	20.2	19.8	19.7	19.3	9.6	9.2	9.1	9.0	9.0	9.0
Forest industry	0	0	0	0	0	0	0	0	0	0
Farmer and other pvt.	.2	.3	.3	.5	6.2	6.5	6.6	6.7	6.7	6.7
Total	20.3	20.1	20.0	19.7	15.8	15.8	15.8	15.7	15.7	15.7
Pacific Southwest										
Public	9.6	9.9	9.9	9.1	9.6	9.1	9.0	9.0	9.0	8.9
Forest industry	2.2	2.4	2.7	2.7	2.8	2.8	2.7	2.6	2.4	2.2
Farmer and other pvt.	6.5	5.9	5.5	5.4	5.1	4.5	4.2	4.0	3.8	3.5
Total	18.2	18.3	18.0	17.3	17.4	16.4	16.0	15.5	15.1	14.7
Total Pacific Coast										
Public	55.4	55.1	54.6	52.7	41.6	40.0	39.7	39.5	39.2	39.0
Forest industry	11.2	11.9	12.3	12.5	12.5	12.8	12.8	12.6	12.4	12.1
Farmer and other pvt.	16.8	15.9	14.9	13.9	18.1	17.4	17.0	16.7	16.3	16.1
Total	83.4	82.9	81.8	79.1	72.1	70.2	69.5	68.7	68.0	67.1

Note: Data for 1952 and 1962 are as of December 31; all other years are as of January 1. Hawaii is included in the Pacific Southwest. Data may not add to totals because of rounding.
Source: Waddell et al. 1989.

acres are in the Alaska interior. Projections of changes in total timberland area in Alaska indicate an essentially constant base between 1987 and 2040. Forest industry ownership is expected to remain negligible, although in time, part of the land transferred to Alaskan Natives may be sold to forest industries.

Projected area changes for forest types in the Pacific Coast section are relatively small. The most substantial changes are projected to occur on forest industry lands as more acres are planted to Douglas-fir. Conversely, hardwood (alder) area on this ownership is projected to decline.

Projected timberland losses on farmer and miscellaneous private lands are distributed across all forest types. This is also the case for other public lands. Projected overall changes in forest type areas are small for the public ownerships.

Pulpwood Supply

Regional pulpwood supply functions in the FPL Pulpwood Model were based on unit price elasticity assumptions, with supply quantities projected to increase at a rate corresponding to the projected regional growth in timber inventories. Projections of actual pulpwood consumption derived from the FPL Pulpwood Model were then used to make quantitative adjustments to timber supply in the TAMM/ATLAS model, with projected pulpwood requirements satisfied partly by projected supplies of wood residues from the solid-wood product sector and partly by timber harvest.

Adjustments for Timber Removals

Estimates of timber harvest (also called roundwood supplies) include removals from several different sources. The most important removals (in an inventory accounting sense) are those from growing stock sources. These include: (1) harvest of roundwood products such as sawlogs, veneer logs and pulpwood from growing stock and sawtimber, (2) logging residues, and (3) other removals resulting from noncommercial thinnings, changes in land use such as clearing for cropland, highways or housing developments, and withdrawal of commercial timberland for parks, wildernesses, and other nontimber uses.

The projected supplies (harvest) of roundwood products are internally generated in the forest sector model. The determination of timber removals is accomplished by adjusting the projected timber harvest for removals from nongrowing stock sources and than adding the other components of removals—logging residues and other removals. The result is an estimate of the timber removed from growing stock inventory. The data for these three adjustments are derived from the timber product output tables (tables 30–32) given in Waddell et al. 1989.

Logging Residues

Logging residues have always been an important component of timber removals, although they have been declining as a percentage of the total. Between 1952 and 1986, for example, softwood logging residues dropped from about 9.8% of product removals from growing stock—roundwood products plus logging residues—to 9.0%; and hardwood residues fell from 22.2% to 13.2% (table 75). These declines largely reflect the effects of rising stumpage prices that have made it economical to remove more of the lower quality material that previously was left as logging residues. Technological innovations such as in-woods chipping and rapid growth in the demand for wood in the pulp industry and for industrial fuelwood have also contributed to the increased utilization.

In the east, softwood logging residues as a percentage of product removals from growing stock are roughly half of those in the Pacific Coast regions. In the Pacific Coast states, softwood logging residues were 12.6% of product removals in 1986, the highest in the country. Total hardwood logging residues, more than 13% of product removals, compose a much larger percentage of product removals than for softwoods. This reflects limited markets for much of the low-quality material in the hardwood inventory.

For the projection period, it has been assumed that logging residues from both hardwoods and softwoods will decline as a percent of product removals from growing stock in regions with relatively high current proportions. Major factors in these declines are the expected increases in stumpage prices and intensified competition for wood fiber. This will result in increased use of small stems, chunks, and low-quality stems for fuelwood and pulpwood. Increased tree-length logging and in-woods chipping of pulpwood and fuelwood will reduce residual formation. Another factor is anticipated improvements in felling and bucking practices. The decline in the harvest of old growth timber in the West and increased use of hardwoods for pulping and as fuelwood are also expected to contribute to the improved utilization.

Other Removals

That part of timber removals classified as other removals is composed of (1) losses from timber inventories resulting from the diversion of timberland to other uses such as crop or pasture land, roads, urban areas, parks and wilderness; and (2) timber removed in cultural operations such as noncommercial thinning.

The historical data on other removals are estimates of actual volumes for the indicated years (USDA FS 1982, Waddell et al. 1989). They do not include the removals associated with the diversion of timberland, such as withdrawals for wilderness that do not take place on a regular and continuing basis. Such land diversions are included in the projections. Thus, and as a result of expected withdrawals for wilderness in the 1990s, other removals in 1990 are substantially above the historical

Table 75.—Logging residues as a percent of timber product removals from growing stock in the United States, by softwoods and hardwoods and section, specified years 1952–1986, with projections to 2040.

						Projections				
Species group and section	1952	1962	1970	1976	1986	2000	2010	2020	2030	2040
						Percent				
Softwoods										
North	11.5	11.0	10.8	11.0	4.6	4.5	4.5	4.5	4.5	4.5
South	6.6	6.3	6.9	5.9	6.7	6.5	6.4	6.3	6.1	6.0
Rocky Mountain	10.9	10.9	11.1	11.0	10.8	10.8	10.7	10.6	10.5	10.4
Pacific Coast[1]	12.2	11.7	12.5	10.2	12.6	12.2	11.9	11.6	11.3	11.0
United States	9.8	9.6	10.0	8.4	9.0	8.9	8.8	8.6	8.4	8.2
Hardwoods										
North	15.8	15.3	15.2	17.2	9.9	9.0	8.7	8.5	8.5	8.5
South	25.9	24.4	22.6	16.6	15.6	15.5	15.3	15.2	15.1	15.0
Rocky Mountain	([2])	([2])	([2])	25.0	19.7	24.0	23.0	22.0	21.0	20.0
Pacific Coast[1]	28.6	26.0	27.4	25.2	7.2	7.4	7.6	7.7	7.8	8.0
United States	22.2	20.7	19.7	17.1	13.2	12.7	12.5	12.3	12.3	12.2

[1]*Includes Alaska.*
[2]*Hardwood timber harvests are too small for accurate estimation of logging residues.*

volumes. After 1990, the major withdrawals for wilderness were assumed to be over and other removals decline in line with the assumed reductions in timberland areas.

Timber Supplies from Nongrowing Stock Sources

Projected timber supplies comes primarily from growing stock inventories. Part of the supplies, however, come from salvable dead trees, rough and rotten trees, tops and limbs, defective sections of growing stock trees in urban areas, fence rows and on forested lands other than timberland. Output of timber products from nongrowing stock sources is influenced by markets for pulpwood and fuelwood.

The proportion of roundwood supply originating from softwood nongrowing stock sources dropped between 1952 and 1976 (table 76). The hardwood supply showed a similar trend until the 1970s and then turned up slightly in the last assessment. Timber product output from nongrowing stock sources rose from 6.9 in 1976 to 11.5% in 1986 for softwoods, and from 14.0% in 1976 to 38.5% in 1986 for hardwoods. These changes are almost entirely explained by the rapid increase in the use of fuelwood during the past decade.

Among the major geographic sections, there are some trends that differ noticeably from the general U.S. trends. Old-growth forests on the Pacific Coast and in the Rockies contain large volumes of salvable dead timber. With high demand for stumpage, and increasing use of lower quality materials for chips and fuelwood, the proportion of softwood timber supplies coming from nongrowing stock sources on the Pacific Coast is expected to remain high relative to the South.

In the Rocky Mountains, nongrowing stock sources provided 4.5% of the softwood supply in 1976. By 1986, this had risen to 11.9%. This is assumed to increase

Weighing lodgepole pine bole sections to determine volumes of useable material.

Table 76.—Timber product output from nongrowing stock sources as a percent of timber supplies in the United States, by softwoods and hardwoods and section, specified years 1952–1986, with projections to 2040.

Species group and section	1952	1962	1970	1976	1986	Projections 2000	2010	2020	2030	2040
					Percent					
Softwoods										
North	13.3	12.6	12.6	12.6	27.4	30.0	30.0	30.0	30.0	30.0
South	8.4	8.7	4.5	5.0	4.0	4.0	4.0	4.0	4.0	4.0
Rocky Mountain	5.8	5.6	4.7	4.5	11.9	12.0	12.0	12.0	12.0	12.0
Pacific Coast[1]	12.4	11.6	8.9	8.6	17.4	17.7	18.0	18.3	18.6	18.9
United States	10.4	10.0	7.0	6.9	11.5	11.8	12.0	12.1	12.2	12.3
Hardwoods										
North	23.5	17.7	11.9	16.5	51.8	53.0	54.0	55.0	55.0	55.0
South	19.0	18.9	13.9	11.9	21.9	23.0	23.5	24.0	24.5	25.0
Rocky Mountains	([2])	([2])	([2])	([2])	79.7	80.0	80.0	80.0	80.0	80.0
Pacific Coast[1]	14.3	11.5	6.1	11.3	46.2	48.4	50.1	51.7	53.3	54.9
United States	20.9	18.5	13.9	14.0	38.5	40.1	40.9	41.7	41.9	42.2

[1]*Includes Alaska.*
[2]*Hardwood timber harvests are too small for accurate estimations of output originating from nongrowing stock sources.*

through the rest of the projection period as fuelwood continues to be an important product.

Nongrowing stock sources provided about 12.6% of the softwood timber supplies in the North in 1976. This increased to 27.4% in 1986, and is expected to increase further as fuelwood consumption continues to increase. The proportion of softwood nongrowing stock output in the South is low—5.0% in 1976 and 4.0% in 1986. This is expected to remain constant over the next five decades.

Hardwood forests contain large volumes of rough and rotten trees and tops and branches. Hardwoods also make up most of the urban forest, fence rows, and other similar sources of nongrowing stock timber supplies. As a result, a substantial fraction of hardwood roundwood supplies, 38.5% in 1986, have come from nongrowing stock sources.

With increasing demand for fuelwood and improvements in techniques for harvesting and processing hardwood for pulp and paper, nongrowing stock is expected to continue to be an important and, in most regions, a growing part of hardwood timber supplies. In the North, for example, the proportion of hardwood timber supplies originating from nongrowing stock rises from 51.8% in 1986 to 55.0% in 2040.

National Forest Harvest Levels

One of the major determinants of future timber supplies are the assumptions concerning national forest harvest levels. These assumptions were derived from both ongoing planning efforts and budget submissions and represent a continuation of recent trends in harvest.

Historical levels of total national forest softwood harvest are shown in the left portion of figure 55 and in table 77. Following World War II, strong demand for forest products and declining private harvests brought ex-

Table 77.—Softwood harvest and growing stock inventory for the national forests ownership, specified years 1952–1986, with projections to 2040.

Item and region	1952	1962	1970	1976	1986	2000	2010	2020	2030	2040
					Million cubic feet					
Northeast										
Standing inventory	459	532	637	636	746	911	999	1,053	1,113	1,085
Harvest	3	3	3	2	6	7	10	12	13	14
North Central										
Standing inventory	1,336	1,988	2,170	2,542	3,270	3,723	3,885	3,963	4,081	3,846
Harvest	24	28	34	32	29	49	53	58	63	67
Southeast										
Standing inventory	1,991	2,152	2,596	2,824	2,855	3,156	3,516	3,864	4,362	4,876
Harvest	14	27	33	61	59	56	64	66	68	70
South Central										
Standing inventory	3,123	4,874	4,952	5,670	6,466	6,822	7,270	7,647	8,387	9,146
Harvest	141	90	147	174	163	185	209	216	223	229
Rocky Mountain[1]										
Standing inventory	58,013	62,979	63,825	65,081	70,832	70,929	70,953	71,293	71,872	72,552
Harvest	218	387	480	426	465	603	642	669	695	722
PSW[2]										
Standing inventory	29,590	29,391	28,694	28,073	27,213	26,257	26,486	26,786	27,346	27,710
Harvest	89	216	346	286	347	296	299	304	309	314
PNW West										
Standing inventory	47,584	47,704	45,478	44,088	33,607	28,993	27,029	25,924	25,342	25,133
Harvest	361	586	489	511	659	562	578	577	577	576
PNW East										
Standing inventory	23,408	25,757	25,911	23,649	17,331	14,624	13,334	12,333	11,689	11,457
Harvest	100	232	286	292	378	316	325	324	324	323
Alaska[3]										
Standing inventory	38,850	38,228	37,555	35,414	6,853	6,027	5,448	5,141	5,162	5,672
Harvest	11	66	100	83	47	83	83	85	86	89
United States Total										
Standing inventory	204,354	213,605	211,818	207,977	169,173	161,144	158,921	158,004	159,355	161,477
Harvest	961	1,635	1,918	1,867	2,153	2,157	2,263	2,311	2,357	2,404

[1]*Rocky Mountains region historical data includes the Great Plain states.*

[2]*PSW exludes Hawaii.*

[3]*Figures for Alaska have been revised since publication of Waddell et al. 1989.*

Note: Inventory data for 1952 and 1962 are as of December 31. Inventory data for 1970 and projection years are as of January 1. Inventory data for 1976 and 1986 are as of January 1 of the following year.

Sources: For historical data: USDA FS 1982, Waddell et al. 1989.

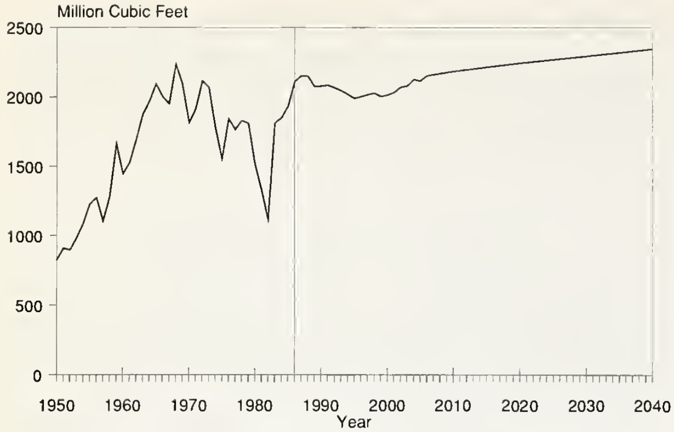


Figure 55.—Total national forest softwood timber harvest.

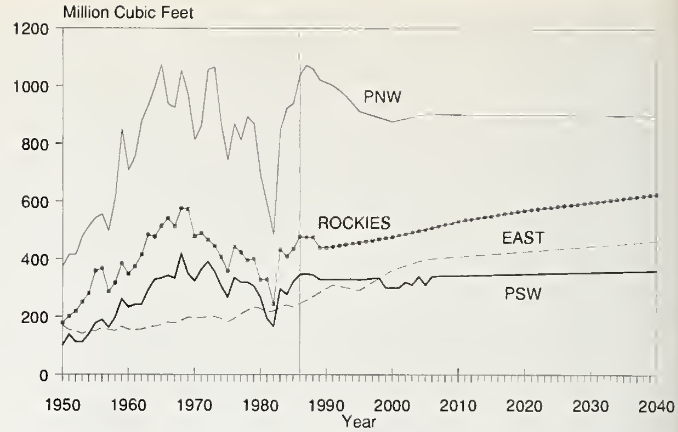


Figure 56.—National forest softwood harvest by region.

panded markets for national forest timber. The USDA Forest Service shifted from its "custodial" management posture of the inter-war years toward a more active policy of timber sales. Harvest grew rapidly as a result. By the late 1960s, cut was approaching sustainable levels under existing management plans in some areas of the West, and an array of new management priorities brought significant changes in USDA Forest Service supply policies. Volume-based methods of harvest scheduling were supplanted, first in 1973 by a nondeclining flow policy, and then in 1976 by the National Forest Management Act (NFMA). As part of NFMA, the Forest Service was required to develop 10-year interdisciplinary forest plans for each administrative unit in the National Forest System. Substantial areas of land were redesignated as wilderness or undeveloped reserves and removed from the allowable cut base. In unreserved areas, harvest planning and practices were modified to minimize adverse environmental impacts and deleterious effects on noncommodity uses of the forest. The consequence of these and other actions has been a stabilization (or in some cases a gradual decline) in harvest over the past 20 years.

The second bulge in national forest harvest (1985–88) reflects a one-time drawdown of uncut volume accumulated during the 1981–82 recession and higher harvesting rates of recent sales. The level of Forest Service timber offered for sale has remained relatively unchanged during the 1980s, ranging from a high of 12.2 billion board feet in 1981 to a low of 11.1 billion board feet in 1982. It was 11.4 billion board feet in (fiscal year) 1988.

Differences in regional patterns of national forest harvest, illustrated in the left portion of figure 56, are a reflection of varying rates of regional industrial development and conditions of the national forest timber resource. The national pattern of figure 56 is derived from the nearly parallel movements of cut in the largest producing areas: the Pacific Northwest, Rocky Mountain, and California regions. In the wake of rapid industrial expansion and harvest in earlier periods, all of these regions faced significant reductions in private supply during the 1950s and 1960s. Large volumes of mature timber, reasonable wood costs, and an expansive supply policy were ample stimuli for increased national forest harvest. Harvest limitations since the mid-1960s have been most pronounced in these regions. Harvest patterns in the East are dominated by the Southern states, where private timber supply and output of the solidwood products industry underwent a major contraction during the 1950s and early 1960s. The reduction in timber demand was sufficient to stabilize national forest harvest as well. With the revival of the industry in the mid-1960s, harvests from the national forests have increased in line with expanding growth and inventory.

The right hand portions of figure 55 and table 77 illustrate the projections of total national forest softwood harvest in the United States. The projections of national forest hardwood harvest is shown in table 78. These harvest levels were derived from projections of allowable sale quantity (plus projections of the nonchargeable harvest). Harvests from national forest lands are assumed to be at the level consistent with the sum of preferred alternatives in forest plans for 2000 and beyond. Harvests for the years 1988–1995 are estimated by the Forest Service timber management staff. For the years 1996–1999, harvests are estimated as a linear extrapolation between 1995 and 2000.

Softwood national forest harvest rises from approximately 2.15 billion cubic feet at present to about 2.40 billion cubic feet by 2040. In effect, these projections change the experience of the last several decades when national forest harvests have been relatively flat. Most of this growth in harvest comes in the East and in the Rockies—particularly in the Northern Region. For hardwoods, the trend in Forest Service harvest is for modest growth. Unlike softwoods, the Forest Service is not a major supplier of hardwood stumpage nor is that expected to change in the future.

Regional projections of the softwood harvest are illustrated in the right hand portion of figure 56. Compared to historical levels, this projected harvest pattern would involve significant changes in the relative importance of various regions in total national forest harvest. Supply in the Pacific Coast regions declines from current levels but remains relatively stable after 2000. In contrast, national forest harvest in the Rocky Mountain regions rises throughout the projection period. Timber

Table 78.—Hardwood harvest and growing stock inventory for the national forests ownership, specified years 1952–1986, with projections to 2040.

Item and region	1952	1962	1970	1976	1986	2000	2010	2020	2030	2040
					Million cubic feet					
Northeast										
Standing inventory	1,983	2,580	3,007	3,749	4,127	4,242	4,224	4,178	4,106	4,070
Harvest	9	9	15	21	26	36	37	38	40	20
North Central										
Standing inventory	2,482	3,491	3,994	4,483	5,470	5,868	5,887	5,810	5,640	5,250
Harvest	32	34	40	43	76	99	104	109	114	119
Southeast										
Standing inventory	2,481	2,979	3,511	4,156	5,055	5,125	5,160	5,199	5,344	5,432
Harvest	9	11	17	15	14	16	20	23	26	29
South Central										
Standing inventory	1,785	2,793	3,010	3,576	4,502	4,591	4,548	4,497	4,689	4,740
Harvest	41	29	32	18	35	53	63	73	83	93
West[2,3]										
Standing inventory	4,522	5,008	5,262	5,080	5,558	156	164	173	183	194
Harvest	10	14	19	4	16	([1])	([1])	([1])	([1])	([1]
United States total										
Standing inventory	13,253	16,851	18,784	21,044	24,712	19,982	19,983	19,858	19,962	19,686
Harvest	101	97	123	101	166	204	224	243	262	260

[1]*Hardwood projections for the western national forests are incomplete.*
[2]*West excludes Hawaii.*
[3]*West projections 2000–2040 are for Alaska only (no data available for other regions).*
Note: See table 77.
Source: See table 77.

harvest from eastern national forests is projected to exceed the Pacific Southwest after 2000.

Other Public Harvest Levels

The smallest ownerships in terms of timber harvest are the various other public ownerships. These ownerships include a diverse collection of different land owners such as the Department of Defense, many counties and states, and the Bureau of Land Management. Historical and projected roundwood supplies, net annual growth, and growing stock inventories are shown in table 79 for softwoods and table 80 for hardwoods. The historical data for 1952–76 was extracted from similar tables in the last Assessment. The data for 1986 was compiled from various material in Waddell et al. 1989. The regional definitions in both tables for 1986 differ from the historical data as described in Chapter 3. The projections were taken from several sources.[23]

Both softwood and hardwood other public inventories are expected to continue increasing during the next five decades. The hardwood inventories increase at a somewhat faster rate than do the softwoods inventories. Only towards the end of the projection period do harvest and growth come into balance for both hardwoods and softwoods. Net growth especially for hardwoods is expected to drop as stands mature and growth rates drop. The largest drops in hardwood growth are expected in the next 15 years.

[23]*The projections in tables 79 and 80 have been revised from similar projections prepared as part of the Fourth Forest (USDA FS 1988b) for the South and for the other regions as part of the last Assessment by first comparing the actual data for 1986 with the projected values for 1986. In the next step, harvest projections from the past studies were judgmentally adjusted by the ratio of projected to actual harvest for 1986. The growth projections were retained from the last Assessment and the value for 2040 was computed as the continuation of the trend between 2000 and 2030. Inventory levels were computed for all projections using a growth-drain identity.*

PROJECTED TRENDS IN PROCESSING COSTS

In addition to timber products demand, the timber resource situation is also influenced by the projected trends in timber processing costs. Timber processing is the conversion of the timber resource into the wood products demanded by consumers.

Processing costs are the costs of converting timber into wood products and generally include labor, energy, and equipment costs. Income offsets from the sale of byproducts, such as wood residues in the production of lumber, are not included. Processing costs do not include the cost of stumpage. The following projected trends in processing costs assume that future technological development and adoption will offset increases in labor, energy, and capital costs.

Logging

Logging involves tree felling, bucking the trees into logs, skidding or yarding the logs to a landing, and loading and hauling them to processing facilities. Timber

Table 79.—Softwood roundwood supplies, net annual growth, and growing stock inventory for other public ownerships, specified years 1952–1986, with projections to 2040.

Item and region	1952	1962	1970	1976	1986	2000	2010	2020	2030	2040
					Million cubic feet					
Northeast										
Roundwood supplies	7	5	7	13	18	25	29	32	35	37
Net annual growth	27	32	37	49	54	57	57	57	56	55
Inventory	885	1,044	1,275	1,555	2,428	3,002	3,392	3,752	4,092	4,412
North Central										
Roundwood supplies	33	35	38	41	43	76	108	110	110	110
Net annual growth	92	120	126	142	168	149	148	149	152	157
Inventory	2,162	2,943	3,237	3,728	4,840	6,240	7,040	7,810	8,590	9,410
Southeast										
Roundwood supplies	51	43	69	88	100	130	134	139	144	144
Net annual growth	70	84	126	149	159	155	162	174	188	188
Inventory	1,506	1,996	2,176	2,648	3,288	3,524	3,724	3,997	4,342	5,015
South Central										
Roundwood supplies	30	30	32	51	64	60	60	60	60	60
Net annual growth	56	58	78	71	55	55	58	65	91	91
Inventory	780	824	1,225	1,340	1,458	1,326	1,223	1,179	1,148	1,127
Rocky Mountains[1]										
Roundwood supplies	72	78	78	85	79	79	78	78	78	78
Net annual growth	119	141	162	162	220	193	171	169	173	183
Inventory	9,923	10,147	10,399	10,429	11,094	12,732	13,702	14,652	15,642	16,732
Pacific Southwest[2]										
Roundwood supplies	3	16	26	22	12	39	41	43	43	43
Net annual growth	14	14	14	14	25	23	25	27	30	33
Inventory	1,892	1,435	1,150	1,108	1,245	1,385	1,215	1,046	906	796
Douglas-fir subregion										
Roundwood supplies	158	290	343	428	418	450	450	450	450	450
Net annual growth	193	316	356	371	495	458	516	606	710	685
Inventory	20,085	19,787	19,610	19,161	19,576	16,748	17,047	17,934	19,754	21,887
Ponderosa pine subregion										
Roundwood supplies	48	61	97	89	77	111	135	138	141	145
Net annual growth	66	88	91	96	139	129	136	145	155	166
Inventory	7,792	6,536	6,483	6,748	7,027	7,067	6,849	6,564	6,198	5,728
Alaska[3]										
Roundwood supplies	1	4	12	5	3	4	5	6	6	7
Net annual growth	93	107	123	137	56	79	64	44	33	26
Inventory	10,173	11,021	11,864	12,334	5,766	6,851	8,001	8,662	8,949	9,143
United States										
Roundwood supplies	403	561	702	822	814	974	1,040	1,056	1,067	1,073
Net annual growth	730	961	1,113	1,191	1,371	1,298	1,337	1,436	1,588	1,584
Inventory	55,198	55,733	57,419	59,051	56,722	58,875	62,193	65,596	69,621	74,249

[1]*Rocky Mountains region historical data (excluding roundwood supply) includes the Great Plain states.*
[2]*PSW exludes Hawaii.*
[3]*Figures for Alaska have been revised since publication of Waddell et al. 1989.*
Note: See table 77.
Source: See table 77.

stand characteristics influencing logging cost include stand diameter, stand volume, and the steepness of the terrain. Historical data and projections are shown in table 81. The higher logging costs in the Rocky Mountains and Pacific Coast are due to a combination of steeper terrain and higher labor costs. Between 1952 and 1985, logging costs increased in all sections and regions. Increases in energy, labor, and equipment costs accounted for part of this increase. The increase in logging costs in the Rocky Mountains and Pacific Coast sections was also attributable to declining stand diameter and volume as well as the harvesting of stands on steeper terrain.

Logging costs are projected to increase at a faster rate than that experienced from 1952 to 1985 (Bradley, in press). The rate of increase in logging costs is the slowest in the Pacific Coast Region, with increases of 45%, 54%, and 49% projected for the Pacific Northwest-West, Pacific Northwest-East, and Pacific Southwest sections. These increases are due primarily to projected declines of approximately 40% in stand diameter between 1985

Table 80.—Hardwood roundwood supplies, net annual growth, and growing stock inventory for other public ownerships, specified years 1952–1986 with projections to 2040.

Item and region	1952	1962	1970	1976	1986	2000	2010	2020	2030	2040
					Million cubic feet					
Northeast										
Roundwood supplies	23	26	28	23	23	36	39	42	44	44
Net annual growth	142	182	210	238	265	242	240	235	227	222
Inventory	3,803	4,838	5,697	6,478	9,844	12,966	15,166	17,296	19,316	21,276
North Central										
Roundwood supplies	45	51	70	72	81	103	119	135	151	151
Net annual growth	213	269	278	304	341	354	353	353	357	366
Inventory	4,583	6,619	7,649	8,343	10,112	14,200	17,050	19,780	22,380	25,020
Southeast										
Roundwood supplies	12	10	20	31	62	65	70	82	90	90
Net annual growth	27	32	55	71	81	85	80	83	97	97
Inventory	767	1,056	1,398	1,816	2,373	2,274	2,140	1,952	2,248	2,126
South Central										
Roundwood supplies	33	36	36	53	66	77	78	79	79	79
Net annual growth	55	71	90	109	101	74	71	81	96	96
Inventory	1,365	1,750	2,106	2,401	3,307	2,524	2,282	2,131	2,086	2,066
Rocky Mountains[1]										
Roundwood supplies	2	2	1	1	1	1	1	1	1	1
Net annual growth	8	9	10	11	28	15	16	14	11	12
Inventory	566	624	670	682	974	1,156	1,296	1,416	1,506	1,606
Pacific Southwest[2]										
Roundwood supplies	1	1	1	2	1	1	5	5	4	4
Net annual growth	6	5	7	7	16	5	5	4	4	4
Inventory	218	190	263	283	554	610	640	660	690	720
Douglas-fir subregion										
Roundwood supplies	5	3	9	12	35	15	16	16	16	16
Net annual growth	33	57	91	92	84	48	51	54	60	55
Inventory	1,080	1,526	2,030	2,263	2,360	2,579	2,323	2,177	2,129	2,093
Ponderosa pine subregion										
Roundwood supplies	1	1	1	1	1	1	1	1	1	1
Net annual growth	1	1	1	1	4	1	1	1	1	1
Inventory	55	58	59	59	82	100	120	146	179	223
Alaska[3]										
Roundwood supplies	([4])	([4])	4	4	6	7	7	8	8	8
Net annual growth	7	7	7	7	58	98	84	49	24	12
Inventory	3,908	3,866	3,873	3,868	1,892	2,802	3,630	4,184	4,465	4,558
United States										
Roundwood supplies	122	130	170	199	276	306	336	369	394	394
Net annual growth	492	633	750	840	977	922	901	874	877	865
Inventory	16,345	20,527	23,745	26,193	31,498	39,211	44,647	49,742	54,999	59,687

[1]*Rocky Mountains region historical data (excluding roundwood supply) includes the Great Plain states.*
[2]*PSW exludes Hawaii.*
[3]*Figures for Alaska have been revised since publication of Waddell et al. 1989.*
[4]*Less than 0.5 million cubic feet.*
Note: See table 77.
Source: See table 77.

and 2040. Declines of 25% in average stand diameter in the Rocky Mountain Region result in a 55% increase in logging costs. Logging costs in the South increase 57% over the projection period as stand diameters decline, especially during the decade following 2000.

Softwood Lumber

Softwood lumber processing includes yard handling of logs, bucking, debarking, log breakdown by primary and secondary sawing, drying, grading and preparation for shipping. Timber characteristics that influence processing costs per unit of lumber output include log diameter, length, shape, and defects. Lumber processing costs are higher in the Rocky Mountain and Pacific Coast regions, reflecting higher labor costs in these areas of the United States.

Softwood lumber processing costs (table 82) are projected to decrease in all sections and regions after 2000 (Skog, in press). This departure from the historic trend is attributable to continued improvements in saw-

Falling trees on a clear cut in the Douglas-fir subregion.

A Skagit tower with a high lead carriage system being used in steep terrain.

Table 81.—Sawtimber logging and hauling costs in the United States, by section and region, specified years 1952–1985, with projections to 2040.

Section and region	1952	1962	1970	1976	1985	Projections 2000	2010	2020	2030	2040
	1982 dollars per thousand board feet, log scale, Scribner									
South	54	74	86	70	65	72	78	84	90	102
Rocky Mountains[1]	98	96	122	154	132	156	168	180	183	204
Pacific Coast										
Pacific Northwest										
Pacific Northwest-West	93	92	107	132	120	135	144	156	153	174
Pacific Northwest-East	81	76	103	116	109	126	135	147	150	168
Pacific Southwest	79	87	97	131	115	132	141	153	153	171

[1]*Excludes North Dakota, Nebraska, and Kansas.*
Source: Adams et al. 1988.

ing technology and projected constant labor and energy costs. With labor and energy costs projected to remain constant, improvements in technology more than compensate for declining log diameters, resulting in declining processing costs. The decline between 1985 and 2040 is similar for all regions, 16% to 24%, even though diameters decrease more rapidly in the Pacific Coast (23%) than in the South (4%). Even though diameters decrease most in the Pacific Coast, the average diameter remains higher than in the South. Pacific Coast mills with larger diameter logs benefit more from the expected increase in throughput rates of future mills. Cost declines most in the Pacific Northwest-East (24%) due to a projected greater improvement in technology for board mills and a more limited decline in log diameters (13%). In the Rocky Mountains, costs decline only 16%, reflecting a slower rate of improvement in sawmilling technology.

Softwood Plywood

Softwood plywood processing involves yard handling of logs, log bucking, debarking, and peeling, veneer drying; layup and pressing; plywood grading; and preparation of plywood for shipping. Timber characteristics that influence processing costs include log diameter, log shape, defects, and specific gravity. Plywood processing costs have traditionally been highest in the Pacific Coast and lowest in the South (table 83). Higher labor costs in the Pacific Coast have been the main reason for higher processing costs there, with emphasis on grade recovery being a contributory factor.

Improved processing technology helped reduce plywood processing costs in all regions from 1952 to 1970. Softwood plywood processing costs increased from 1970 to 1976 reflecting higher labor and energy costs. Since 1976, costs have declined in all regions. This decline in softwood plywood processing costs was attributable to labor and energy costs and improved processing efficiency. The increasing share of smaller but more sound second-growth timber has also helped improve efficiency.

Plywood processing costs are projected to decline further (Spelter and Sleet 1989). With labor and energy costs constant, improvements in technology—principally the incorporation of labor saving equipment in veneer stacking, gluing, and handling—are expected to lead to declines of 4% to 7% between 1986 and 2040. The decline is greatest in the Douglas-fir subregion as the focus of production is projected to shift from sanded and specialty products to lower cost sheathing items. Accompanying this transformation is a decline in log diameters of about 25%. Processing costs in the South are projected to drop by only 5%, reflecting little change in log diameters.

Oriented Strand Board and Waferboard

Oriented strand board (OSB) and waferboard processing involves yard handling of logs, log debarking and

Table 82.—Softwood lumber nonwood processing costs in the United States, by section and region, specified years 1952–1985, with projections to 2040.

Section and region	1952	1962	1970	1976	1985	Projections 2000	2010	2020	2030	2040
	1982 dollars per thousand board feet									
South	60	63	76	89	89	78	78	75	72	69
Rocky Mountains[1]	74	64	84	106	96	96	96	93	87	81
Pacific Coast										
Pacific Northwest										
Pacific Northwest-West	100	85	108	112	104	105	93	93	84	81
Pacific Northwest-East	77	67	90	100	106	99	93	87	84	81
Pacific Southwest	118	101	109	120	110	99	99	93	87	87

[1]*Excludes North Dakota, Nebraska, and Kansas.*
Source: Adams et al. 1988.

Table 83.—Softwood plywood nonwood processing costs in the United States, by section and region, specified years 1952–1985, with projections to 2040.

Section and region	1952	1962	1970	1976	1985	Projections 2000	2010	2020	2030	2040
	1982 dollars per thousand square feet, 3/8-inch basis									
South			87	91	82	81	81	81	81	78
Pacific Coast										
Pacific Northwest										
Pacific Northwest-West	123	93	96	110	103	99	96	96	96	96
Pacific Northwest-East	120	105	76	95	81	78	78	78	78	78
Pacific Southwest		93	96	110	103	99	99	96	96	96

Source: Adams et al. 1988.

slashing, flaking, drying, gluing, forming, and pressing of flakes, and preparation of final product for shipping. OSB and waferboard processing costs are not strongly influenced by timber characteristics. Processing costs for OSB and waferboard in 1986 were higher in the North than in the South, reflecting higher labor costs in the North (table 84).

OSB and waferboard mills are already highly automated and are likely to show only minimal gains in labor productivity. Improvement in glue application resulting in reduced glue consumption is expected to be the main source of cost reductions. Declines in processing costs are projected at 7% and 4% for the North and the South.

Table 84.—Oriented strand board and waferboard nonwood processing costs in the United States, by section and region, 1986, with projections to 2040.

Section and region	1986	Projections 2000	2010	2020	2030	2040
		1982 dollars per thousand square feet, 3/8-inch basis				
North	90	84	84	84	84	84
South	87	84	84	84	84	84

Pulp and Paper

Pulp and paper processing includes wood debarking, chipping, and screening, conversion of chips into pulp using chemical or mechanical processes, mixing of pulp with additives or recycled fiber; and conversion of pulp into paper, which involves sheet formation, pressing, and drying. Pulp and paper processing may also involve recovery of pulping chemicals, bleaching of pulp fibers, and, in the case of market pulp, drying and shipping of pulp. Wood characteristics that can influence processing costs include wood density, cellulose content, resin content, and the proportion of bark or immature wood.

Pulp and paper processing costs vary among different product grades due to variations in pulping process, size of facility, different application of bleaching, and different use of recycled fiber (table 85). Processing costs for newsprint and solid bleached board in 1986 were above those for other grades, due in part to the use of smaller scale facilities. In the case of newsprint, these higher processing costs also result from higher energy costs relative to other grades. Solid bleached board processing involves bleaching which contributes to the higher cost for this grade. Unbleached kraft and semichemical board facilities are often larger in scale and involve significant cogeneration of energy, resulting in lower processing costs. Recycled board costs are low relative to other grades as they do not involve conventional pulping.

Declines of 3% and 1% are projected for newsprint and semichemical board processing costs to 2040, while unbleached kraft and solid bleached board are both projected to decrease by 20%.[24] Processing costs for recycled board are projected to remain unchanged at 1986 levels. The costs decline for unbleached kraft board is due to the adoption over time of wide-nip or high-impulse press sections, greater use of recycled fiber, and reduced energy consumption. For solid bleached board, the cost decline is attributable to improvements in bleaching technology and greater use of mechanical pulps.

[24]*Ince, Peter J.; Durbak, Irene; and Howard, James. [In preparation]. The FPL Pulpwood Model: data, assumptions, and projections to the year 2040. Madison, WI: U.S. Department of Agriculture, Forest Service. On file with: Timber Demand and Technology Assessment Research Project, Forest Products Laboratory, One Gifford Pinchot Drive, Madison, WI 53705-2398.*

Table 85.—Nonwood processing costs at integrated pulp and paper facilities in the United States, by product, 1986, with projections to 2040.

Section and region	1986	Projections 2000	2010	2020	2030	2040
		1982 dollars per ton				
Newsprint	363	359	356	352	351	351
Unbleached kraft board	177	162	155	147	142	141
Semichemical board	206	202	204	204	204	204
Recycled board	235	235	235	235	235	235
Solid bleached board	460	398	371	370	370	370

Wood Fuel

The trend in use of wood fuel versus other fuels for home heating and industrial energy is determined by the cost of burning wood versus the cost of burning nonwood fuels. These costs are determined by equipment costs, operating costs, fuel costs, and efficiency of converting fuel to energy. Wood fuel is favored to the extent that it maintains a cost advantage over systems using nonwood fuels.

Installation costs for home wood heating systems (stoves and furnaces) increased between 1970 and 1986 in the North and Rocky Mountains, but declined in other regions (table 86). Cost increases occurred in those regions where increased demand for wood burning equipment grew faster than available supplies.

Installation costs for home heating systems are projected to decline in most regions as the demand for wood fuel declines (High and Skog, in press). Installation costs vary by region depending on the proportion of a home that is heated with wood, the changing mix of installations in single-family versus multifamily housing, and the rate of demand for wood heating systems.

Equipment costs for industrial boilers are projected to remain constant at 1986 levels (table 87). Wood boiler equipment costs are higher than costs for equipment to burn fuel oil or natural gas and about as costly as coal burning equipment. Emission control costs are projected to remain highest for coal, followed by oil, wood and

Table 86.—Residential wood stove installation costs in the United States, by section and region, specified years 1970–1986, with projections to 2040.

Region	1970	1976	Projections 1986	2000	2010	2020	2030	2040
	Thousands of 1982 dollars							
North[1]								
Northeast	.73	1.53	1.73	1.40	1.27	1.24	1.11	1.01
North Central[1]	1.16	1.20	1.78	1.24	1.21	1.20	1.08	.95
South								
Southeast	2.21	2.26	1.56	1.67	1.49	1.49	1.45	1.41
South Central	2.21	2.24	1.55	1.66	1.32	1.35	1.32	1.30
Rocky Mountains[2]	1.58	1.41	1.64	1.47	1.62	1.57	1.75	1.47
Pacific Coast								
Pacific Northwest	1.70	1.20	1.28	1.19	.90	1.69	1.56	1.52
Pacific Southwest	1.97	1.34	1.50	1.22	1.28	1.24	2.00	1.80

[1]*Includes North Dakota, Nebraska, and Kansas.*
[2]*Excludes North Dakota, Nebraska, and Kansas.*
Source: Marshall et al. 1983.

natural gas. Operating costs are also projected to remain higher for wood and coal than for oil and natural gas.

TECHNOLOGY AND RELATED ASSUMPTIONS

Technological change in wood products processing is measured by product recovery factors. Product recovery factors measure the volume of the wood product produced per unit volume of logs consumed or, in the case of pulp and paper, the volume of pulpwood or fiber consumed per ton of product produced. These factors are used to describe technological change in lumber, structural panel, and pulp and paper processing. Conversion efficiencies measure the percentage of energy recovered and are used to compare energy producing technologies for wood and alternative energy sources.

Softwood Lumber

Softwood lumber recovery has increased in all sections and regions between 1952 and 1976 (table 88). There were continued increases through 1985 in the South, Rocky Mountains, and Pacific Northwest-East. Between 1976 and 1986 recovery declined in the Pacific Northwest-West and Pacific Southwest due to a decline in average diameter of logs processed.

Table 87.—Boiler installation cost by boiler type and size, 1986.

Boiler type	Less than 100 million btu's per hour	100 million btu's or more per hour
	Thousands of 1982 dollars per million Btu per hour	
Wood	29.6	32.7
Coal	29.5	34.2
Fuel oil	3.3	8.9
Natural gas	3.0	7.7

Source: High 1985.

Softwood lumber recovery is projected to increase in all sections and regions to 2040 (Skog, in press). In the Rocky Mountains and Pacific Northwest-West, the rate of increase projected between 1985 and 2040 is less than the rate experienced between 1952 and 1976. In the South and Pacific Northwest-East where log diameter decreases are limited, technological improvements increase projected recovery (1985–2040) by 19% and 24%. The recovery increase in the Pacific Northwest-East is also due to considerable technical improvements in board mills which comprise a large portion of sawmill capacity in the region. Technology improvements yield the least recovery improvement in the Pacific Northwest-West (7%) due to a projected 23% decline in average log diameter.

Softwood Plywood

Softwood plywood recovery factors have traditionally been highest in the Pacific Northwest-East because of the larger log diameters. Softwood plywood recovery factors increased in all sections and regions between 1962 and 1985 (table 89). The largest increase occurred in the Pacific Northwest-East where an estimated 26% improvement occurred. This improvement in recovery was the result of new processing technology which allows logs to be peeled down to core diameters of three inches. Gains made in other parts of the Pacific Coast were the result of these improvements in peeling technology as well as the decreasing share of defective old-growth logs.

Softwood plywood recovery is projected to increase in all sections and regions to 2040 (Spelter and Sleet 1989). The increases range from 5% in the Pacific Northwest-West to 20% in the South. These increases reflect continued technical advances in log peeling.

Maintaining the identity of logs, such as this red alder, is a critical part of mill recovery studies.

Table 88.—Softwood lumber recovery factors in the United States, by section and region, specified years 1952–1985, with projections to 2040.

Section and region	1952	1962	1970	1976	1985	Projections 2000	2010	2020	2030	2040
	Board feet lumber tally, per cubic feet, log scale									
South	5.05	5.21	5.35	5.75	6.02	6.47	6.65	6.80	6.98	7.18
Rocky Mountains[1]	5.71	5.95	6.17	6.76	6.80	7.17	7.27	7.40	7.52	7.67
Pacific Coast										
Pacific Northwest										
Pacific Northwest-West	6.67	6.71	6.76	7.94	7.87	8.18	8.18	8.26	8.38	8.47
Pacific Northwest-East	5.41	5.46	5.49	6.02	6.33	6.74	6.97	7.23	7.51	7.82
Pacific Southwest	6.21	6.37	6.54	6.90	6.80	7.57	7.70	7.83	7.99	8.14

[1]*Excludes North Dakota, Nebraska, and Kansas.*
Source: Adams et al. 1988.

Table 89.—Softwood plywood recovery factors in the United States, by section and region, specified years 1952–1985, with projections to 2040.

Section and region	1952	1962	1970	1976	1985	Projections 2000	2010	2020	2030	2040
	Square feet, 3/8-inch basis, per cubic foot, log scale									
South		12.2	12.8	13.3	13.9	16.2	16.4	16.5	16.6	16.7
Rocky Mountains[1]		12.3	12.8	13.3	14.3	15.5	15.6	15.6	15.6	15.6
Pacific Coast										
Pacific Northwest										
Pacific Northwest-West	12.5	13.0	13.3	13.7	14.5	15.1	15.2	15.3	15.3	15.3
Pacific Northwest-East	13.3	13.7	14.3	14.7	17.2	18.8	18.9	19.0	19.0	19.0
Pacific Southwest	12.5	13.0	13.3	13.7	14.3	15.3	15.5	15.6	15.6	15.6

[1]*Excludes North Dakota, Nebraska, and Kansas.*
Source: Adams et al. 1988.

Maintaining the identity of lumber produced in the sawing phase of mill recovery studies is also a critical part of the study.

Oriented Strand Board and Waferboard

Product recovery factors in OSB and waferboard mills vary between 17 and 18 square feet (3/8-inch basis) per cubic foot, log scale (table 90). Southern recoveries are lower because a substantial proportion of the log mix is southern pine, a species that is more difficult to flake without generating high rates of reject particles.

OSB and waferboard recovery is projected to increase by only 2% to 2040 in the North and the South as improvement in flaking reduces wood loss due to production of fine sized particles. The installation of continuous presses also helps by reducing end-trim losses.

Table 90.—Oriented strand board and waferboard recovery factors in the United States, by section and region, 1986, with projections to 2040.

Section and region	1986	Projections 2000	2010	2020	2030	2040
	Square feet, 3/8-inch basis, per cubic foot, log scale					
North	17.9	18.3	18.3	18.3	18.3	18.3
South	16.9	17.3	17.3	17.3	17.3	17.3

Pulp and Paper

Fiber requirements in the production of paper and board consist of varying amounts and grades of woodpulp, wastepaper and other natural fibers. These requirements depend on the grade of paper or board produced and on the production process used. Woodpulp requirements and pulping technology determine, in turn, the amount and type of pulpwood required.

Projections show the total amount of fiber required per ton of paper and board will be declining slowly (table 91).[24] This slow trend results from increased use of fillers and coatings, especially in printing and writing papers, and addition of synthetic polymer fibers to reinforce some paper and paperboard products. Total fiber use per ton of paper and board is projected to decrease 5% by 2040, to 0.977 tons.

Use of woodpulp is projected to decrease 14%, from .810 to .697 tons from 1986 to 2040, as technological developments enable greater use of wastepaper, especially in newsprint, tissue and unbleached kraft. Use of waste-

Table 91.—Fiber consumption per ton of paper and board produced in the United States, specified years 1952–1986, with projections to 2040.

Year	Total	Woodpulp	Wastepaper	Other[1]
		Tons		
1952	1.080	.708	.323	.050
1962	1.029	.762	.242	.026
1970	1.021	.807	.198	.016
1976	1.004	.794	.198	.012
1986	1.025	.810	.209	.005
		Projections		
2000	0.998	.785	.210	.002
2010	0.988	.764	.222	.002
2020	0.978	.730	.246	.002
2030	0.976	.709	.267	([2])
2040	0.977	.697	.280	([2])

[1]*Includes cotton linters, rags, bagasse, straw, kenaf, etc.*
[2]*Less than .001 tons.*
Note: Data may not add to totals because of rounding.
Source: Ulrich 1989.

paper is projected to increase 34%, to .280 tons by 2040. Use of other natural fibers is projected to fall below .001 tons by the year 2040, when fiber use will consist of, on average, 71% woodpulp and 29% wastepaper.

Use of pulpwood per ton of woodpulp produced has been decreasing slowly during the past few decades (table 92). In 1986, an average of 1.504 cords of pulpwood were used to produce one ton of pulp. Use of pulpwood is projected to continue decreasing as high-yield mechanical pulps replace chemical pulps, which have lower yields and therefore require more pulpwood. By the year 2040 use of pulpwood is projected to average 1.362 cords per ton of woodpulp.

The large increase in the use of hardwoods relative to softwoods has contributed to lower pulpwood requirements since hardwoods have a higher pulp yield. Hardwoods increased from 14% of total pulpwood use in 1952, to 31% in 1986. Hardwood use is projected to increase further with wider adoption of improved paper pressing technology and increased use of modern mechanical pulping processes which can incorporate more hardwood fiber. Hardwoods are projected to comprise 41% of total pulpwood use by the year 2040.

Table 92.—Pulpwood consumption per ton of woodpulp produced and percent consumption of softwood and hardwood pulpwood in the United States, specified years 1952–1986, with projections to 2040.

Year	Pulpwood consumption per ton of woodpulp produced	Consumption: Softwood pulpwood	Consumption: Hardwood pulpwood
	Cords	*Percent*	
1952	1.606	85.6	14.4
1962	1.579	77.6	22.4
1970	1.552	75.9	24.1
1976	1.509	74.8	25.2
1986	1.504	69.2	30.8
	Projections		
2000	1.488	63.3	36.7
2010	1.459	59.9	40.1
2020	1.428	59.7	40.3
2030	1.411	59.4	40.6
2040	1.362	59.2	40.8

Sources: Pulpwood consumption: Ulrich 1989. Percent softwood and hardwood pulpwood, 1952 and 1962: American Paper Institute 1970. Percent softwood and hardwood pulpwood, 1970, 1976, and 1986: USDC BC 1970, 1976a, 1986.

Wood Fuel

Efficiency of home wood burning increased substantially between 1970 and 1986 with increased use of airtight stoves and fireplace inserts (table 93). The average efficiency of wood heating equipment is projected to improve relative to nonwood systems though 2000. Wood burning efficiency is expected to improve as more wood stoves sold meet new national performance standards set by the U.S. Environmental Protection Agency (High and Skog, in press). Relative wood burning and nonwood system efficiencies are projected to remain constant after 2000.

Conversion efficiencies for industrial boilers are projected to remain constant at 1986 levels (table 94). Boiler conversion efficiency is projected to remain higher for coal, oil, and natural gas than for wood.

Table 93.—Efficiency of residential heating equipment, specified years 1970–1986, with projections to 2040.

Heating equipment	1970	1976	1986	Projections: 2000	2010	2020	2030	2040
	Percent energy recovered							
Wood stoves	30	51	57	60	60	60	60	60
Electric furnances	95	95	95	95	95	95	95	95
Fuel oil furnaces	50	50	56	65	65	65	65	65
Natural gas furnaces	60	60	63	65	65	65	65	65

Source: Marshall 1981.

Table 94.—Efficiency of boilers by type and size, 1986.

Boiler type	Less than 100 million btu's per hour	100 million btu's or more per hour
	Percent energy recovered	
Wood	62	67
Coal	72	80
Fuel oil	82	83
Natural gas	82	83

Source: Van Wie 1983

CHAPTER 7. PROJECTED TIMBER DEMAND/SUPPLY RELATIONSHIPS

The preceding chapters of this assessment have been largely concerned with assessing the current situation and with the development of the various assumptions needed to project the demand for timber on domestic forests, and the supply of timber that would be available for harvest. One of the primary objectives of this study is to use these assumptions to project prospective changes in the Nation's timber resource. Projections of changes in timber supplies, removals, growth, and inventories, along with projections of timber demands, provide a means of identifying developing and future timber supply/demand situations. These projections help shape our collective perceptions that, in turn, influence stewardship and industrial decisions in the next decade. Finally, projections also provide the data base needed for analyzing the economic, social, and environmental implications of a range of policy and program options.

These projections derive directly from the assumptions regarding major determinants of changes in demand and the timber resource described in Chapter 6. The projections will change as these assumptions are modified. Further, there is no intent to portray the projected trends as socially or economically desirable. Indeed, the economic, social, and environmental implications associated with these trends may stimulate actions to change them.

In this analysis, all projections are made at equilibrium price levels.[25] That is, prices and production factors are allowed to change until the quantities supplied and demanded are equal.

The purpose of this chapter is to present the projections of future market activity for both product and stumpage markets. The first section contains a discussion of the consumption and prices for major forest products. The next section describes harvest and price levels in the stumpage markets. The third section presents the economic and environmental implications of the base projections of resource changes.

PROJECTED CONSUMPTION, PRODUCTION, TRADE AND PRICES FOR TIMBER PRODUCTS

Based on the projections and assumptions about the major markets discussed earlier, consumption, production, and prices for various forest products are projected to follow somewhat diverse trends over the next five decades. In this section, projections of consumption by end use are presented for the solid-wood products (lumber, structural panels, and nonstructural panels). For all products, net trade is the difference between consumption and production.

Lumber

Lumber consumption in all uses in 1986 was 57.2 billion board feet (table 95). This was almost 40% above average consumption in the 1950s and 1960s, and 10% more than the previous high, 52.1 billion, reached in 1978. Consumption of lumber is projected to rise throughout the projection period, reaching 70.0 billion board feet in 2040. The most rapid increases occur early in the next century, as the use of softwoods in construction and hardwoods in manufacturing and shipping continue to increase at relatively high levels. After 2020, declining use in housing is more than offset by continued growth in nonresidential consumption of both hardwood and softwood. This is especially the case for the last decade of the projection where the greatest growth in consumption is for manufacturing purposes.

In 1986 softwood species comprised nearly 82.3% of all lumber consumed and this percentage is expected to change relatively little over the projection period. In some end uses of lumber, such as shipping (pallets) and manufacturing (furniture), a slow increase in the proportion of hardwoods is expected.

Trade in lumber products is dominated by softwood lumber imports from Canada (table 96). Between 1952 and 1986, softwood lumber imports (nearly all from Canada) rose from 2.3 billion to 14.3 billion board feet; however, a large part of this increase has taken place over the past decade. Projections show a decline by 2000 to 10.2 billion board feet. After 2000, imports from Canada start to rise. Softwood lumber imports peak around 2020 and fall to 9.3 billion board feet by 2040. Hardwood lumber imports are expected to remain constant throughout the next five decades.

Like softwood lumber imports, softwood lumber exports have increased since the early 1950s. Most of the growth has consisted of shipments to Japan, South and Central America, and Western Europe. Softwood lumber exports are expected to be stable after 2020. Hardwood lumber exports have also grown and are expected to stabilize at about 600 million board feet.

Production of lumber in the United States shows continued growth (table 96). In the near term, expansions in softwood production outpaces that for hardwood lumber. In percentage terms, however, increases in hardwood lumber production outpace those for softwood lumber. The projections reflect a steady drop in the Canadian share because of relatively more rapid cost increases in Canada.

Projections of regional production of softwood lumber are shown in table 97. These projections show a dynamic and increasing industry, with lumber production

[25] *In this study, equilibrium prices and quantities are determined by the intersection of supply and demand curves. The equilibrium prices are those prices at which the amount willingly supplied and the amount willingly demanded are equal. These prices and the associated equilibrium timber supply/demand projections were developed by means of regionally desegregated economic simulation models. For further details, see: Adams and Haynes (1980), Haynes and Adams (1985), and Binkley and Cardellichio (1986).*

Table 95.—Lumber consumption in the United States, by species group, end use, specified years 1962–1986, with projections to 2040.

Year	Total	Species group: Softwoods	Species group: Hardwoods	End use: New housing	End use: Residential upkeep & improvements	End use: New nonresident construct	End use: Manufacturing	End use: Shipping	End use: All other
	Billion board feet								
1962	39.1	30.8	8.5	14.5	4.4	4.2	4.5	4.6	6.9
1970	39.9	32.0	7.9	13.3	4.7	4.7	4.7	5.7	6.8
1976	44.7	36.6	8.0	17.0	5.7	4.5	4.9	5.9	6.7
1986	57.2	47.1	10.1	19.3	9.9	5.3	4.8	6.8	11.1
2000	55.4	45.5	10.0	12.9	12.8	6.6	7.0	6.1	10.0
2010	61.0	49.7	11.3	13.8	14.5	7.2	7.6	7.3	10.7
2020	66.5	54.3	12.2	15.2	15.9	7.9	8.3	7.9	11.3
2030	68.2	55.3	12.9	13.5	16.7	8.7	9.1	8.6	11.7
2040	70.0	56.7	13.2	12.0	17.0	9.5	10.1	9.0	12.4

Note: Data may not add to totals because of rounding.

Table 96.—Lumber consumption, imports, exports, and production in the United States, specified years 1960–1986, with projections to 2040.

Year	Consumption: Total	Consumption: Softwood lumber	Consumption: Hardwood lumber	Imports: Total	Imports: Softwood lumber[1]	Imports: Hardwood lumber	Exports: Total	Exports: Softwood lumber[1]	Exports: Hardwood lumber	Production: Total	Production: Softwood lumber	Production: Hardwood lumber
	Billion board feet											
1960	37.7	29.6	8.1	3.9	3.6	.3	.9	.7	.2	34.7	26.7	8.0
1970	39.9	32.0	7.9	6.1	5.8	.3	1.2	1.1	.1	35.0	27.3	7.7
1976	44.7	36.6	8.0	8.2	8.0	.3	1.8	1.6	.2	38.3	30.3	8.0
1986	57.2	47.1	10.1	14.6	14.3	.3	2.4	1.9	.5	45.0	34.7	10.3
2000	55.2	45.3	9.9	10.5	10.2	.3	3.1	2.5	.6	47.9	37.7	10.0
2010	60.8	49.5	11.3	12.8	11.9	.3	3.1	2.5	.6	51.6	40.0	11.0
2020	66.0	53.9	12.1	13.5	12.8	.3	3.2	2.6	.6	56.2	43.8	12.0
2030	67.7	54.8	12.9	10.5	10.2	.3	3.2	2.6	.6	60.4	47.2	13.9
2040	69.4	56.2	13.2	9.6	9.3	.3	3.2	2.6	.6	63.0	49.5	13.0

[1]*Includes small volumes of mixed species not classified as softwoods or hardwoods.*
Note: Data may not add to totals because of rounding.

shifting among regions largely in response to changes in relative costs.[26] The primary cost that drives these shifts is that for raw material (stumpage). There is, for example, an initial shift in softwood lumber production from the Pacific Coast regions to those in the South. By 2040, the South has increased its share of lumber production to 40% while the share of the Pacific Coast regions drop to 38%. The initial drop within the Pacific Coast regions, results from rising stumpage costs (relative to other regions) associated with roughly stable timber inventories in the Douglas-fir subregion and declining private inventories in the Pacific Southwest. Softwood lumber production in the northern regions and in the Rocky Mountains rises through the projection period, and substantially so in the Rocky Mountains. The growth in the Rocky Mountains is fueled by the assumed increases in national forest harvest (table 77). These increases are sufficient to slow the rate of growth in stumpage prices.

The regional projections of hardwood lumber production shift in response to changing cost conditions. Most of the increase in hardwood lumber production is in the North. By 2040, 72% of hardwood lumber is produced in the North. Production in the South remains roughly stable until 2020 and then declines because of declines in hardwood inventories.

[26]*In these projections, expansion and contraction of softwood lumber production and imports were determined by current profit margins (as measured by the difference between prices and total production costs) realized in each producing region relative to historical levels. Production cost disadvantages faced by domestic regions stem both from rising stumpage and nonwood costs. The increases in production costs (fueled by rapidly increasing stumpage prices) and attendant reductions in profit margins are particularly important determinants of downward capacity adjustments in the Pacific Coast regions during the first decade of the projection period.*

Structural Panel Products

Structural panels (softwood plywood and oriented strand board and waferboard) consumption reached 26 billion square feet (3/8-inch basis) in 1986—83% above the volume consumed in 1970 and nearly 3 times total use in 1962 (table 98). Until the late 1970s, softwood ply-

Table 97.—Lumber production in the contiguous states, by softwoods, hardwoods, and region, specified years 1952–1986, with projections to 2040.

Species group & region	1952	1962	1970	1976	1986	Projections 2000	2010	2020	2030	2040
						Billion board feet, lumber tally				
Softwoods										
Northeast	1.3	0.9	0.6	0.9	1.4	1.8	2.2	2.5	2.6	2.8
North Central[1]	0.4	0.3	0.3	0.5	0.3	0.5	0.7	0.9	1.0	1.1
Southeast	5.2	2.7	2.8	3.5	5.2	6.2	6.8	7.5	7.0	6.7
South Central	3.6	3.2	4.2	4.7	6.1	6.9	6.4	8.3	11.0	13.4
Rocky Mtn.	2.5	3.6	4.2	4.6	4.5	5.4	6.0	6.2	6.3	6.5
Pacific NW[2]										
Douglas-fir subregion (Western Oregon & Western Washington)	10.3	8.6	7.4	8.4	9.2	9.1	9.4	9.6	10.5	10.5
Ponderosa pine subregion (Eastern Oregon & Eastern Washington)	2.3	2.4	2.3	2.8	2.8	3.3	3.9	4.3	4.5	4.6
Pacific SW[3]	4.6	5.0	5.1	4.9	5.1	4.6	4.8	4.5	4.3	4.0
Total U.S. Softwoods	30.2	26.6	26.9	30.3	34.6	37.8	40.2	43.8	47.2	49.6
Hardwoods										
Northeast	0.9	1.0	1.4	1.9	2.2	2.8	3.1	3.9	4.5	4.8
North Central[1]	2.4	1.2	1.5	2.6	3.1	3.3	3.8	4.2	4.6	4.9
Southeast	1.6	1.5	1.7	1.4	2.0	1.7	1.7	1.6	1.4	1.1
South Central	2.3	2.6	2.5	1.8	2.6	2.3	2.4	2.4	2.5	2.6
West	([4])	0.1	0.1	0.3	0.4	0.2	0.2	0.2	0.2	0.2
Total U.S. Hardwoods	7.2	6.4	7.2	8.0	10.3	10.3	11.5	12.3	13.2	13.5

[1]*The Great Plains are included in the Northcentral region.*
[2]*Excludes Alaska.*
[3]*Excludes Hawaii.*
[4]*Less than 50 million board feet.*
Note: Data may not add to totals because of rounding.

Table 98.—Structural panel consumption in the United States, by panel type, end use, specified years 1962–1986, with projections to 2040.

		Panel type		End use					
Year	Total	Softwood plywood	OSB/ waferboard	New housing	Residential upkeep & improvements	New nonresident construct	Manufacturing	Shipping	All other
				Billion square feet (3/8-inch basis)					
1962	9.5	9.5	([1])	4.0	1.0	1.7	0.7	0.2	1.9
1970	14.2	14.2	([1])	5.6	2.4	1.9	0.9	0.3	3.2
1976	18.0	17.7	0.2	7.8	3.3	1.9	1.1	0.3	3.6
1986	26.0	21.7	4.3	10.0	6.2	3.1	1.3	0.4	5.1
2000	25.6	17.3	8.3	7.0	8.0	4.7	2.9	1.8	1.1
2010	28.9	18.2	10.7	7.9	9.2	5.3	3.6	2.0	0.8
2020	33.0	20.1	13.0	9.2	10.4	6.0	4.3	2.5	0.7
2030	35.6	21.3	14.4	8.4	11.3	6.8	5.3	3.2	0.7
2040	39.2	23.2	16.0	7.6	12.2	7.7	6.5	4.4	0.9

[1]*Less than 50 million square feet.*
Note: Data may not add to totals because of rounding.

wood was the only structural panel in wide use; and primarily because of its substitution for softwood lumber, its growth was particularly fast in the 1950s and 1960s. With the introduction of oriented strand board and waferboard and their subsequent substitution for softwood plywood, however, consumption of those products have increased rapidly slowing the growth in the use of softwood plywood.

Projections of total structural panel consumption rise to 39.2 billion square feet in 2040, about 50% above 1986 consumption (table 98). Most of the increase over the projection period is due to continued growth in oriented strand board and waferboard consumption, which is projected to reach 16.0 billion square feet by 2040, more than 3.6 times its use in 1986. After slowly declining through 2010, softwood plywood consumption increases to 23.2 billion square feet in 2040. As a result of these trends, oriented strand board and waferboard panels comprise over 40% of total structural panel consumption in 2040, up sharply from about 16.6% in 1986. Consumption of panels is expected to increase across all end uses except for new housing and the all other category (table 98).

Imports of oriented strand board and waferboard from Canada increased rapidly in the late 1970s as demands outstripped the small, but growing, domestic industry's ability to manufacture these products (table 99). Continued increases in imports are expected through 2010, but fall afterwards as the domestic industry expands. Softwood plywood imports are small and are not expected to rise over the projection period.

Exports of softwood plywood, though showing some fluctuation, have trended upward since the early 1970s and are expected to continue to rise further as European markets grow and other markets open up. Exports of oriented strand board and waferboard have been small, and are expected to remain so in the projection period.

Domestic production of structural panel products is expected to grow in line with increases in U.S. consumption (table 99). Regional production of structural panel products has been undergoing wide-scale changes since the start of Southern pine plywood production in 1964. During the last decade, the expansion of oriented strand board and waferboard production has lead to the North becoming a major producer of structural panel products (table 100). There are other substantial regional shifts projected for structural panel production. By 2000, softwood plywood production declines both in the south-central and Douglas-fir regions. Oriented strand board and waferboard production nearly doubles in the North during the same period. Between 2000 and 2040, panel production for both softwood plywood and oriented strand board and waferboard expands in the North, South, and Pacific Coast sections. By 2040, production shares are 19%, 50%, and 26% for these three sections.

Nonstructural Panel Products

Nonstructural panels consumption, including hardwood plywood, insulating board, hardboard, and particleboard, rose to 18.2 billion square feet (3/8-inch basis) in 1986, nearly 3 times total use in 1960 (table 101).

Projected total demand for nonstructural panels increases to 23.2 billion square feet in 2000 and 26.6 billion square feet by 2040. Because of trends in major markets, as well as the assumptions about market penetration and product substitution, somewhat different trends in demand are projected for the various products. Little growth in insulating board, whose major market is residential construction, is expected. Hardwood plywood, used in manufacturing as well as construction, increases slowly through 2040, while particleboard rises until 2010, but shows little growth afterwards. Hardboard is the only nonstructural panel product to show a steady increase throughout the projection period.

Imports of hardwood plywood are the most important trade flow for the nonstructural panel products. Currently, about two-thirds of all the hardwood plywood consumed in the United States is imported, chiefly from Taiwan and Indonesia. Imports from such sources have risen rapidly over the past three decades, but are expected to stabilize in the future. Imports of the other nonstructural panel products—insulating board, hardboard, and particleboard—have also increased since the early 1980s but (with the exception of particleboard) are expected to continue at about current levels through 2040. Hardwood plywood exports, which have generally been less than 50 million square feet over the past 35 years, are expected to remain small through 2040. Insulating board exports have been relatively constant since the

Table 99.—Structural panel consumption, imports, exports, and production in the United States, specified years 1950–1986, with projections to 2040.

Year	Consumption			Imports			Exports			Production		
	Total	Softwood plywood	OSB/ waferboard	Total	Softwood plywood	OSB/ waferboard	Total	Softwood plywood	OSB/ waferboard	Total	Softwood plywood[1]	OSB/ waferboard
	Billion square feet (3/8-inch basis)											
1960	7.8	7.8	(2)	(2)	(2)	(2)	(2)	(2)	(2)	7.8	7.8	(2)
1970	14.2	14.2	(2)	(2)	(2)	(2)	0.1	0.1	(2)	14.3	14.3	(2)
1976	18.0	17.7	.2	.2	(2)	.1	.7	.7	(2)	18.5	18.4	.1
1986	25.3	20.8	4.5	.9	.1	.8	.6	.6	(2)	24.8	21.2	3.6
2000	25.4	17.1	8.3	1.3	.1	1.2	.7	.7	(2)	24.8	17.7	7.1
2010	28.6	17.9	10.7	1.4	.1	1.3	.7	.7	(2)	28.0	18.6	9.4
2020	32.7	19.7	13.0	1.1	.1	1.0	.9	.9	(2)	32.5	20.5	12.0
2030	35.3	20.9	14.4	.5	.1	.4	1.1	1.1	(2)	35.8	21.8	14.0
2040	38.8	22.8	16.0	.1	.1	(2)	1.1	1.1	(2)	39.8	23.8	16.0

[1]*Includes production from both domestic and imported species.*
[2]*Less than 50 million square feet.*
Note: Data may not add to totals because of rounding.

Table 100.—Structural panel production in the contiguous states by region, specific years 1952–1986, with projections to 2040.

Species group & region	1952	1962	1970	1976	1986	Projections 2000	2010	2020	2030	2040
	Billion square feet, 3/8-inch basis									
Softwoods										
Northeast	0	0.0	0.1	0.1	0.6	1.2	1.7	2.0	2.6	3.1
North Central[1]	0	0.0	0	0.1	1.5	2.5	3.0	3.4	3.9	4.3
Southeast	0	0.0	0.9	1.7	3.8	4.4	5.9	6.2	6.0	5.8
South Central	0	0.0	2.4	5.1	8.2	7.8	7.3	10.3	12.1	14.2
Rocky Mtn.	0	0.2	0.9	1.2	1.5	1.5	1.7	1.9	1.8	2.0
Pacific NW[2]										
Douglas-fir subregion (Western Oregon & Western Washington)	2.7	7.9	8.5	8.9	8.2	6.3	6.9	6.8	7.0	7.9
Ponderosa pine subregion (Eastern Oregon & Eastern Washington)	0	0.2	0.8	0.9	0.8	0.8	1.0	1.3	1.4	1.5
Pacific SW[3]	0.3	1.2	0.8	0.6	0.3	0.3	0.5	0.5	0.8	1.0
Total United States	3	9.5	14.4	18.6	24.9	24.8	28.0	32.6	35.6	39.8

[1]*The Great Plains are included in the North Central region.*
[2]*Excludes Alaska.*
[3]*Excludes Hawaii.*
Note: Data may not add to totals because of rounding.

Table 101.—Nonstructural panel consumption, imports, exports, and production in the United States, specified years 1960–1986, with projections to 2040.

Year	Consumption Total	Hardwood plywood	Insulating board	Hard-board	Particle-board[1]	Imports Total	Hardwood plywood	Insulating board	Hard-board	Particle-board[1]
	Billion square feet (3/8-inch basis)									
1960	6.5	1.8	3.8	.7	.5	.9	.7	.1	0.1	([2])
1970	13.2	3.8	4.3	1.6	3.5	2.3	2.0	.1	.2	([2])
1976	16.9	3.4	4.5	2.1	6.9	2.7	2.4	.1	.2	.1
1986	18.2	2.7	3.8	2.0	9.8	3.8	1.9	.5	.3	1.1
2000	23.2	3.6	4.0	3.7	11.9	2.6	1.7	.3	.3	.3
2010	24.7	4.0	4.2	4.3	12.1	2.8	1.7	.3	.4	.4
2020	25.9	4.6	4.3	5.0	12.1	2.8	1.7	.3	.4	.4
2030	25.5	4.4	4.1	5.3	11.8	2.8	1.7	.3	.4	.4
2040	26.6	4.5	4.1	5.5	12.5	2.8	1.7	.3	.4	.4
	Exports					**Production**				
1960	.1	([2])	([2])	([2])	([2])	6.1	1.1	3.8	.6	.5
1970	.2	0.1	.1	([2])	([2])	11.0	1.8	4.3	1.4	3.5
1976	.4	.1	.1	.1	.2	14.6	1.1	4.5	2.0	7.0
1986	.6	.1	.2	.1	.3	15.0	.8	3.5	1.7	9.0
2000	.4	([2])	.1	.1	.2	21.0	1.9	3.8	3.5	11.8
2010	.6	([2])	.1	.2	.3	22.5	2.3	4.0	4.1	12.0
2020	.6	([2])	.1	.2	.3	23.7	2.9	4.1	4.8	12.0
2030	.6	([2])	.1	.2	.3	23.3	2.6	3.9	5.1	11.7
2040	.6	([2])	.1	.2	.3	24.4	2.8	3.9	5.3	12.4

[1]*Includes medium density fiberboard.*
[2]*Less than 50 million square feet.*
Note: Data may not add to total because of rounding.

early 1950s and are expected to remain at about 0.1 billion square feet over the projection period. Exports of both hardboard and particleboard are expected to increase slowly in response to growth in the major offshore markets.

Paper and Board

Consumption and production of paper and board is projected to increase although not as strongly as in the past (table 102). Total consumption is projected to exceed 100 million tons in 2000. By 2040, consumption reaches 173 million tons—more than double the 1986 level. Imports exceed exports over the projection period, with production approaching 166 million tons by 2040.[27]

Per capita consumption of paper and board rose 83% between 1952 and 1986. From 1986 to 2040, per capita consumption is projected to increase by 54%. This reflects continued substitution of plastics and other materials in packaging and construction products, as well as slower growth in consumption of paper products in the communication industry, and in computer and copier applications.

Projected Fiber Consumption

By the year 2040, total fiber consumption in U.S. paper and board production is projected to increase to 162 million tons, more than double the 76 million tons consumed in 1986 (table 103). Projections show consumption of woodpulp increasing 93% from 1986 to 2040, to 116 million tons. At the same time, consumption of wastepaper is projected to triple between 1986 and 2040, to over 46 million tons. The woodpulp proportion of total fiber (79% in 1986) is projected to drop to 71% in 2040. This decline is due to technological developments that enable higher and more efficient use of recycled fiber while maintaining a high quality in the final product.

Consumption of woodpulp for nonpaper products, such as rayon, cellulose acetate, and plastics is projected to remain at its current level of about one million tons. Thus, total woodpulp consumption is projected to increase from 61 million tons in 1986 to over 116 million tons in 2040 (table 104). Imports of woodpulp are

[27]*The FPL Pulpwood Model is an economic model of the North American pulp and paper industry designed to project pulpwood consumption over the next five decades. The model is based in part on a general price-endogeneous linear programming system (PELPS) developed by Gilless and Boungiorno (1987). The FPL Pulpwood Model introduces various "processes" for manufacturing paper and board along with regional and product disaggregation found in previous applications of PELPS. The model incorporates 10 commodity groups, including 5 paper and board grades and 5 fiber input commodities. Projections are developed for paper and board consumption and price by grade and region, paper and board production by grade, process and region, and regional pulpwood consumption and price. Projections of woodpulp consumption and production, and projections for three paper and board grades not included in the FPL Pulpwood Model are developed by a spreadsheet model developed by Durbak (1988). Additional information on the FPL Pulpwood Model can be found in Ince et al. (in prep.).*

Table 102.—Paper and board consumption, exports, imports, and production in the United States, specified years 1952–1986, with projections to 2040.

Year	Consumption: Total	Consumption: Per capita	Exports	Imports	Production
	Thousand tons	*Pounds*		*Thousand tons*	
1952	29,092	369	499	5,173	24,418
1962	42,360	454	1,003	5,820	37,543
1970	58,058	567	2,698	7,239	53,516
1976	63,952	586	3,195	7,249	59,898
1986	81,720	676	4,222	11,838	74,104
2000	100,358	730	5,300	10,300	95,358
2010	121,591	826	5,500	11,200	115,891
2020	141,702	908	5,700	12,000	135,402
2030	158,258	972	5,800	12,700	151,358
2040	173,055	1038	5,900	13,000	165,955

Note: Data may not add to totals because of rounding.

Table 103.—Fiber consumption in U.S. paper and board production, specified years 1952–1986, with projections to 2040.

Year	Total fiber	Woodpulp	Wastepaper	Other
		Thousand tons		
1952	26,378	17,286	7,881	1,211
1962	38,636	28,598	9,075	963
1970	54,614	43,192	10,594	828
1976	60,156	47,541	11,874	742
1986	75,940	60,049	15,491	400
2000	95,155	74,902	20,062	191
2010	114,467	88,584	25,672	211
2020	132,440	98,847	33,361	232
2030	147,718	107,324	40,394	0
2040	162,175	115,675	46,500	0

Note: Data may not add to totals because of rounding.

Table 104.—Woodpulp consumption, exports, imports and production in the United States, specified years 1952–1986, with projections to 2040.

Year	Consumption: Total	Consumption: Per capita	Exports	Imports	Production
	Thousand tons	*Pounds*		*Thousand tons*	
1952	18,198	231	212	1,937	16,473
1962	29,511	316	1,186	2,789	27,908
1970	43,969	429	3,095	3,518	43,546
1976	48,930	449	2,518	3,727	47,721
1986	60,697	502	4,459	4,594	60,562
2000	75,595	550	4,500	4,636	75,459
2010	89,277	607	5,500	5,667	89,110
2020	99,540	638	6,000	6,182	99,358
2030	108,017	664	6,600	6,800	107,817
2040	116,368	698	7,200	7,418	116,150

Note: Data may not add to totals because of rounding.

projected to continue to exceed exports. Net trade (imports minus exports) is projected to increase from 135 thousand tons in 1986, to 218 thousand tons in the year 2040. Given the projected trends in woodpulp consumption and exports, total U.S. woodpulp production increases from 61 million tons in the year 1986 to 116 million tons in 2040.

Pulpwood

Pulpwood consumption in the United States is projected to increase at a slower rate between 1986 and 2040 than over the historical period 1952 to 1986. From 1986 to 2040, pulpwood consumption is projected to increase 72%, to 158 million cords (table 105). Exports of pulpwood are projected to exceed imports by 0.5 million cords in 2040. Thus, total demand for U.S. pulpwood (pulpwood produced for consumption in U.S. mills and for export) increases to 159 million cords by the year 2040.

A slowing in the projected growth in pulpwood consumption is due to technological developments resulting in greater use of wastepaper, higher yields from pulpwood, and lower overall fiber requirements in the U.S. pulp and paper industry.

Consumption of hardwood and softwood pulpwood in the production of woodpulp more than tripled between 1952 and 1986 (fig. 57). This follows closely the trend in woodpulp production, which also more than tripled during this time. The projections show hardwood pulpwood consumption increasing from 2.2 billion cubic feet in 1986 to 5.1 billion cubic feet by 2040—an increase of more than 130%. Softwood pulpwood consumption is projected to increase by 50% from 1986 to 2040. The higher rate of increase for hardwood pulpwood reflects a gradual shift in the industry toward use of high-yield mechanical pulps which use more hardwood and away from chemical pulps which primarily use softwoods.

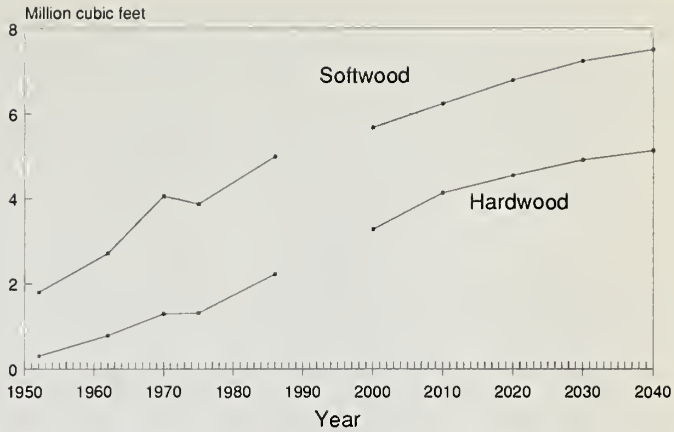


Figure 57.—Pulpwood consumption in the woodpulp industry by species group.

Pulpwood consumption is projected to more than double between 1986 and 2040 in the Northeast, North Central, and Pacific Northwest-East regions between 1986 and 2040 (table 106). Softwood pulpwood consumption increases the greatest in the Pacific Northwest-East, with the lowest rate of increase in the Pacific Northwest-West. Hardwood pulpwood consumption increases more than 140% in the Northeast, North Central, and the Southeast.

Other Industrial Timber Products

A variety of other industrial timber products; including poles, piling, posts, round mine timbers, bolts used for shingles, handles, and woodturnings, and chemical wood, is consumed in the United States. This total also includes roundwood used for oriented strand board and waferboard and particleboard not manufactured from byproducts. Total consumption of roundwood for these products amounted to an estimated 534 million cubic feet in 1986.

Table 105.—Pulpwood consumption, exports, imports, and production in the United States, specified years 1952–1986, with projections to 2040.

				Production				
Year	Consumption	Exports	Imports	Total	Roundwood	Softwood Roundwood	Hardwood Roundwood	Chips
				Thousand cords				
1952	27,155	15	2,125	25,045	23,475	20,000	3,475	1,570
1962	44,060	115	1,405	42,770	33,330	24,315	9,015	9,440
1970	69,620	1,965	1,120	70,460	50,220	36,660	13,560	20,240
1976	75,255	3,270	1,115	77,410	47,650	32,970	14,680	29,760
1986	92,060	1,945	630	93,380	57,130	35,290	21,840	36,250
2000	112,311	1,900	1,300	112,911	84,683	49,370	35,313	28,228
2010	129,992	1,700	1,200	130,492	101,784	56,388	45,396	28,708
2020	141,907	1,600	1,100	142,407	110,223	60,182	50,041	32,184
2030	152,147	1,500	1,000	152,647	118,607	63,929	54,678	34,040
2040	158,213	1,500	1,000	158,713	124,114	66,649	57,465	34,599

Note: Data may not add to totals because of rounding.

Table 106.—Pulpwood consumption by the woodpulp industry in the United States, by species group, roundwood and residue, and region, 1986, with projections to 2040.

	1986	Projections 2000	2010	2020	2030	2040
			Million cubic feet			
Northeast	672	885	1,098	1,276	1,372	1,444
Softwood	333	363	445	528	566	594
Roundwood	241	262	322	382	409	429
Residue	92	100	123	146	157	165
Hardwood	340	522	652	748	806	850
Roundwood	239	366	458	525	566	597
Residue	101	156	194	223	240	253
North Central[1]	593	852	1,062	1,224	1,319	1,390
Softwood	139	152	186	221	237	249
Roundwood	117	128	157	186	199	209
Residue	22	24	30	35	38	40
Hardwood	457	700	876	1,003	1,082	1,141
Roundwood	405	621	776	889	958	1,011
Residue	52	80	100	114	123	130
Southeast	2,143	2,722	3,080	3,324	3,663	3,791
Softwood	1,607	1,925	2,038	2,187	2,395	2,476
Roundwood	1,280	1,581	1,674	1,798	2,062	2,208
Residue	328	345	364	388	333	267
Hardwood	535	797	1,042	1,138	1,268	1,316
Roundwood	431	701	944	1,048	1,203	1,275
Residue	103	97	98	89	65	41
South Central	2,440	3,102	3,458	3,670	3,888	4,025
Softwood	1,624	1,941	2,014	2,143	2,274	2,350
Roundwood	1,154	1,526	1,747	1,735	1,690	1,655
Residue	470	415	267	408	584	695
Hardwood	816	1,161	1,445	1,526	1,614	1,675
Roundwood	683	1,033	1,329	1,409	1,500	1,558
Residue	133	129	116	118	114	116
Rocky Mountains[2]	182	171	258	279	284	310
Softwood	182	171	258	279	284	310
Roundwood	29	27	41	45	45	50
Residue	153	144	216	235	238	260
Pacific Southwest[3]	157	151	223	244	249	270
Softwood	146	139	206	227	231	251
Roundwood	15	22	100	133	157	208
Residue	131	117	107	94	74	44
Hardwood	10	12	16	17	18	19
Roundwood	([4])	([4])	([4])	([4])	([4])	([4])
Residue	10	12	15	17	18	19
Pacific Northwest-West	978	946	1,038	1,142	1,183	1,203
Softwood	907	865	932	1,028	1,061	1,076
Roundwood	297	304	372	444	460	482
Residue	610	561	559	584	601	594
Hardwood	68	81	106	114	122	127
Roundwood	53	66	91	98	106	112
Residue	15	15	15	15	16	15
Pacific Northwest-East	55	53	89	107	121	131
Softwood	55	53	89	107	121	131
Roundwood	1	1	1	1	1	1
Residue	54	52	88	106	119	130
United States	7,219	8,885	10,304	11,265	12,076	12,564
Softwood	4,994	5,609	6,168	6,720	7,167	7,437
Roundwood	3,134	3,851	4,414	4,724	5,023	5,242
Residue	1,860	1,758	1,754	1,996	2,144	2,195
Hardwood	2,225	3,276	4,136	4,545	4,909	5,127
Roundwood	1,811	2,787	3,598	3,969	4,333	4,553
Residue	414	489	538	576	576	574

[1]*Includes North Dakota, Nebraska, and Kansas.*
[2]*Excludes North Dakota, Nebraska, and Kansas.*
[3]*Excludes Hawaii.*
[4]*Less than 500 thousand cubic feet.*
Note: Data may not add to totals because of rounding.

The long downward trend in the use of miscellaneous roundwood products appears to have bottomed out in recent years. Since the mid-1970s, the amount of roundwood consumed in these products has been gradually increasing. In these projections, it has been assumed that this upward trend will continue; consumption of these products (including roundwood for oriented strand board and waferboard, and particleboard) will rise slowly to 1.4 billion cubic feet in 2040. Much of the increase is expected to come from expanding consumption of roundwood for these board products.

Imports of logs, both softwood and hardwood, are expected to be negligible. Exports of softwood logs, largely from the Pacific Northwest to Pacific Rim markets, are expected to continue. This trade flow has been the subject of controversy and restrictions in the past. Exports in 1988 amounted to about 3.7 billion board feet, an all time peak. Projections of future softwood log exports from Washington, Oregon, and California decline to roughly 2.5 billion board feet by 2000 and remain at that level through 2040. This outlook is consistent with expected decline in the future Japanese housing market being partly offset by increases in the demand for logs in South Korea, China, and Taiwan. Potential expansions of softwood supplies from Chile and New Zealand by the late 1990s and the Soviet Union after 2000 are assumed to impact fiber markets and low-grade lumber and log markets (Flora and Vlosky 1986). The ultimate impact of demand from the People's Republic of China, currently about half as large as shipments to Japan, is difficult to assess at this time. Another uncertainty is that supply constraints in the Douglas-fir region will affect both the quantity and quality of log exports. Exports of hardwood logs, about 30 million cubic feet in 1986, are projected to remain below 50 million over the projection period.

Fuelwood

Total fuelwood consumption in 1986 was an estimated 3.12 billion cubic feet. Of this total, 26% or 0.80 billion cubic feet came from growing stock volume. The remainder came from nonmerchantable portions of growing stock trees, nongrowing stock trees on timberland, and from trees on other timberland including fence rows, and urban areas. About 74% of the growing stock volume was from hardwoods.

The rapid growth of wood energy use in the 1970s and continued high levels of use are discussed in detail in Chapter 2. The marked reduction in oil prices after 1985 has, however, led to some reduction in residential fuelwood use and a slowing of the increase in industrial use.

Wood energy sources include: (1) chips, logs, and sticks from trees cut specifically for fuel; (2) chips, logs and sticks from logging residue; (3) mill residue of wood waste or bark; and (4) black pulp liquor left over from the pulping process. The models used to project wood energy demand consider all these sources because in some sectors they are partially interchangeable. The projections of wood demand for fuel given later in this section, however, include only the fuel derived from the first source above. Logging residue and pulp liquor, although derived from trees, are byproducts and the volumes harvested to produce them are included in the projections of nonfuelwood timber products given elsewhere in this chapter (High and Skog, in press).

Fuelwood Demand Projections

Both the residential[28] and industrial/commercial[29] models project fuelwood use for five regions (table 107). Each region is considered to have separate fuelwood supply and demand. This assumption is generally valid because the relatively low value of fuelwood makes it uneconomic to transport it out of a region.

As a result of a projected cost advantage of fuelwood over nonwood fuels in all regions, industrial/commercial and residential fuelwood use from all sources (both growing stock and nongrowing stock) is projected to increase from 3.1 billion cubic feet in 1986 to 5.1 billion cubic feet in 2040 with most of the increase occurring before 2010. Total fuelwood use declines after 2020 due to declines in residential use.

The amount of fuelwood from growing stock volume is projected to increase from 0.8 billion cubic feet in 1986 to 1.2 billion cubic feet by 2020, then decline to 1.0 billion cubic feet by 2040. This smaller increase (compared to total fuelwood use) and eventual decline is due to the

[28]*The residential wood energy forecasting model (WOODSTOV-III) is a regionally desegregated model that represents the behavior of households. Its structure is discussed in papers by Marshall (1981, 1982) and Marshall et al. (1983). Demand for fuelwood depends on total energy needed for heating various types of residential buildings, the prices for competing residential fuels, and the price for residential fuelwood. The model calculates wood use separately for heating and esthetic fireplace use. The amount of wood used for heating is the product of the fuelwood use capacity installed and the proprotion used. Capacity is modified each successive period as a function of fuel cost savings, pay back period and retirement. Capacity utilization is a function of fuelwood cost savings relative to fossil fuel cost. Fireplace use is determined as a function of wood fuel cost savings. The proportion of hardwood used for fuelwood in each region in 1986 is from Waddell et al. 1989, table 30. The proportion changes with the relative cost of hardwood and softwood fuelwood chips as estimated by the industrial/commercial wood energy model (CHIPS).*

[29]*The industrial/commercial wood energy forecasting model (CHIPS) is a set of five independent regional models that represents the behavior of numerous energy using companies and fuelwood suppliers. Demand for fuelwood and mill residue depends on total energy demanded in various industrial/commercial sectors, the demand for nonfuel timber products, and the prices of competing fuels in the industrial/commercial sector. The price of fuelwood is determined within the model by the interaction of the fuelwood supply submodel with energy demand. The model has been calibrated for the period 1975 to 1985 primarily against fuelwood/mill residue consumption in the pulp and paper industry (the only sector for which consistent data on fuelwood/mill residue consumption is available). Fuelwood and mill residue demand is tracked separately for four sectors; pulp and paper companies, other forest products companies, large nonforest product industries, and small nonforest product industries together with commercial and institutional users. The fuelwood/mill residue supply submodel tracks inventories and consumption of (1) timber by hardwoods and softwoods, growing stock volume and nongrowing stock by timber size class; (2) mill residues; and (3) logging residues. Demand for nonfuel timber products is exogenous but is not included in the inventory accounting and price structure in the CHIPS model.*

Table 107.—Fuelwood consumed from timberland in the United States by species group, growing stock/nongrowing stock source, and end use, 1986, with projections to 2040.[1]

Year	All roundwood			Growing stock			Industrial and commercial fuelwood use	Residential fuelwood use
	Total	Hard-woods	Soft-woods	Total	Hard-woods	Soft-woods		
				Billion cubic feet				
				Northeast				
1986	0.98	0.89	0.09	0.13	0.12	0.01	0.02	0.96
2000	1.04	0.88	0.16	0.10	0.09	0.01	0.09	0.94
2010	1.33	1.13	0.20	0.09	0.10	0.01	0.09	1.24
2020	1.37	1.15	0.22	0.09	0.08	0.01	0.09	1.28
2030	1.28	1.07	0.21	0.09	0.08	0.01	0.09	1.19
2040	1.20	0.99	0.21	0.08	0.07	0.01	0.09	1.11
				North Central[2]				
1986	0.85	0.81	0.04	0.11	0.10	0.01	0.06	0.79
2000	1.05	0.93	0.12	0.12	0.10	0.02	0.12	0.94
2010	1.41	1.24	0.17	0.13	0.11	0.02	0.15	1.26
2020	1.33	1.15	0.18	0.11	0.08	0.02	0.15	1.18
2030	1.15	0.98	0.17	0.09	0.07	0.02	0.15	1.00
2040	1.02	0.85	0.17	0.08	0.06	0.02	0.15	0.87
				South				
1986	0.75	0.69	0.05	0.32	0.29	0.03	0.06	0.69
2000	1.41	1.31	0.09	0.58	0.53	0.05	0.26	1.14
2010	1.81	1.69	0.12	0.72	0.66	0.06	0.31	1.50
2020	1.90	1.78	0.12	0.73	0.67	0.06	0.32	1.57
2030	1.88	1.77	0.12	0.70	0.64	0.06	0.31	1.57
2040	1.88	1.76	0.12	0.68	0.61	0.06	0.29	1.59
				Rocky Mountains[3]				
1986	0.11	0.02	0.08	0.01	0.00	0.01	0.00	0.11
2000	0.22	0.05	0.17	0.01	0.00	0.01	0.01	0.21
2010	0.31	0.06	0.25	0.02	0.00	0.01	0.01	0.30
2020	0.34	0.06	0.28	0.02	0.00	0.02	0.01	0.33
2030	0.33	0.06	0.28	0.02	0.00	0.02	0.01	0.33
2040	0.33	0.05	0.28	0.02	0.00	0.02	0.01	0.32
				Pacific Coast[4]				
1986	0.44	0.16	0.28	0.22	0.08	0.15	0.03	0.41
2000	0.55	0.21	0.34	0.28	0.14	0.05	0.04	0.51
2010	0.74	0.27	0.47	0.24	0.18	0.07	0.04	0.70
2020	0.79	0.27	0.52	0.25	0.18	0.08	0.04	0.76
2030	0.74	0.25	0.49	0.22	0.16	0.07	0.03	0.71
2040	0.67	0.22	0.45	0.19	0.14	0.06	0.02	0.65
				United States[4]				
1986	3.12	2.57	0.55	0.80	0.59	0.21	0.16	2.96
2000	4.26	3.38	0.88	0.99	0.86	0.14	0.52	3.74
2010	5.60	4.39	1.21	1.20	1.05	0.18	0.60	5.00
2020	5.73	4.42	1.31	1.19	1.01	0.19	0.61	5.12
2030	5.38	4.11	1.27	1.12	0.95	0.18	0.59	4.80
2040	5.09	3.88	1.22	1.04	0.89	0.16	0.56	4.54

[1]*Excludes logging residue used for fuel.*
[2]*Includes North Dakota, Nebraska, and Kansas.*
[3]*Excludes North Dakota, Nebraska, and Kansas.*
[4]*Excludes Alaska and Hawaii.*
Note: Data may not add to totals because of rounding.

projected decline in proportion of fuelwood from growing stock volume. The proportion from growing stock is projected to decline from 26% in 1986 to 20% in 2040.

For residential fuelwood, growing stock makes up 20–25% of the total and is expected to remain low over the projection period. For industrial and commercial use, fuelwood from sources other than logging residues will be in the form of whole-tree chips. Chipping operations will take wood for both fuel and pulp from stands with below average growing stock. Thus, fuelwood chips for industrial/commercial uses will have a low growing stock content. As industrial and commercial use increases relative to residential use, the overall proportion of growing stock used is projected to decline.

Residential fuelwood use is currently much larger than industrial/commercial fuelwood use because most industrial/commercial wood boilers use mill waste or spent pulp liquor. Industrial/commercial fuelwood is expected to grow much more rapidly in the future than residential use (281% versus 73% between 1986 and 2020) as more nonforest products firms burn fuel from roundwood rather than mill waste. After 2020 residential fuelwood use is projected to decline as residential fossil fuel prices remain constant and residential fuelwood prices continue to increase.

Softwoods are projected to increase from 18% of all fuelwood in 1986 to 24% in 2040 as industrial/commercial use increases. Industrial/commercial users have less of a bias toward use of hardwood than residential users. The proportion of softwood roundwood use in 1986 varies from 73% and 64% for the Rocky Mountains and Pacific Coast regions to less than 10% in other regions.

The Northeast, North Central, and the South have the largest total fuelwood demand both currently and in 2040. The higher use in the Northeast and North Central results from the widespread availability of low-grade (inexpensive) wood and relative competitiveness of fuelwood due to higher than average fossil fuel prices in those regions. Demand in the South is expected to grow much more rapidly, and increase 150% between 1896 and 2040. Fuelwood use in the two western regions is lower than in the eastern regions. In both the Rocky Mountains and the Pacific Coast regions residential use dominates fuelwood use. This is expected to continue through 2040 by which time total consumption is expected to nearly double to 1.0 billion cubic feet.

Product Price Projections

The general increases in product prices shown in table 108 are largely due to increases in stumpage prices. Higher raw material costs raise production costs and affect timber product (lumber, plywood, paper and board) prices, demand, trade, and domestic production (demand on domestic forests). They are also the driving force behind interregional shifts in mill capacity since they are the only components of costs whose relative levels among regions change significantly over time. Other production costs such as labor, materials, and capital change, but the relationships among regions and products remain much the same.

Softwood lumber prices are relatively flat after 2010 (table 108). The rate of increase is most rapid in the 1986–2010 period, averaging about 1.2% per year. This reflects upward pressure on stumpage prices resulting from diminishing softwood sawtimber inventories on private timberlands in the West and South.

The projected rate of increase in equilibrium real softwood lumber prices is consistent with the long historical trend in lumber prices. Since 1900, the price of lumber measured in constant dollars has been rising at

Table 108.—Price[1] indexes for selected timber products in the United States, by softwoods and hardwoods, specified years 1952–1986, with projections to 2040.

Product, unit & species group	1952	1962	1970	1976	1986	Projections 2000	2010	2020	2030	2040
	Index of price per unit - 1982 = 100									
Lumber (1,000 board feet)										
Softwoods	99.8	88.3	95.3	126.0	114.3	132.1	151.2	159.8	164.6	160.7
Hardwoods	104.7	103.7	118.6	109.9	126.2	133.6	147.0	163.8	182.6	201.1
Structural panels (1,000 square feet, 3/8-inch basis)										
Plywood	172.0	119.0	109.2	143.6	121.1	112.8	133.1	146.4	154.1	140.5
OSB-waferboard				163.0	92.7	77.6	82.6	100.5	85.1	88.7
Nonstructural panels (1,000 square feet, 3/8-inch basis)										
Plywood	184.5	174.5	153.4	110.6	90.7	88.4	86.7	85.0	83.3	81.6
Other panels[2]		151.4	115.0	92.1	107.1	107.1	107.1	107.1	107.1	107.1
Paper & board (tons)	100.2	105.3	101.5	101.5	115.8	107.6	105.7	102.9	100.3	98.9

[1]*Prices are measured in constant (1982) dollars and are net inflation or deflation. They measure price changes relative to the general price level and most competing materials.*
[2]*Hardboard, particleboard, and fiberboard products.*

an average rate of 1.4% per year. In addition, the historical increases have not been evenly spread. Typically, there have been periods of a decade or two when prices showed little change (the 1950s). This has been followed by periods such as the 1940s and 1970s when prices rose rapidly. Similar price movements are expected over the projection period, with rapid increases from 1990 to 2010 and then near stability through 2040.

Equilibrium hardwood lumber prices rise at an average annual rate of about .9% per year. This reflects continuous growth in major shipping uses and a steady decline in the availability of larger timber for higher quality lumber grades. The increases in hardwood lumber prices are more evenly spread over the projection period than are the increases in softwood lumber prices.

The equilibrium projections for structural panel prices (table 108) also show rising real prices for plywood but roughly constant prices for oriented strand board and waferboard. Like softwood lumber, softwood plywood prices are relatively stable in the last three decades of the projection. For the entire projection period, softwood plywood prices increase at about .3% per year. The price projections for the other structural panel products (oriented strand board and waferboard) show little growth. This is the consequence of the greater dependence of these products on residential construction markets and slower growth in wood costs due to lower quality requirements.

As with lumber, the projected changes in softwood plywood prices largely reflect changes in stumpage costs: stumpage costs rise nearly four times faster than processing costs in the Douglas-fir subregion and nearly five times faster in the South Central region.

In contrast to structural panels, there is little change in the projected prices for nonstructural panels. Prices for hardwood plywood are expected to continue to decline in real terms throughout the projection period. Prices for the other board products are expected to remain constant in real terms for the next several decades.

The projected decreases in paper and board prices, shown in table 108, largely reflect efficiency improvements in the manufacture of paper and board. The expectation is that future price decreases will mirror the experience of the period 1962 to 1976. Prices for other timber products such as posts, poles, piling, mine timbers, and cooperage logs are expected to be similar to the price increases for lumber shown in table 108. As for lumber, panels, and paper and board, the projections will depend on the demand levels for the various products and the importance of stumpage costs relative to product selling prices.

Projected Demands for Timber

The projections of demand for timber products discussed in preceding sections have been presented, for the most part, in standard units of measure such as board feet of lumber, square feet of panel products, cords of pulpwood and fuelwood, and cubic feet of miscellaneous industrial roundwood products. In order to compare demand for these products with projections of timber supplies, these projections are converted to a common unit of measure—cubic feet of roundwood.

Demands for Roundwood

In 1986, total U.S. consumption of timber products in terms of roundwood volume was 20.5 billion cubic feet, including fuelwood obtained from nongrowing stock sources (table 109).[30] Total consumption will continue to grow throughout the next five decades at .6% per year. Growth in hardwood consumption is expected to be nearly three times as fast as growth in softwood consumption. Total consumption of timber products increases to 22.9 billion cubic feet in 2000 and 28.6 billion cubic feet in 2040. Although demand for each of the products (except veneer) is higher in 2040 than in 1986, fuelwood and pulpwood show the largest increases in volume. By 2040, these two products account for 56% of the timber consumed in the United States. In terms of percentages, miscellaneous products exhibits the largest increase because of the increase in roundwood used for oriented strand board and waferboard.

Part of this total consumption is met by trade with other producing countries. The scale of this trade can be illustrated when the various product trade projections are converted to roundwood equivalent. In 1986, nearly 25% of total demand was filled by imports (table 110). Total imports in 1986 amounted to 4.4 billion cubic feet, triple the volume imported in 1952. Over the same period, exports rose more than 9 times, to 1.9 billion cubic feet.

Projected levels of total imports, currently at about 4.4 billion cubic feet, roundwood equivalent, are expected to fall in the next two decades but rise again around 2020 (table 110). This trend is the result of increasing softwood product imports around 2020. Total hardwood imports are projected to increase slowly throughout the next five decades to the equivalent of 0.5 billion cubic feet by 2040. Projected total exports increase about 32% to 2.5 billion cubic feet in 2040 as a result of general increases in exports of all products. Exports of hardwood products are projected to rise 75%, to about 0.7 billion cubic feet over the projection period.

The trade situation differs between the hardwood and softwood sectors. The softwood sector is expected to remain a net importer of timber products. The primary imports are expected to remain softwood lumber and newsprint, both from Canada. The hardwood sector, on the other hand, is a net exporter of timber products. These projections of timber products imports and exports show only a modest overall decline in net imports into the United States, from 2.5 billion cubic feet in 1986 to 1.5 billion cubic feet in 2040.

[30] *This assumption is consistent with past Assessments but differs from the assumptions in the 1983 Assessment Supplement (Haynes and Adams 1985) and the South's Fourth Forest Study (USDA FS 1988) that did not include fuelwood obtained from nongrowing stock sourcs in the estimates of total consumption.*

Table 109.—Roundwood consumption in the United States, by species group and product, specified years 1952–1986, with projections of demand to 2040.

Species group and product	Historical					Projections					
	1952	1962	1970	1976	1986	1990	2000	2010	2020	2030	2040
	Billion cubic feet, roundwood equivalent										
Softwoods											
Sawlogs	5.0	4.8	4.9	5.5	7.6	7.0	6.4	6.9	7.4	7.4	7.4
Veneer logs	0.2	0.7	0.9	1.2	1.6	1.3	1.1	1.1	1.2	1.3	1.4
Pulpwood[1]	2.4	2.6	3.4	3.3	4.2	4.0	4.8	5.5	5.9	6.3	6.6
Miscellaneous products[2]	0.3	0.2	0.2	0.2	0.3	0.3	0.5	0.6	0.7	0.8	0.9
Fuelwood	0.2	0.1	0.1	0.1	0.6	0.7	0.9	1.2	1.3	1.3	1.2
Total[3]	8.1	8.4	9.5	10.5	14.3	13.4	13.7	15.3	16.6	17.1	17.5
Hardwoods											
Sawlogs	1.1	1.1	1.1	1.3	1.5	1.5	1.8	2.0	2.1	2.2	2.2
Veneer logs	0.2	0.2	0.3	0.3	0.2	0.2	0.3	0.3	0.3	0.3	0.3
Pulpwood[1]	0.3	0.7	1.0	1.1	1.7	1.9	2.6	3.3	3.7	4.0	4.2
Miscellaneous products[2]	0.4	0.2	0.2	0.1	0.2	0.3	0.4	0.4	0.5	0.5	0.5
Fuelwood	0.7	0.4	0.3	0.3	2.7	2.9	3.4	4.4	4.4	4.1	3.9
Total[3]	2.7	2.6	2.9	3.1	6.2	6.9	8.3	10.4	11.0	11.1	11.1
All species											
Sawlogs	6.1	5.9	6.0	6.8	9.0	8.6	8.2	8.9	9.5	9.6	9.6
Veneer logs	0.4	0.9	1.2	1.5	1.8	1.6	1.3	1.4	1.5	1.6	1.7
Pulpwood[1]	2.7	3.3	4.4	4.4	5.8	5.9	7.4	8.8	9.6	10.3	10.8
Miscellaneous products[2]	0.7	0.5	0.4	0.4	0.5	0.7	0.8	1.0	1.2	1.3	1.4
Fuelwood	1.0	0.5	0.3	0.3	3.3	3.6	4.3	5.6	5.7	5.4	5.1
Total[3]	10.9	11.1	12.3	13.5	20.5	20.3	22.9	25.7	27.6	28.2	28.6

[1]*Includes both pulpwood and the pulpwood equivalent of the net imports of pulp, paper, and board.*
[2]*Includes cooperage logs, poles, piling, fence posts, round mine timbers, box bolts, shingle bolts, roundwood used in waferboard, oriented strand board, and particleboard manufacture, and other miscellaneous items.*
[3]*Includes imported logs not shown by product use.*

Table 110.—Timber demand, exports, imports, and demand on timberland in the United States, by species group, specified years 1952–1986, with projections to 2040.

Species group and product	Historical[1]					Projections					
	1952	1962	1970	1976	1986	1990	2000	2010	2020	2030	2040
	Billion cubic feet										
Softwoods											
Total demand[2]	8.1	8.4	9.5	10.5	14.3	13.4	13.7	15.3	16.6	17.1	17.5
Exports	0.1	0.4	1.3	1.6	1.6	1.7	1.7	1.7	1.8	1.8	1.8
Imports	1.3	1.7	2.1	2.5	4.1	3.8	3.2	3.7	3.9	3.6	3.5
Demand on U.S. forest land	6.9	7.1	8.7	9.5	11.7	11.3	12.1	13.4	14.5	15.3	15.8
Hardwoods											
Total demand[2]	2.7	2.6	2.9	3.1	6.2	6.9	8.3	10.5	11.0	11.1	11.1
Exports	([3])	0.1	0.2	0.2	0.3	0.4	0.5	0.6	0.6	0.7	0.7
Imports	0.1	0.2	0.3	0.3	0.3	0.3	0.4	0.5	0.5	0.5	0.5
Demand on U.S. forest land	2.6	2.5	2.8	3.0	6.3	7.0	8.4	10.5	11.1	11.3	11.3
All species											
Total demand[2]	10.9	11.1	12.3	13.5	20.5	20.3	22.0	25.7	27.6	28.7	28.6
Exports	0.2	0.5	1.5	1.9	1.9	2.1	2.2	2.3	2.4	2.5	2.5
Imports	1.4	1.9	2.4	2.8	4.4	4.2	3.7	4.1	4.4	4.1	4.0
Demand on U.S. forest land	9.7	9.7	11.4	12.6	18.0	18.2	20.5	23.9	25.6	26.5	27.1

[1]*Data are estimates of actual consumption and harvests.*
[2]*Total demand for products converted to a roundwood equivalent basis.*
[3]*Less than 50 million cubic feet.*

Demands on U.S. Timberland

Given the projections of total demands and net trade (shown in tables 96, 99, and 101), demands on U.S. timberland increase sharply over the next five decades, rising about 50%, from 18.0 billion cubic feet in 1986 to 27.1 billion in 2040 (table 110). Demands for both softwoods and hardwoods increase; in line with projected trends discussed above, however, hardwood demand rises somewhat more rapidly. Between 1986 and 2040, demand on U.S. timberland for hardwoods is projected to increase about 79%, to 11.3 billion cubic feet. Demands on U.S. timberland for softwoods during the same period is expected to grow about 35%, to 15.8 billion cubic feet.

In summary, demands on U. S. timberland will grow fairly rapidly over the next five decades. These demands increase about 50%, to 27.1 billion cubic feet, roundwood equivalent, in 2040. At the same time, prospective imports are projected to be only slightly smaller than current levels. Consequently, in the future the United States will look to its domestic timber resources to meet a larger proportionate share of its demands for timber products.

THE STUMPAGE MARKET

The preceding section of this chapter has been largely concerned with assessing the situation in the product market and with the development of the demand for timber from domestic forests. This section focuses on the supply of timber needed to meet that demand, the associated stumpage prices, and the levels of timber inventories.

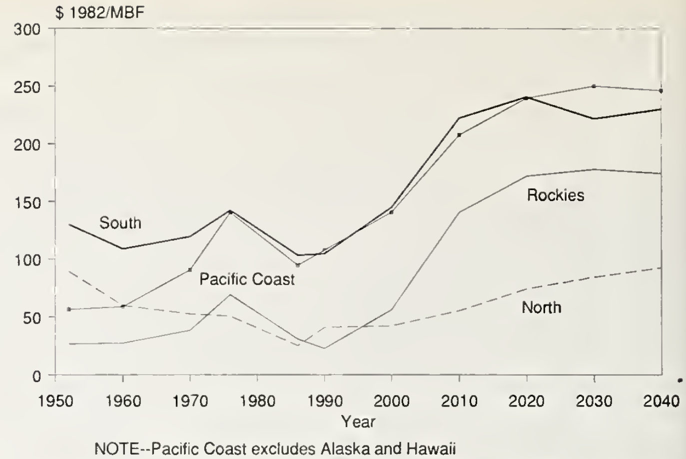


Figure 58.—Softwood stumpage prices, 1952–1986, with projections 1990–2040.

Projections of the regional sawtimber[31] softwood stumpage prices[32] are summarized in table 111 and shown for selected regions in figure 58. These projections show softwood sawtimber stumpage prices rising substantially in all regions. There are, however, marked differences among the various regions. Stumpage prices in the South rise at an annual rate of about 1.5% between 1986 and 2040. Stumpage prices in the North rise at about 2.5% per year. The Rocky Mountain Region is expected to experience the most rapid increase in stumpage prices averaging 3.2% per year between 1986 and

[31] *That part of harvest being used in the manufacture of lumber, plywood, and miscellaneous products and as log exports.*

[32] *All stumpage prices are measured in 1982 dollars. This excludes the effect of general price inflation or deflation. The increases shown, therefore, measure change relative to the general prices of most competing materials.*

Table 111.—Softwood sawtimber stumpage prices[1] in the contiguous states, by region, specified years 1952–1986, with projections to 2040.

Region	1952	1962	1970	1976	1986	Projections 2000	2010	2020	2030	2040
	Price per thousand board feet, Scribner log rule									
North	90	60	54	51	25	42	55	74	85	93
South	129	108	120	141	103	145	222	242	222	231
Rocky Mountain	27	27	39	69	31	56	141	172	178	175
Pacific Northwest[2]										
Douglas-fir subregion (Western Washington & Western Oregon)	54	63	105	156	99	147	215	249	251	244
Ponderosa Pine subregion (Eastern Washington & Eastern Oregon)	66	39	60	105	93	127	204	216	257	267
Pacific Southwest[3]	54	39	66	114	82	134	187	236	241	234

[1] *Prices are measured in constant (1982) dollars and are net of inflation or deflation. They measure price changes relative to the general price level and most competing materials.*

[2] *Excludes Alaska.*

[3] *Excludes Hawaii.*

Sources: Data for 1952, 1962, 1970, 1976, and 1986 based on information published by the U.S. Department of Agriculture and summarized by Adams et al. 1988.

Cost competition will force the use of appropriate technologies including horse logging, here being used in a thinning operation.

2040. The Pacific Coast Region (composed of the Douglas-fir, Ponderosa Pine, and Pacific Southwest subregions) is expected to experience rates of increase of roughly 1.7–2.0% per year.

Rates of stumpage price increase also vary greatly over time. During the next two decades, rapid price escalation is expected in the Rocky Mountain Region and in the Douglas-fir subregion. In the Douglas-fir subregion, this is the consequence of fairly rapid declines in sawtimber harvest. In the Rocky Mountains, price growth accompanies a major expansion in regional lumber processing capacity to absorb increases in national forest harvest.

These different rates of price growth do not materially change the relationships in stumpage prices among regions over the projection period. The regional variations in the rates of increase are caused by a number of complex forces. In general, however, they reflect the degree of competition for available timber, differences in stumpage quality characteristics, and variations in regional logging, manufacturing, and transportation costs.

These computed rates of price growth depend heavily on the choice of the initial time point (1986) used for comparison. This is particularly the case for the two northern subregions (the Northeast and the North Central subregions) and for the Rocky Mountain Region where low prices in 1986 sharply raise rates of increase expressed in percentage terms.

Hardwood sawtimber prices are expected to increase at about 1.4% per year as illustrated in the following tabulation:

Price index (1982 = 100) per thousand board feet

1986	123
2000	135
2010	163
2020	194
2030	229
2040	263

Hardwood stumpage prices are expected to grow relatively slowly over the next 15 years as hardwood inventories continue to expand. After 2000, the growth rate for hardwood stumpage prices increases because of slowing growth in hardwood inventories and increased demand, especially for pulpwood.

Price projections for sawtimber harvested by Forest Service region are shown in table 112. These price projections, except for Alaska (Region 10), were developed from those in table 111. Price projections for Alaska were developed from those for the Region 6-Westside and assume declining private (Native corporation) harvest and roughly stable national forest harvests (Haynes and Brooks, in press).

Projected regional national forest harvest generally follows the projections of allowable sale quantity shown in tables 77 and 78 except for the four Rocky Mountain regions where the softwood sold volumes average 150–180 million cubic feet less than the offered volumes throughout the projection period. The majority of this unsold volume is in Region 1.

Table 112.—Price projections for sawtimber harvested in each Forest Service region.

Region	1986	2000	2010	2020	2030	2040
			1982 dollars per MBF			
1	69	68	171	210	217	213
2	24	23	59	72	74	73
3	85	84	210	258	267	261
4	32	32	79	97	100	98
5	85	134	187	235	241	234
6–Westside	123	146	215	249	251	243
6–Eastside	101	127	204	216	256	267
8–Hardwoods	69	81	106	134	166	197
8–Softwoods	129	145	223	241	217	230
9–Hardwoods	97	107	129	154	182	209
9–Softwood	35	42	55	66	85	93
10[1]	34	34	56	66	67	65

[1]*Price projections for Region 10 (Alaska) are for timber sold rather than timber harvested.*

Delivered prices (stumpage price plus logging costs and transportation cost to the mill) are projected to increase for sawtimber, pulpwood and fuelwood (table 113). The most rapid increase in delivered prices is for softwood sawtimber, which increase over the period 1986 to 2040 at 1.2% a year in the South, 1.6% per year in the Rocky Mountains, and 1.4% a year in the Pacific Coast. Delivered prices for hardwood pulpwood increase at 0.9% a year in the North and 1.1% a year in the South, or about twice as fast as softwood pulpwood delivered prices in the South. Hardwood fuelwood prices in the North increase at 0.8% a year. Both fuelwood and pulpwood remain far below the delivered prices for softwood sawtimber (fig. 59).

There are significant changes in the demands and supplies of timber associated with the projected increases in softwood and hardwood stumpage prices (table 114). In terms of total (both softwood and hardwood) harvest, there are also some changes in regional shares of total supply as shown in figure 60. The projections shown in tables 111 and 114 indicate impending limitations on softwood timber harvest in the 1990–2000 decade in the Douglas-fir subregion and between 2000 and 2010 in the South. Harvest in the Douglas-fir subregion falls by 2000 driving up stumpage prices and leading to retrenchments in the forest products industry. In the South, after increasing at roughly 0.8% per year until 2000, timber harvests grow at only 0.1–0.2% per year during the next decade. Stumpage prices rise and growth in regional solid-wood product output stalls as a result. After 2010, softwood harvest grows more rapidly, reflecting both the maturing of large areas of young growth in both the South and the Douglas-fir subregion and the investments in forest management during the 1980s and 1990s. This increase in harvest slows the rates of stumpage price increases in both the South and in the Douglas-fir subregion.

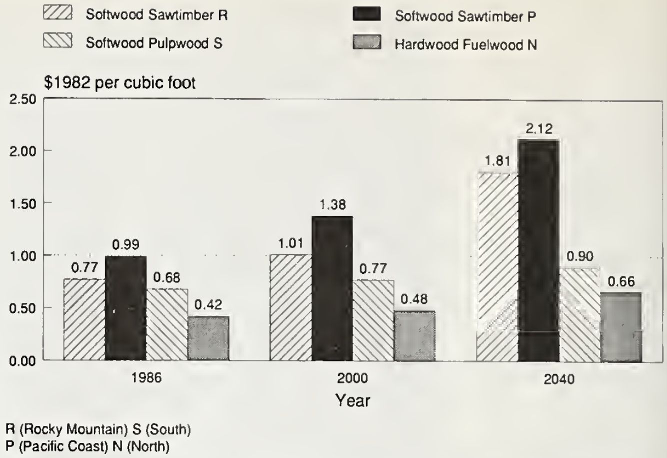


Figure 59.—Delivered prices for timber by product and region.

Only modest softwood harvest shifts are expected in the relative importance of the various regions. The Southern and the Pacific Coast regions will continue to dominate. Specific regional shares do change during the projection period. For example, the shares of the total softwood roundwood supplies originating in the eastern regions, Rocky Mountain Region, and the Ponderosa Pine subregion increase over the projection period. The share originating in the Douglas-fir subregion, on the other hand, drops from 27% of the total in 1986 to 19% by 2040. There is also a small decline in the share coming from the Pacific Southwest.

Hardwood harvest is expected to increase in all regions although not uniformly. The largest increases are in the South where both growth in fuelwood and

Table 113.—Delivered prices for sawtimber, pulpwood, and fuelwood, by section and region, and species group, 1986, with projections to 2040.

Section and region	1986	Projections 2000	2010	2020	2030	2040
		1982 dollars per cubic foot, log scale				
Softwood sawtimber						
South	0.79	1.01	1.40	1.52	1.46	1.55
Rocky Mountain[1]	0.77	1.01	1.48	1.69	1.73	1.81
Pacific Coast[2]	0.99	1.38	1.76	1.98	2.04	2.12
Softwood pulpwood						
South	0.68	0.77	0.82	0.82	0.88	0.90
Hardwood pulpwood						
North[3]	0.45	0.56	0.71	0.71	0.73	0.75
South	0.49	0.71	0.83	0.81	0.86	0.90
Hardwood fuelwood						
North[3]	0.42	0.48	0.56	0.61	0.65	0.66
South	0.38	0.39	0.39	0.42	0.42	0.39

[1]*Excludes North Dakota, Nebraska, and Kansas.*
[2]*Excludes Alaska and Hawaii.*
[3]*Includes North Dakota, Nebraska, and Kansas.*

Table 114.—Timber harvests (roundwood supplies) from forest land in the contigous states, by region, specified years 1952–1986, with projections through 2040.

Item	1952[1]	1962[1]	1970[1]	1976[1]	1986[1]	Projections 2000	2010	2020	2030	2040
					Billion cubic feet					
Softwoods										
Northeast	0.48	0.37	0.38	0.43	0.60	0.74	0.91	1.05	1.10	1.13
North Central[2]	.17	.20	.17	.21	.24	.38	.50	.59	.64	.66
Southeast	1.65	1.40	1.63	1.72	2.33	2.81	3.06	3.27	3.42	3.48
South Central	1.21	1.16	1.96	2.28	2.80	3.18	3.27	3.70	4.12	4.49
Rocky Mountain	.47	.61	.79	.85	1.01	1.18	1.35	1.40	1.40	1.41
Pacific Northwest[3]										
Douglas-fir subregion (Western Washington and Western Oregon)	1.85	2.01	2.44	2.69	3.14	2.56	2.77	2.88	2.97	3.00
Ponderosa pine subregion (Eastern Washington and Eastern Oregon)	.38	.50	.48	.54	.60	.59	.69	.73	.75	.76
Pacific Southwest[4]	.68	.86	.85	.78	.78	.75	.84	.85	.85	.85
Softwoods total harvests	6.89	7.11	8.70	9.50	11.50	12.19	13.39	14.47	15.25	15.78
Hardwoods										
Northeast	.55	.55	.54	.52	1.52	1.79	2.25	2.44	2.48	2.49
North Central	.98	.80	.75	.81	1.93	2.25	2.81	2.91	2.86	2.82
Southeast	.77	.62	.63	.64	1.35	1.83	2.31	2.47	2.58	2.60
South Central	1.27	.96	.89	.84	1.58	2.10	2.60	2.74	2.83	2.91
West	.03	.07	.09	.09	.29	.38	.48	.49	.46	.43
Hardwoods total harvests	3.60	3.00	2.90	2.90	6.67	8.35	10.45	11.05	11.21	11.25

[1]*Data are estimates of actual consumption or harvests and differ somewhat from the "trend" estimates shown in the preceding section on timber supplies.*
[2]*Includes the Great Plains States—Kansas, Nebraska, North Dakota, and eastern South Dakota.*
[3]*Excludes Alaska.*
[4]*Excludes Hawaii.*
Note: Data may not add to totals because of rounding.
Sources: The historial data is published in Adams et al. 1988.

pulpwood demands push up harvest. The lowest rate of growth in the east is in the Northcentral subregion.

Associated with these changes in harvest are changes in the size of harvested trees. The average diameters of timber harvested on private timberlands in the various Assessment regions are shown in table 115. The largest changes are expected for softwoods on the Pacific Coast where the average diameter of harvested trees is expected to drop 20%. Decreasing sizes of future harvests are expected in most regions and for both hardwoods and softwoods.

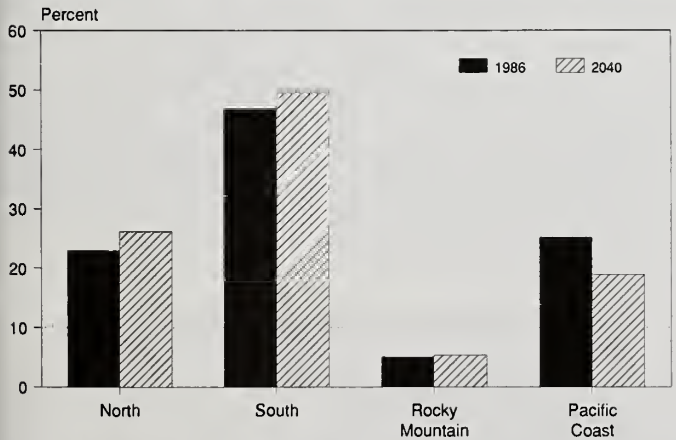


Figure 60.—Regional percentage of total roundwood supply, 1986 and 2040.

EFFECTS OF EQUILIBRIUM LEVELS OF TIMBER HARVESTS ON INVENTORIES

The higher timber harvests expected in the future accelerate various trends in net annual growth and inventories. These projections for private timberlands are shown in tables 116–119. Similar figures for the public timberlands as shown in tables 77–80. This data is summarized for all owners and all regions in tables 120 and 121 and figure 61. Essentially, changes in inventories are the result of harvest levels and assumptions regarding forest management and investment. As a result of declining growth, increasing harvests, and conversion of forest land to other uses, total softwood inventories remain constant through 2000 (table 120). However, by 2040, softwood inventories are projected to expand to roughly the same level as they were in the mid-1970s. Net growth falls by 2000 but increases rapidly afterwards as older, slow growing stands are replaced by younger stands. The trend in softwood inventory for the entire United States (roughly flat over the period 1970 to 2040)

Table 115.—Average diameter[1] of timber harvested on private timberlands in the Assessment regions.

	Pacific Coast		Rockies		North		South	
	Hardwood	Softwood	Hardwood	Softwood	Hardwood	Softwood	Hardwood	Softwood
	inches							
1986	16.6	18.7	18.9	9.6	14.2	12.0	12.4	9.9
2000	17.2	16.0	14.1	9.3	13.4	11.9	11.4	9.0
2040	16.5	15.2	12.7	9.3	13.1	12.3	10.8	8.8

[1]*Diameter measured at breast height.*

masks changes in regional softwood timber stocks. This, and the fact that the projected inventory in 2040 is composed of a larger number of younger trees, contributes to the relatively rapid increase in softwood stumpage prices shown in table 111.

The trends in inventory differ between ownerships and are compounded by land area changes (particularly on the farmer and other private ownership). Softwood inventories for both the national forest and forest industry ownerships decline by 2000 while, over the same period, inventories for the other two ownerships are projected to increase. Some of the decline of national forest inventories is due to changes in definitions regarding forest lands that are considered as suitable for timber production. Inventories on forest industry timberlands increase after 2000 and by 2010, are projected to exceed current levels.

Trends in hardwood inventories present a very different picture. Hardwood inventories are expected to increase in the North and the Pacific Coast (table 120). Until 2000, decreases in the South are more than offset by increases in hardwood inventories in the North; after 2010 declines in Southern inventories accelerate.

Net annual growth for hardwoods, after stabilizing between 1976–86, starts to drop early in the projection period because of increasing stand age and the shift from hardwood types to softwood types in the South. This trend is most prominent for the forest industry ownership (see table 117).

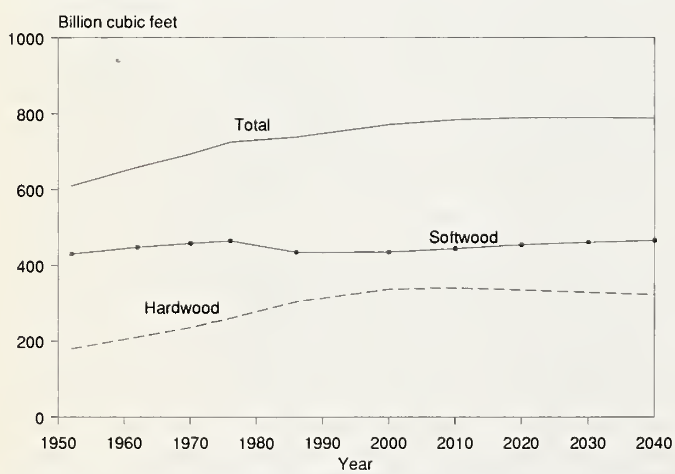


Figure 61.—Growing stock inventories on timberland, 1952–1986, with projections to 2040.

Regional shares for total softwood and hardwood harvest, derived from tables 120 and 121, are shown in the following tabulation:

	1986	2000	2040
		Percent	
North	23.0	25.0	26.1
South	46.7	48.0	49.6
Rocky Mountains	5.1	5.9	5.3
Pacific Coast	25.2	21.2	18.9

These data illustrate that nearly all of the near-term increase in both softwood and hardwood harvest comes in the East. In the longer term, the Pacific Coast Region continues to lose share of harvest in spite of modest harvest increases in the Douglas-fir subregion.

Table 121 illustrates that nearly all of the increase in timber harvest comes from other private and forest industry ownerships. Supply from the national forests, and supply from other public ownerships in all regions is determined by various planning efforts that are not, for the most part, affected by expected future prices. National forest harvests (as distinct from the volume of timber offered for sale) in the Rocky Mountains are an exception. There harvest levels initially fall below projected offerings, because industry capacity is unable to absorb the prospective increase over current levels. As capacity expands, unsold volume falls and harvests rise toward projected public supply.

The ownership pattern of the increases in harvest differs between the hardwood and softwood sectors (table 121). The increase in softwood harvest is shared between the two types of private timberland owners. Increase in hardwood harvest, on the other hand, is concentrated on the other private ownership. This ownership accounts for 77% of the hardwood harvest in 1986 and by 2040 their share is expected to increase to 82%. This increase is the result of declining harvests from forest industry timberlands due to conversion of hardwood forest types to softwood plantations.

IMPLICATIONS OF THE BASE PROJECTIONS

The projections suggest that forest industry timberlands in the South and in the Pacific Northwest will be approaching a roughly regulated state within the next three decades. In a regulated forest, growth and harvest are nearly equal and there is a roughly uniform distri-

Table 116.—Softwood removals, harvest, net annual growth, and growing stock inventory on forest industry timberlands[1] in the contiguous states, specified years 1952–1986, with projections to 2040.

Item	1952	1962	1970	1976	1986	Projections 2000	2010	2020	2030	2040
					Million cubic feet					
Northeast										
Removals	105	92	138	182	273	239	185	183	178	178
Timber harvest	99	87	128	168	356	310	287	285	273	268
Net growth	179	236	339	377	188	177	169	172	176	178
Inventory	5,246	6,427	9,753	10,824	9,232	8,251	8,043	7,905	7,846	7,817
North Central[2]										
Removals	34	23	28	33	37	41	45	50	54	59
Timber harvest	30	22	25	28	41	62	71	76	80	82
Net growth	43	44	63	55	50	52	52	55	56	54
Inventory	917	1,314	1,521	1,690	1,653	1,669	1,732	1,765	1,770	1,715
Southeast										
Removals	325	262	458	518	821	1,121	1,267	1,531	1,597	1,511
Timber harvest	318	252	430	473	740	984	1,210	1,393	1,433	1,503
Net growth	375	411	558	688	789	1,206	1,462	1,484	1,532	1,539
Inventory	6,469	7,455	8,286	8,737	10,264	10,962	12,510	13,437	12,633	12,463
South Central										
Removals	494	341	564	898	1,088	1,082	1,457	1,807	1,891	2,065
Timber harvest	484	328	530	893	1,045	1,038	1,532	1,664	1,827	2,094
Net growth	707	971	889	894	829	1,500	1,878	1,910	2,122	2,106
Inventory	9,738	13,087	13,501	14,430	13,515	14,533	20,444	21,416	23,655	24,979
Pacific Southwest										
Removals	456	449	318	344	435	309	235	187	134	151
Timber harvest	393	385	294	321	452	300	291	255	300	323
Net growth	90	108	135	139	205	189	167	167	178	158
Inventory	11,268	9,639	8,244	7,457	7,918	5,207	4,353	3,930	4,206	4,143
Douglas-fir subregion										
Removals	1,150	909	1,272	1,302	1,222	1,059	1,003	1,004	1,034	1,114
Timber harvest	1,244	976	1,234	1,268	1,244	1,178	1,303	1,383	1,496	1,530
Net growth	337	393	455	606	915	949	1,052	1,162	1,254	1,273
Inventory	32,725	27,399	23,767	21,978	20,137	17,779	18,308	19,873	22,038	23,530
Ponderosa pine subregion										
Removals	103	95	120	162	179	104	128	135	145	148
Timber harvest	100	94	117	151	166	97	116	120	128	132
Net growth	62	71	84	85	115	147	139	149	139	153
Inventory	3,975	3,972	4,038	3,849	4,279	5,355	5,423	5,518	5,439	5,482
United States total										
Removals	2,666	2,171	2,898	3,439	4,055	3,955	4,320	4,897	5,033	5,226
Timber harvest	2,668	2,144	2,758	3,302	4,043	3,969	4,810	5,176	5,537	5,932
Net growth	1,793	2,234	2,523	2,844	3,091	4,220	4,919	5,099	5,457	5,461
Inventory	70,338	69,293	69,110	68,965	66,998	63,756	70,813	73,844	77,587	80,129

[1]The forest industry timberlands in the Rocky Mountains are included with the farmer and other private timberlands for that region.

[2]Data for the Great Plains are included in the Rocky Mountains for the historical period and in the North Central subregion for the projection period.

Note: Supply data for 1952, 1962, 1970, 1976, and 1986 are estimates of the trend level of harvests and differ somewhat from the estimates of actual consumption shown in some tables. For the projection years, the data shows the volume that would be harvested given the assumptions of the study. Inventory data for 1952 and 1962 are as of December 31. Inventory data for 1970 and the projection years are as of Janaury 1. Inventory data shown under 1976 and 1986 are as of January 1 of following year.

Table 117.—Hardwood removals, harvest, net annual growth, and growing stock inventory on forest industry timberlands[1] in the contiguous states, specified years 1952–1986, with projections to 2040.

Item	1952	1962	1970	1976	1986	Projections 2000	2010	2020	2030	2040
					Million cubic feet					
Northeast										
Removals	47	51	91	121	110	116	136	157	174	188
Timber harvest	44	45	69	89	216	231	289	316	323	328
Net growth	129	156	193	226	230	211	207	207	206	206
Inventory	4,742	5,554	6,819	7,636	8,835	11,039	11,739	12,230	12,540	12,702
North Central[2]										
Removals	74	45	64	69	142	119	124	125	121	117
Timber harvest	73	41	57	55	201	200	223	207	187	169
Net growth	99	100	118	118	105	99	95	98	102	96
Inventory	2,048	2,673	3,129	3,376	3,430	2,909	2,596	2,291	2,075	1,843
Southeast										
Removals	169	158	161	147	185	241	279	288	289	289
Timber harvest	127	96	108	107	176	239	286	291	296	304
Net growth	171	174	230	259	271	193	175	179	190	194
Inventory	5,149	5,801	6,738	7,080	7,781	7,217	6,192	4,948	3,817	2,860
South Central										
Removals	211	375	202	213	322	379	401	391	385	380
Timber harvest	157	227	213	184	323	394	430	423	412	415
Net growth	203	285	379	453	348	317	261	306	333	343
Inventory	5,656	7,753	8,086	9,661	9,594	9,751	7,793	6,535	5,641	5,302
Pacific Southwest										
Removals	3	4	5	4	4	3	3	4	4	5
Timber harvest	2	3	3	3	24	28	27	26	24	26
Net growth	11	15	24	19	46	41	43	38	30	26
Inventory	336	449	717	679	1,374	1,427	1,585	1,709	1,777	1,777
Douglas-fir subregion										
Removals	18	24	44	44	44	144	142	79	78	74
Timber harvest	18	22	37	34	57	107	126	137	139	134
Net growth	75	98	124	145	154	135	127	121	116	112
Inventory	1,889	2,663	3,264	3,336	3,872	3,480	3,061	3,312	3,684	4,031
Ponderosa pine subregion										
Removals	0	0	0	0	0	0	0	0	0	0
Timber harvest	0	0	0	0	0	([3])	([3])	([3])	([3])	([3])
Net growth	0	0	0	0	0	0	0	0	0	0
Inventory	11	12	18	19	16	8	6	5	4	3
United States total										
Removals	522	657	567	597	807	1,002	1,085	1,044	1,051	1,053
Timber harvest	421	434	487	472	998	1,197	1,379	1,398	1,379	1,373
Net growth	688	828	1,068	1,220	1,154	996	908	949	977	977
Inventory	19,831	24,905	28,771	31,787	34,902	35,831	32,972	31,030	29,538	28,518

[1]*The forest industry timberlands in the Rocky Mountains are included with the farmer and other private timberlands for that region.*
[2]*Data for the Great Plains are included in the Rocky Mountains for the historical period and in the North Central subregion for the projection period.*
[3]*Less than .5 million cubic feet.*
Note: Supply data for 1952, 1962, 1970, 1976, and 1986 are estimates of the trend level of harvests and differ somewhat from the estimates of actual consumption shown in some tables. For the projection years, the data shows the volume that would be harvested given the assumptions of the study. Inventory data for 1952 and 1962 are as of December 31. Inventory data for 1970 and the projection years are as of Janaury 1. Inventory data shown under 1976 and 1986 are as of January 1 of following year.

Table 118.—Softwood removals, harvest, net annual growth, and growing stock inventory on farmer and other private timberlands in the contiguous states, specified years 1952–1986, with projections to 2040.

Item	1952	1962	1970	1976	1986	Projections 2000	2010	2020	2030	2040
					Million cubic feet					
Northeast										
Removals	358	274	263	300	226	210	321	418	487	523
Timber harvest	338	258	244	278	296	402	582	717	775	809
Net growth	433	538	510	623	441	468	464	462	456	453
Inventory	13,438	16,031	16,214	17,976	18,985	24,119	25,445	25,607	25,066	24,177
North Central[1]										
Removals	59	61	72	79	109	121	153	209	258	286
Timber harvest	62	63	70	74	99	194	271	348	391	405
Net growth	128	152	170	196	250	221	220	222	226	233
Inventory	2,610	3,382	4,010	4,899	6,246	8,251	8,893	8,978	8,616	8,054
Southeast										
Removals	1,444	1,234	1,235	1,365	1,821	1,835	1,831	1,866	1,966	2,027
Timber harvest	1,414	1,189	1,157	1,247	1,693	1,644	1,652	1,677	1,778	1,768
Net growth	1,349	1,567	1,882	2,130	1,904	1,626	1,765	1,740	1,745	1,769
Inventory	23,857	26,687	30,665	34,487	34,397	33,907	32,796	32,101	30,247	27,725
South Central										
Removals	606	787	1,117	1,278	1,569	2,003	1,606	1,712	2,068	2,164
Timber harvest	584	748	1,129	1,264	1,507	1,899	1,464	1,756	2,012	2,105
Net growth	792	1,182	1,668	2,000	1,762	1,646	2,013	2,103	2,023	2,062
Inventory	11,273	16,128	23,646	28,760	31,555	26,666	27,001	33,199	33,920	32,986
Rocky Mountains[2]										
Removals	226	241	280	287	299	397	472	491	468	441
Timber harvest	207	219	256	262	305	502	630	652	625	609
Net growth	293	341	388	388	440	387	343	336	344	366
Inventory	19,610	20,097	20,336	19,601	18,372	18,692	17,378	15,800	14,535	13,761
Pacific Southwest										
Removals	542	271	178	145	34	110	147	176	160	133
Timber harvest	468	230	163	136	120	115	209	245	199	167
Net growth	178	192	211	197	238	263	245	225	192	180
Inventory	15,256	12,900	9,608	9,337	9,931	12,526	12,912	12,747	12,388	12,138
Douglas-fir subregion										
Removals	302	201	259	200	203	292	327	344	332	333
Timber harvest	317	207	245	195	250	371	443	473	451	449
Net growth	265	308	358	340	409	393	373	363	358	361
Inventory	9,510	9,520	10,304	8,458	10,171	12,008	12,169	12,135	12,214	12,404
Ponderosa pine subregion										
Removals	103	68	49	65	70	52	112	156	180	179
Timber harvest	100	67	48	60	91	64	113	148	160	155
Net growth	109	136	148	121	122	160	158	162	150	148
Inventory	4,495	4,319	4,725	4,604	3,896	5,440	5,875	5,904	5,588	5,269
Alaska										
Removals			4	2	61	42	32	28	26	26
Timber harvest			5	2	65	44	34	30	28	28
Net growth		1	2	2	3	37	69	102	143	165
Inventory	218	284	323	666	8,018	9,125	9,676	10,643	11,922	13,319
United States total										
Removals	3,640	3,137	3,457	3,721	4,392	5,062	5,001	5,400	5,945	6,112
Timber harvest	3,490	2,981	3,317	3,518	4,426	5,235	5,398	6,046	6,419	6,495
Net growth	3,548	4,418	5,337	5,998	5,603	5,233	5,683	5,756	5,659	5,739
Inventory	100,267	109,348	119,831	128,788	141,571	150,734	152,145	157,114	154,496	149,833

[1]*Data for the Great Plains are included in the Rocky Mountains for the historical period and in the North Central subregion for the projection period.*
[2]*The forest industry timberlands in the Rocky Mountains are included with the farmer and other private timberlands for that region.*
Note:Supply data for 1952, 1962, 1970, 1976, and 1986 are estimates of the trend level of harvests and differ somewhat from the estimates of actual consumption shown in some tables. For the projection years, the data shows the volume that would be harvested given the assumptions of the study. Inventory data for 1952 and 1962 are as of December 31. Inventory data for 1970 and the projection years are as of Janaury 1. Inventory data shown under 1976 and 1986 are as of January 1 of following year.

Table 119.—Hardwood removals, harvest, net annual growth, and growing stock inventory on farmer and other private timberlands in the contiguous states, specified years 1952–1986, with projections to 2040.

Item	1952	1962	1970	1976	1986	Projections 2000	2010	2020	2030	2040
					Million cubic feet					
Northeast										
Removals	424	503	591	623	630	737	877	1,024	1,125	1,211
Timber harvest	404	438	448	462	1,241	1,484	1,881	2,040	2,074	2,096
Net growth	1,018	1,296	1,465	1,491	1,620	1,481	1,466	1,438	1,389	1,355
Inventory	32,669	39,863	44,751	49,457	54,938	70,842	76,287	79,066	80,587	81,133
North Central[1]										
Removals	629	661	797	793	932	1,032	1,222	1,401	1,502	1,572
Timber harvest	751	685	738	737	1,326	1,852	2,366	2,464	2,404	2,384
Net growth	961	980	1,084	1,137	1,377	1,428	1,424	1,426	1,443	1,476
Inventory	24,385	29,009	31,821	35,636	42,884	52,871	54,067	53,558	52,378	50,951
Southeast										
Removals	817	861	843	801	1,096	1,525	1,879	2,031	2,089	2,079
Timber harvest	617	523	566	586	1,043	1,508	1,935	2,075	2,166	2,181
Net growth	1,020	1,175	1,439	1,715	1,701	1,368	1,339	1,345	1,388	1,330
Inventory	29,227	32,794	36,543	41,962	48,153	45,497	41,833	35,254	27,955	20,527
South Central										
Removals	1,396	1,313	1,012	948	1,208	1,495	1,847	1,990	2,075	2,108
Timber harvest	937	730	848	713	1,212	1,579	2,031	2,169	2,260	2,322
Net growth	1,424	1,459	1,845	2,117	1,800	1,495	1,448	1,610	1,813	1,969
Inventory	37,669	39,691	42,243	45,836	53,471	57,444	54,182	49,311	45,553	43,631
Rocky Mountains[2]										
Removals	30	24	21	20	18	10	14	14	12	5
Timber harvest	1	1	2	2	44	32	47	47	41	36
Net growth	48	54	59	62	85	45	50	42	34	35
Inventory	2,354	2,514	2,701	2,784	3,495	2,772	3,129	3,396	3,611	3,905
Pacific Southwest										
Removals	4	7	10	8	1	12	18	21	20	17
Timber harvest	2	4	7	7	8	10	10	11	12	13
Net growth	29	30	40	36	95	92	80	73	77	65
Inventory	998	1,050	1,562	1,598	3,352	4,124	4,457	4,663	4,891	5,003
Douglas-fir subregion										
Removals	8	29	22	47	7	104	132	153	141	118
Timber harvest	6	24	16	37	9	186	253	250	226	206
Net growth	98	130	154	146	186	184	168	158	150	143
Inventory	3,135	3,902	4,634	3,728	5,099	6,015	6,157	6,050	6,004	6,190
Ponderosa pine subregion										
Removals	0	0	0	0	0	1	1	2	1	1
Timber harvest	0	0	0	0	0	([3])	([3])	([3])	([3])	([3])
Net growth	1	1	2	2	3	0	2	1	3	1
Inventory	62	70	77	79	102	79	88	81	93	90
Alaska										
Removals						1	1	1	1	([3])
Timber harvest						1	2	1	1	([3])
Net growth					27	43	46	39	25	13
Inventory	39	83	102	121	1,397	1,906	2,408	2,890	3,221	3,423
United States total										
Removals	3,308	3,398	3,296	3,240	3,892	4,917	5,991	6,637	6,966	7,111
Timber harvest	2,718	2,405	2,625	2,544	4,883	6,650	8,523	9,055	9,182	9,235
Net growth	4,599	5,125	6,088	6,706	6,894	6,136	6,023	6,132	6,322	6,387
Inventory	130,538	148,976	164,434	181,201	212,891	241,550	242,608	234,269	224,293	214,853

[1]*Data for the Great Plains are included in the Rocky Mountains for the historical period and in the North Central subregion for the projection period.*
[2]*The forest industry timberlands in the Rocky Mountains are included with the farmer and other private timberlands for that region.*
[3]*Less than .5 million cubic feet.*
Note: Supply data for 1952, 1962, 1970, 1976, and 1986 are estimates of the trend level of harvests and differ somewhat from the estimates of actual consumption shown in some tables. For the projection years, the data shows the volume that would be harvested given the assumptions of the study. Inventory data for 1952 and 1962 are as of December 31. Inventory data for 1970 and the projection years are as of Janaury 1. Inventory data shown under 1976 and 1986 are as of January 1 of following year.

Table 120.—Softwood and hardwood timber harvest and growing stock inventory in the contiguous states, by region, specified years 1952–1986, with projections to 2040.

Item	1952	1962	1970	1976	1986	Projections 2000	2010	2020	2030	2040
					Million cubic feet					
North[1]										
Softwoods										
Timber harvest	596	501	549	636	888	1,125	1,411	1,638	1,740	1,791
Inventory	27,053	33,661	38,817	43,850	47,400	56,166	59,429	60,832	61,174	60,516
Hardwoods										
Timber harvest	1,381	1,329	1,465	1,502	3,190	4,041	5,058	5,351	5,337	5,310
Inventory	76,695	94,627	106,867	119,158	139,640	174,937	187,016	194,210	199,021	202,246
South										
Softwoods										
Timber harvest	3,036	2,707	3,527	4,251	5,370	5,996	6,325	6,971	7,544	7,973
Inventory	58,737	73,203	87,047	98,896	103,798	100,895	108,484	116,840	118,694	118,316
Hardwoods										
Timber harvest	1,933	1,662	1,840	1,707	2,930	3,931	4,913	5,215	5,412	5,513
Inventory	84,099	94,617	103,635	116,488	134,236	134,423	124,130	109,827	97,333	86,683
Rocky Mountains										
Softwoods										
Timber harvest	497	684	814	773	849	1,184	1,350	1,399	1,398	1,409
Inventory	87,546	93,223	94,560	95,111	100,298	102,353	102,033	101,745	102,049	103,045
Hardwoods										
Timber harvest	10	13	13	5	57	33	48	48	42	37
Inventory	5,074	5,596	6,035	6,138	7,681	3,928	4,425	4,812	5,117	5,511
Pacific Coast[2]										
Softwoods										
Timber harvest	3,393	3,430	3,805	3,849	4,329	4,029	4,424	4,581	4,697	4,731
Inventory	256,821	247,892	237,754	226,924	182,968	175,391	174,126	175,140	179,141	183,811
Hardwoods										
Timber harvest	37	62	87	102	145	352	443	451	427	402
Inventory	14,099	16,419	19,197	18,441	22,446	23,286	24,639	26,050	27,320	28,305
United States										
Softwoods										
Timber harvest	7,522	7,322	8,698	9,510	11,436	12,336	13,511	14,589	15,380	15,904
Inventory	430,157	447,979	458,178	464,781	434,464	434,805	444,072	454,557	461,058	465,688
Hardwoods										
Timber harvest	3.361	3,066	3,405	3,316	6,322	8,357	10,462	11,065	11,217	11,263
Inventory	179,967	211,259	235,734	260,225	304,003	336,574	340,210	334,899	328,792	322,744

[1] *Great Plains states included in North.*

[2] *Historical data may not match information in Chapter 3 due to changes in Alaska data.*

Note: Supply data for 1952, 1962, 1970, 1976, and 1986 are estimates of the trend level of harvests and differ somewhat from the estimates of actual consumption shown in some tables. For the projection years, the data shows the volume that would be harvested given the assumptions of the study. Inventory data for 1952 and 1962 are as of December 31. Inventory data for 1970 and the projection years are as of Janaury 1. Inventory data shown under 1976 and 1986 are as of January 1 of following year.

Table 121.—Softwood and hardwood timber harvest and growing stock inventory in the contiguous states, by ownership, specified years 1952–1986, with projections to 2040.

						Projections				
Item	1952	1962	1970	1976	1986	2000	2010	2020	2030	2040
					Million cubic feet					
National forest										
Softwoods										
Timber harvest	961	1,635	1,918	1,867	2,153	2,156	2,263	2,311	2,357	2,404
Inventory	204,354	213,605	211,818	207,977	169,173	161,441	158,921	158,004	159,355	161,477
Hardwoods										
Timber harvest	100	97	123	101	166	204	224	243	262	260
Inventory	13,253	16,851	18,784	21,044	24,712	19,982	19,983	19,858	19,962	19,686
Other public										
Softwoods										
Timber harvest	403	562	702	822	814	974	1,040	1,056	1,067	1,073
Inventory	55,198	55,733	57,419	59,051	56,722	58,875	62,193	65,596	69,621	74,249
Hardwoods										
Timber harvest	122	130	170	199	276	306	336	369	394	394
Inventory	16,345	20,527	23,745	26,193	31,498	39,211	44,647	49,742	54,999	59,687
Forest industry										
Softwoods										
Timber harvest	2,668	2,144	2,758	3,302	4,044	3,969	4,810	5,176	5,537	5,932
Inventory	70,338	69,293	69,110	68,965	66,998	63,756	70,813	73,844	77,587	80,129
Hardwoods										
Timber harvest	421	434	487	472	998	1,197	1,379	1,398	1,379	1,373
Inventory	19,831	24,905	28,771	31,787	34,902	35,831	32,972	31,030	29,538	28,518
Farm and other private										
Softwoods										
Timber harvest	3,490	2,981	3,317	3,518	4,426	5,235	5,398	6,046	6,419	6,495
Inventory	100,267	109,348	119,831	128,788	141,571	150,734	152,145	157,114	154,496	149,833
Hardwoods										
Timber harvest	2,718	2,405	2,625	2,544	4,883	6,650	8,523	9,055	9,182	9,235
Inventory	130,538	148,976	164,434	181,201	212,891	241,550	242,608	234,269	224,293	214,853
United States[1]										
Softwoods										
Timber harvest	7,522	7,322	8,698	9,510	11,436	12,336	13,511	14,589	15,380	15,904
Inventory	430,157	447,979	458,178	464,781	434,464	434,805	444,072	454,557	461,058	465,688
Hardwoods										
Timber harvest	3,361	3,066	3,405	3,316	6,322	8,357	10,462	11,065	11,217	11,263
Inventory	179,967	211,259	235,734	260,225	304,003	336,574	340,210	334,899	328,792	322,744

[1]*Historical data may not match information in Chapter 3 due to change in Alaska data.*

Note: Supply data for 1952, 1962, 1970, 1976, and 1986 are estimates of the trend level of harvests and differ somewhat from the estimates of actual consumption shown in some tables. For the projection years, the data shows the volume that would be harvested given the assumptions of the study. Inventory data for 1952 and 1962 are as of December 31. Inventory data for 1970 and the projection years are as of Janaury 1. Inventory data shown under 1976 and 1986 are as of January 1 of following year.

bution of forest land across age classes. Projections for forest industry timberlands show this happening after 2005 in the South and roughly 2010 in the Douglas-fir region.

There are (at least) three other ways to view the base projections. The first is in terms of employment associated with harvesting and processing timber. The Southern Timber Study (USDA FS 1988b), an analysis comparable to this study, found that employment in the forest sector is likely to decline as productivity per employee increases faster than production. This conclusion reflects a new awareness of employment implications of long-term projections, and an interest in the employment impacts associated with current forest policy issues such as log export restrictions and old-growth retention.

A second view of the base projections considers the broad environmental effects of projected developments in the U.S. forest sector. Chief among these broad-based concerns is substitution between materials derived from renewable resources (such as timber) and materials derived from nonrenewable resources (such as minerals). At issue here are the environmental effects of increased production, consumption, and disposal of nonrenewable materials.

Finally, the base projections must be examined in terms of the likely impact on wildlife, fish, forage, and water resources. These concerns are addressed in detail in other resource Assessments. In this chapter, for nontimber resources, we will review only the broad implications of projected changes in timber harvests and timber inventories.

Employment

Projected employment in U.S. forest products industries is shown in table 122. There are significant differences in trends in employment within the projection period, across industries, and across regions. For example, between 1985 and 2000, employment in the softwood lumber industry declines in the Pacific Northwest-West and the Pacific Southwest, but increases elsewhere. In the softwood plywood industry, employment declines in all regions between 1985 and 2000. By 2040, employment in both industries is down significantly in all regions (Lange et al., in press). Total employment in the lumber and wood products industries (all regions) decreases 5% between 1986 and 2000, and 13% between 1986 and 2040.

Two factors contribute to these declines in employment. First, reduction in timber harvest and timber processing (in the Pacific Northwest-West and Pacific Southwest lumber and wood products industries, for example) result in direct reductions in employment. The second factor is the employment impact of technological change. Even in those regions where the long-term trend is nondeclining levels of harvest and processing, employment may decrease as a result of labor-saving technological change in processing industries. Competitive firms in the forest products industry have generally been those that utilize technology in place of labor and raw material as modernization takes place. The historical trend—that we expect will continue—is increased productivity of labor in new mills that more than offsets increases in employment that might have resulted from higher levels of production. Expected increases in labor productivity are clear when total employment (table 122) is compared to production (tables 97, 100, and 102).

The character of technological change is a consequence of a long-term trend of increasing wage rates (relative to other costs of production), and the fact that labor costs comprise a major component of total production costs. Changes in the cost and physical characteristics of raw material (in particular, decreasing average size of logs) are also factors that motivate the development and implementation of new, more mechanized production processes. In addition to providing some control over increasing costs, technological improvements also facilitate changes in product mix (Keegan and Polzin 1987).

Table 123 shows trends in wages and salaries (in constant dollars). As a result of trends in wage rates, these trends are less pronounced and, in some cases, are counter to the trends in employment. Here, too, there are considerable differences between regions, and between industry groups within the broad categories shown in table 123. For example, workers in the softwood plywood industries earn roughly 40% more than those in the lumber industry. Between 2000 and 2040, wages and salaries are lower in the softwood lumber industry and constant to substantially higher in the softwood plywood industry.

Projected increases in forest products prices can be expected to increase the use of substitute materials in the housing, nonresidential construction, manufacturing and shipping sectors. Through these changes, declines in production and employment in the forest products industry would induce increased activity in the industries producing substitute materials. Higher production levels in these industries would increase employment, mitigating at least some of the jobs lost in the forest products industry. However, jobs created through expansion in these industries will be in different regions of the country and will require different skills. In addition, increased demand for nonwood products will lead, in turn, to higher prices and possible environmental problems associated with these industries.

Environmental Effects

The broad-based environmental impacts of these forest products industry projections cannot be viewed in isolation because forest products compete with a variety of materials in most end-use markets. An assessment of the environmental impact of changes in forest products production and consumption must take into consideration the wide range of materials that can be substituted for forest products, and the fact that each of the industries producing substitute materials has its own set of environmental impacts.

Table 122.—Employment in the softwood lumber and plywood industries, by section and region, 1986, with projections to 2040.

Section and region	1986	Projections 2000	2010	2020	2030	2040
		Thousand employees				
Softwood lumber industry						
South	36.0	39.9	43.3	44.8	41.3	37.0
Rocky Mountain	13.2	15.0	13.6	14.3	12.6	11.1
Pacific Coast						
Pacific Northwest						
Pacific Northwest-West	20.8	20.3	18.9	18.2	16.1	13.6
Pacific Northwest-East	9.2	9.8	10.6	10.9	10.6	9.8
Pacific Southwest[1]	12.0	10.9	10.3	8.5	7.3	5.8
Softwood plywood industry						
South	17.3	13.5	15.5	17.0	18.4	19.9
Rocky Mountain	1.7	1.3	1.4	1.6	1.7	1.8
Pacific Coast						
Pacific Northwest						
Pacific Northwest-West	16.6	10.4	9.2	9.6	10.0	10.4
Pacific Northwest-East	1.2	0.9	1.0	1.2	1.3	1.5

[1]*Excludes Hawaii.*

Table 123.—Wages and salaries in the softwood lumber and plywood industries, by section and region, 1986, with projections to 2040.

Section and region	1986	Projections 2000	2010	2020	2030	2040
		Millions of 1982 dollars				
Softwood lumber industry						
South	411	455	494	511	471	422
Rocky Mountain	223	253	230	241	213	187
Pacific Coast						
Pacific Northwest						
Pacific Northwest-West	410	401	373	359	318	269
Pacific Northwest-East	180	193	208	216	210	193
Pacific Southwest[1]	232	210	199	164	141	113
Softwood plywood industry						
South	486	380	436	477	518	559
Rocky Mountain	48	36	40	43	47	51
Pacific Coast						
Pacific Northwest						
Pacific Northwest-West	467	294	259	270	282	293
Pacific Northwest-East	35	26	29	33	38	42

[1]*Excludes Hawaii.*

Rising prices for forest products are likely to induce greater consumption and production of other industrial commodities. In construction, for example, steel, aluminum, plastic, and concrete can be used in place of wood products in structural and nonstructural applications. In manufacturing, plastics and metal products have proven to be viable substitutes for wood used in furniture, and in a variety of other uses. In shipping, increased use of containers in cargo handling has resulted in greater use of steel in place of wood; a variety of plastics have also been substituted for wood and paper products used in packaging and materials handling. Based on analysis of historical data we expect similar substitution to take place in the future (Alexander and Greber 1988).

Industrial materials generate environmental problems at each of four stages in the material's life cycle: (a) raw material extraction, (b) manufacturing, (c) material use, and (d) disposal. At each stage, the environmental impacts can be categorized as soil, air, water, and health and miscellaneous problems. Soil problems include general soil scarification and disturbance, disposal of displaced soils, and landfill problems associated with disposal of waste material. Air quality problems include production of particulates, production of pollutant gasses (such as sulphur dioxide and sulfides), and the production of so-called "greenhouse gasses" (such as carbon dioxide). Water quality problems include acid runoff from exposing low pH materials (during mining operations), pollution resulting from disposal of materials used in manufacturing, pollution resulting from biological and chemical processes that deplete aquatic oxygen, and problems with suspended solids (including sedimentation).

Some general health and ecological concerns that have been associated with the production and use of various industrial materials include production (as byproducts) of heavy metals (such as chromium), and production or use of toxic chemicals such as cyanide, radon, dioxins, formaldehyde, and poly-chlorinated bi-phenols (PCBs). All of these contaminants may be harmful to production workers, to users of the materials, or to the broader environment. Assessments of the likely damage, and the acceptability of risks associated with these materials and, even more broadly, with particular industries, often depend on perceptions of opportunities to gain, or likelihood of loss (of employment, income, or health). Uncertain, diffuse risks are frequently outweighed in the social balance by certain, concentrated gains.

Finally, the durability of disposed materials presents a variety of environmental problems. All industrial materials present disposal problems, even taking into account differentiation between industrial and municipal (household) wastes. Industrial wastes from steel, pulp and paper, and plastic manufacture include waste waters, that often contain toxic contaminants, and solid waste whose chief problem is its quantity. Wastes from aluminum manufacture present landfill space problems, as do industrial wastes from panel product manufacture. Municipal waste contains a large proportion of metal, plastic, and aluminum products. These materials can be recycled (reducing disposal impacts, and decreasing requirements for virgin raw material); unfortunately, recycling is not widespread and the material endures when buried. Wood products (other than panel products), and concrete products pose the fewest long-term disposal problems for both industries and municipalities because they will break down over time.

The environmental impacts of the forest products industries, or those industries producing substitute materials, are not easily summarized and cannot be easily translated into comparable terms. In general, forest products, steel, plastics, aluminum, and cement all give rise to substantial environmental impacts through harvesting or raw material extraction. Raw material production for steel, cement, and aluminum manufacturing generally results in impacts on soil that are relatively greater—or at least more concentrated—than is the case with timber production. Steel manufacturing has a significant (negative) impact on local and regional air quality, and the cement and plastics industries have significant impacts on water quality. On the other hand, timber production and forest products industries have been associated with extensive changes in forest-based wildlife habitat, damage to productivity of anadromous fisheries, and reductions in local air quality.

Clearly, the magnitude, type, and duration of environmental impacts differ across these industries. In addition, the location of production (of both raw materials and processed products) differs widely for forest products and industries producing substitute materials. As a result, the concentration of environmental impacts will shift as materials use patterns change. In many cases, shifts in the use of industrial materials will have environmental impacts that are multinational in scope. The lack of empirical methods and the absence of a national environmental policy, or a national materials policy make it impossible to provide unambiguous measures of the environmental consequences of projected developments in the forest products sector.

Effects on Wildlife and Fish, Forage and Water

The projected changes in timber production will lead to structural changes in the Nation's forest resources. These changes will affect wildlife and fish habitat, forage availability, and watershed outputs. Changes in harvest levels, changes in the type and intensity of forest management, and changes in the pattern of land uses are important determinants of the short- and long-term impacts on nontimber forest resources.

Over the next five decades the United States will continue to reduce its dependence on timber produced from the old-growth, softwood forests of the Pacific Northwest. Timber production will increase from the private forests in the North and South. The pressures placed on forest owners in the West (both public and private) to maintain, or increase the nontimber benefits of forests will be felt increasingly by owners and managers in the North and South.

Because total (national) timber production is projected to increase, and because forests in the North and South are, on average, less densely stocked than those in the West, the total area harvested will increase by more than 25%. Between 2030 and 2040, an average of 5.4 million acres will be harvested each year in U.S. private forests. In 1986, approximately 4.3 million acres were harvested from these forests. A 16% decline in harvested area in the West will be more than offset by a 30% increase in the North, and a 33% increase in the South. The biggest relative change is a doubling of the area of softwood stands harvested in the North.

Projections of timber harvests, timber growth, and timber inventories incorporate assumptions regarding changes in forest management. Most of these changes (and the most significant changes) take place in the industrial forests in the Northwest and in the South. It is difficult to quantify the likely impact on nontimber resources of the broad array of management activities that will be undertaken. These management activities include controlling the species composition of forest stands, the use of genetically "improved" seed stock, efforts to manage stand density, and shortening the average age of harvested stands. Some of the most noticeable changes bear mentioning.

In the South, for example, the rate of harvest and likely management strategies will combine to nearly eliminate natural pine stands on industrial lands by the year 2040. In their place will be a considerable area of pine plantations, many of which will reflect "managed" genetic characteristics. These plantation forests will have a more balanced age-class structure than existing forests in the region, and few stands will be allowed to reach the age of the stands of natural origin that they replace. A similar—and even more dramatic—replacement of older stands with younger, more actively managed stands will take place in the West. Forest type transitions will not be as significant in the West (or in the North), but managed forests on private lands in the West in the future will also provide a different blend of nontimber benefits.

The area of timberland in the United States is projected to decline by 21 million acres by the year 2040 (table 70). This is slightly more than half of the timberland area reduction that occurred between 1962 and 1987 (37.3 million acres), and roughly 4% of the current timberland area. The largest portion of this reduction is expected to occur by the year 2000.

The impacts of these changes in timberland on nontimber resources will vary across regions, and depend largely on the causes of the changes within each region. In the South, for example, where most timberland is privately owned, and the majority of timberland is nonindustrial, most timberland conversion is to agricultural and urban uses. This implies a significant change in, if not elimination, of the forest cover and associated resources. Roughly 40% of the total (national) timberland reduction occurs in the South. In the Pacific Coast region (including Alaska), where one-fourth of the reduction occurs, some of the reduction is the result of conversion to urban and other uses; however, much of the land that is no longer classified as timberland will remain forested. The impact on nontimber resources will be considerably less in this case.

Projected changes in timber harvests, forest management practices, and timberland area will have both direct and indirect impacts on nontimber resources that can be either detrimental or beneficial. Direct, negative impacts include those associated with the conversion of timberland to nontimber uses. The replacement of existing forests with forests composed of younger stands, or different species will have direct, but mixed impacts that will depend on the resource being considered. The quantity and type of wildlife supported, forage production, and watershed production will adjust to the new forest environment.

CHAPTER 8. ALTERNATIVE FUTURES

Chapter 7 was concerned with one view of the future based on the complex set of assumptions about determinants of timber demands and supplies described in Chapter 6. These projections of long-run demands and supplies are strongly influenced by short-run conditions at the time they are made,[33] but views of the future may differ from those assumed in the basic assumptions. In addition, the U.S. forest sector appears to be verging on several major shifts (changes in public harvests, assumptions about recycling, etc.) from past conditions of supply and demand for both products and stumpage. Acting in concert, such changes could lead to future trends that differ significantly from traditional expectations. This chapter examines some of these potential shifts and their impacts on the forest sector.

These futures differ from the base projection with respect to key assumptions about timber supply and demand. Eight alternative futures will be examined. Most were derived from reviews of, and public comments on, past Assessments. The following descriptions highlight key points in each.

1. **Increased productivity.**—An alternative view of the future where the rates of softwood lumber and plywood product yield improvement for western regions rise faster than those assumed in the base Assessment projection.
2. **Higher exports of timber products.**—An alternative view of the future where projected exports of pulpwood (including pulpwood and the pulpwood equivalent of pulp, paper, and board) lumber, and plywood double by 2040.
3. **Lower rates of timber growth.**—An alternative view of the future where the net annual growth for softwoods and hardwoods in the East is reduced. This future is intended to reflect the potential impacts of air pollutants on major U.S. forest ecosystems.
4. **Greater forest management.**—An alternative view of the future where all intensive management opportunities on timberland in private ownerships (that yield a 10% rate of return or more, net of inflation or deflation) would be implemented. Details on the various opportunities are described in Chapter 9.
5. **Reforestation of surplus crop and pastureland.**—An alternative view of the future where all surplus crop and pastureland (some 32.5 million acres) projected in the review draft of the Second RCA Appraisal (SCS 1988) is assumed to revert to natural cover with a 10-year time lag.
6. **Reduced timber harvests on national forests.**—Two alternative views of timber harvests levels on the national forests. First, timber harvests on national forests are assumed to drop from 2.3 to 2.1 billion cubic feet per year by 2000 and remain at that level to 2040. Second, timber harvests on national forests in the Douglas-fir subregion are reduced by 25% to represent protection for old-growth and old-growth dependent species such as the northern spotted owl.
7. **Increased use of recycled fiber.**—An alternative view of the future where the use of recycled fiber in paper and board production rises to 39% of total fiber furnished by 2040.
8. **Higher housing starts.**—An alternative view of the future where replacement rates for single-family homes in the housing stock increase by 2040 to maintain the average age of the housing stock at roughly its current level.

[33] *The base projections were made in the spring of 1989. Most data series had been revised through 1987 and some were revised for 1988.*

SELECTED FUTURES

This section examines the important differences in product and stumpage markets of each of these selected futures from those shown in the base projections. In their own way, each of these futures is a potential alternative to the base Assessment projection. The objective here is to demonstrate both the sensitivity of the base projections to changes in input assumptions and to provide a basis for assessing the robustness[34] of policy conclusions drawn from the base Assessment projections.

Increased Productivity

In the base Assessment projection, softwood lumber recovery was projected to increase in all sections and regions (see Chapter 6 for details). The rates of increase were greatest in the South and in the Ponderosa Pine subregion where decreases in log diameters were the smallest. The rates of increase were the least in the Douglas-fir subregion where expected decreases in log diameters offset improvements resulting from the adoption of new technology.

In this future, the rate of change for western regions is assumed to be roughly the same as the rate used in the base Assessment projection for the southern subregions. The rationale is that producers in the western sections and regions, facing more rapid increases (than southern producers) in stumpage prices during the next two decades, will adopt technology that will overcome shrinking log sizes. For example, the average lumber recovery factor for the Pacific Coast states is assumed to rise from 7.2 to 8.7 (rather than 8.4) board feet (lumber scale) per cubic foot (log input) by 2040. Changes in rates of recovery improvement were made also for the Canadian regions.

In this future there is very little change from the base projections in softwood harvest levels (timber supplies) and timber inventories on private timberlands (table 124). Although harvests are little changed, production

[34] *Robustness is used in the context of flexibility. A robust policy conclusion is one that leads the forest sector into more acceptable final states.*

Table 124.—Simulated effects of selected futures on projected consumption, production, prices, and harvest, by region, selected years 1986–2040.

	Base	Increased solidwood recovery	Higher exports	Reduced growth	Increased forest management	Surplus cropland	Reduced USFS harvest	Spotted owl protection	Increase recycle fiber	Higher housing starts
	Softwood lumber consumption			Million board feet						
1986	46,283	46,283	46,283	46,283	46,283	46,283	46,283	46,283	46,283	46,283
2000	47,610	47,853	47,653	47,281	47,645	47,667	47,317	47,118	47,652	47,608
2010	49,564	50,036	49,588	49,212	49,745	49,582	49,211	49,435	49,950	49,579
2020	53,783	54,176	53,638	52,905	54,066	53,842	53,241	53,475	54,473	54,646
2030	55,008	55,447	54,693	53,921	55,501	55,192	54,446	54,678	56,140	56,758
2040	56,094	56,522	55,510	54,806	56,678	56,281	55,563	55,908	57,622	58,743
	Softwood lumber production									
1986	33,889	33,889	33,889	33,889	33,889	33,889	33,889	33,889	33,889	33,889
2000	39,118	39,285	39,119	38,277	39,128	39,138	38,392	38,379	39,136	39,134
2010	40,049	41,497	40,459	37,822	40,656	40,563	38,237	38,818	41,465	40,120
2020	43,612	45,387	44,053	38,890	44,991	44,473	41,339	42,528	46,480	43,686
2030	46,805	48,608	47,037	41,862	48,594	47,590	44,604	45,912	52,888	47,420
2040	49,173	51,003	49,375	44,095	51,553	50,175	46,804	48,086	56,186	50,033
	Softwood lumber imports									
1986	14,363	14,363	14,363	14,363	14,363	14,363	14,363	14,363	14,363	14,363
2000	10,962	11,038	11,004	11,474	10,987	10,999	11,396	11,210	10,987	10,944
2010	12,021	11,046	11,684	13,896	11,595	11,524	13,479	13,123	10,992	11,964
2020	12,764	11,383	12,985	16,609	11,668	11,963	14,496	13,541	10,586	13,553
2030	10,804	9,439	11,956	14,659	9,507	10,203	12,442	11,366	6,194	11,938
2040	9,521	8,119	11,245	13,311	7,726	8,706	11,359	10,421	4,036	11,311
	Softwood plywood consumption			Million square feet						
1986	19,766	19,766	19,766	19,766	19,766	19,766	19,766	19,766	19,766	19,766
2000	17,752	17,890	17,820	17,561	17,764	17,775	17,635	17,560	17,653	17,755
2010	17,977	18,184	17,997	17,627	18,026	17,986	17,704	17,817	18,282	17,936
2020	19,812	19,940	19,743	19,215	19,888	19,891	19,576	19,622	20,168	20,088
2030	21,117	21,344	20,975	20,783	21,358	21,304	20,927	21,070	21,606	21,550
2040	22,612	22,757	22,244	21,981	22,938	22,741	22,289	22,510	22,952	23,150
	All softwood lumber price index			(1982 = 100)						
1986	111.6	111.6	111.6	111.6	111.6	111.6	111.6	111.6	111.6	111.6
2000	146.3	143.5	146.2	152.1	146.1	145.7	150.7	152.1	145.7	146.6
2010	155.0	150.9	156.6	161.4	153.4	154.4	161.4	154.8	148.9	155.5
2020	162.7	158.8	165.9	175.7	159.5	160.9	168.6	165.4	153.2	164.9
2030	159.8	156.0	165.0	174.1	154.9	157.9	166.6	163.7	140.7	165.1
2040	157.7	154.5	164.8	176.7	150.8	155.5	167.2	159.4	140.4	166.7
	All softwood plywood price index									
1986	109.6	109.6	109.6	109.6	109.6	109.6	109.6	109.6	109.6	109.6
2000	128.1	125.4	127.0	134.7	128.3	128.0	132.4	133.9	127.2	128.6
2010	139.8	135.2	140.1	151.6	138.0	140.4	149.3	143.6	128.3	141.8
2020	142.2	141.0	145.7	161.4	140.7	139.5	151.1	147.9	130.6	141.9
2030	144.5	138.7	148.3	153.1	134.1	136.0	148.2	142.4	126.4	147.3
2040	142.2	143.3	156.9	163.1	131.4	139.6	152.5	145.4	129.3	155.8
	All hardwood lumber price index									
1986	120.3	120.3	120.3	120.3	120.3	120.3	120.3	120.3	120.3	120.3
2000	132.6	143.1	132.7	134.5	133.1	132.0	132.6	132.6	132.7	143.1
2010	146.3	146.2	146.5	149.1	147.2	144.0	146.4	146.3	146.2	146.3
2020	163.0	162.9	163.6	166.8	164.4	157.1	163.2	163.0	162.3	163.0
2030	181.7	181.7	182.9	186.5	179.7	146.2	182.0	181.7	180.1	181.7
2040	198.5	198.5	200.0	203.4	200.4	150.0	198.9	198.5	196.0	198.7
	United States softwood demand			Billion cubic feet						
1986	11.7	11.7	11.7	11.7	11.7	11.7	11.7	11.7	11.7	11.7
2000	12.1	12.1	12.1	12.1	12.1	12.2	12.0	12.1	11.8	12.1
2010	13.4	12.4	13.3	13.2	13.4	13.4	13.2	13.2	13.0	13.3
2020	14.5	14.6	14.5	14.1	14.6	14.5	14.3	14.4	14.1	14.5
2030	15.3	15.3	15.4	14.8	15.4	15.4	15.0	15.2	14.8	15.4
2040	15.8	15.9	15.9	15.3	14.8	15.9	15.5	15.7	15.3	15.9

Table 124.—Continued

	Base	Increased solidwood recovery	Higher exports	Reduced growth	Increased forest management	Surplus cropland	Reduced USFS harvest	Spotted owl protection	Increase recycle fiber	Higher housing starts
	United States hardwood demand									
1986	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3
2000	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4
2010	10.5	10.4	10.6	10.5	10.5	10.5	10.5	10.5	10.3	10.5
2020	11.1	11.1	11.3	11.1	11.1	11.1	11.1	11.1	10.8	11.1
2030	11.3	11.3	11.6	11.3	11.3	11.3	11.3	11.3	10.9	11.3
2040	11.3	11.3	11.7	11.3	11.3	11.4	11.3	11.4	10.9	11.4
	North stumpage prices			(1982 $/MBF)						
1986	34.7	34.7	34.7	34.7	34.7	34.7	34.7	34.7	34.7	34.7
2000	42.9	42.9	43.1	46.0	42.2	43.2	43.7	42.9	42.4	42.9
2010	55.2	55.1	56.7	64.7	53.5	55.7	56.6	55.1	51.3	55.2
2020	73.6	73.4	76.3	87.7	69.9	72.4	75.6	73.5	65.2	73.6
2030	84.2	84.0	88.0	103.2	78.1	81.0	87.1	84.1	70.3	84.3
2040	91.5	91.3	96.1	114.2	83.3	85.6	95.3	91.4	75.8	91.8
	South stumpage prices									
1986	123.6	123.6	123.6	123.6	123.6	123.6	123.6	123.6	123.6	123.6
2000	169.4	155.3	166.7	204.5	167.1	165.0	188.3	191.1	152.5	169.5
2010	218.4	205.4	237.5	325.4	206.5	210.6	253.8	236.6	171.5	221.1
2020	243.1	231.0	264.0	334.9	233.3	232.1	276.8	261.3	200.3	247.2
2030	222.3	208.9	265.8	299.5	177.3	188.4	258.1	229.5	138.8	251.6
2040	232.4	223.1	295.1	335.0	176.8	194.5	260.7	230.5	175.5	275.1
	Rockies stumpage prices									
1986	43.3	43.3	43.3	43.3	43.3	43.3	43.3	43.3	43.3	43.3
2000	89.9	67.4	89.5	101.9	88.5	88.1	99.3	91.2	88.1	89.9
2010	145.1	140.5	145.0	171.8	139.3	144.1	174.8	149.1	122.6	148.4
2020	184.3	179.2	197.6	222.2	177.7	181.6	213.3	200.5	144.3	187.5
2030	189.0	181.7	202.9	234.1	168.6	174.8	218.7	197.3	119.6	207.9
2040	184.4	174.7	219.7	236.0	153.7	169.2	211.9	193.2	88.9	233.2
	Pacific Coast stumpage prices									
1986	113.5	113.5	113.5	113.5	113.5	113.5	113.5	113.5	113.5	113.5
2000	160.2	134.7	145.5	176.5	157.0	155.2	198.6	185.3	153.5	160.1
2010	211.8	181.5	187.2	238.4	206.3	207.2	253.7	219.6	192.4	211.3
2020	240.0	222.4	228.8	298.0	222.4	232.5	277.2	249.8	199.4	246.8
2030	248.5	226.4	243.3	306.5	224.7	235.0	283.5	259.8	187.8	263.8
2040	244.9	216.3	246.7	299.0	209.8	229.5	282.6	251.2	178.8	279.7
	Hardwood sawtimber stumpage prices									
1986	179.4	179.4	179.4	179.4	179.4	179.4	179.4	179.4	179.4	179.4
2000	203.6	203.6	203.7	207.4	204.6	202.3	203.7	203.6	203.8	203.6
2010	245.6	245.6	246.1	251.6	247.6	240.7	245.8	245.6	245.5	245.6
2020	292.6	292.5	293.9	301.0	295.7	283.8	293.0	292.5	291.2	292.6
2030	344.6	344.5	347.5	355.9	349.2	331.5	345.3	344.6	340.6	344.7
2040	391.9	391.7	395.7	404.5	396.9	374.7	392.8	391.9	385.2	392.2
	Softwood North harvest			Million cubic feet						
1986	879	879	879	879	879	879	879	879	879	879
2000	1,142	1,142	1,149	1,142	1,142	1,142	1,142	1,142	1,124	1,142
2010	1,421	1,419	1,435	1,327	1,420	1,421	1,418	1,419	1,398	1,421
2020	1,641	1,639	1,666	1,641	1,641	1,641	1,641	1,640	1,603	1,644
2030	1,750	1,750	1,785	1,733	1,750	1,750	1,750	1,751	1,704	1,755
2040	1,803	1,802	1,849	1,805	1,799	1,801	1,803	1,801	1,755	1,811
	Softwood South harvest									
1986	5,237	5,237	5,237	5,237	5,237	5,237	5,237	5,237	5,237	5,237
2000	6,163	6,134	6,208	6,051	6,166	6,159	6,157	6,185	5,905	6,164
2010	6,327	6,337	6,428	6,090	6,378	6,350	6,289	6,329	6,267	6,324
2020	7,017	6,999	7,132	6,513	7,136	7,083	6,959	6,993	6,804	7,032
2030	7,610	7,618	7,777	7,179	7,762	7,675	7,567	7,619	7,728	7,653
2040	7,997	7,997	8,182	7,563	8,216	8,083	7,933	7,999	7,872	8,041

Table 124.—Continued

	Base	Increased solidwood recovery	Higher exports	Reduced growth	Increased forest management	Surplus cropland	Reduced USFS harvest	Spotted owl protection	Increase recycle fiber	Higher housing starts
	Softwood Rockies harvest									
1986	877	877	877	877	877	877	877	877	877	877
2000	1,083	1,066	1,083	1,091	1,081	1,081	1,089	1,092	1,054	1,083
2010	1,237	1,238	1,238	1,252	1,233	1,237	1,255	1,237	1,218	1,240
2020	1,306	1,306	1,317	1,322	1,303	1,306	1,317	1,312	1,281	1,307
2030	1,310	1,308	1,316	1,321	1,299	1,303	1,316	1,308	1,269	1,317
2040	1,318	1,315	1,336	1,327	1,304	1,314	1,319	1,317	1,272	1,340
	Softwood Pacific Coast harvest									
1986	4,086	4,086	4,086	4,086	4,086	4,086	4,086	4,086	4,086	4,086
2000	4,023	4,052	3,949	4,039	4,023	4,032	3,940	3,953	3,979	4,024
2010	4,369	4,439	4,269	4,385	4,381	4,391	4,222	4,283	4,203	4,370
2020	4,490	4,615	4,440	4,584	4,496	4,507	4,342	4,438	4,356	4,495
2030	4,569	4,659	4,510	4,650	4,582	4,578	4,420	4,349	4,290	4,597
2040	4,607	4,686	4,545	4,587	4,590	4,610	4,465	4,536	4,398	4,657
	Hardwood North harvest									
1986	3,355	3,355	3,355	3,355	3,355	3,355	3,355	3,355	3,355	3,355
2000	4,093	4,091	4,109	4,095	4,093	4,095	4,091	4,092	4,098	4,093
2010	5,043	5,038	5,081	5,039	5,044	5,055	5,035	5,038	4,997	5,043
2020	5,362	5,358	5,428	5,367	5,367	5,387	5,362	5,361	5,288	5,370
2030	5,367	5,367	5,466	5,377	5,379	5,402	5,367	5,371	5,268	5,379
2040	5,368	5,368	5,483	5,377	5,370	5,405	5,369	5,366	5,240	5,388
	Hardwood South harvest									
1986	2,694	2,694	2,694	2,694	2,694	2,694	2,694	2,694	2,694	2,694
2000	3,953	3,954	3,988	3,952	3,952	3,953	3,954	3,954	3,979	3,953
2010	4,904	4,903	4,988	4,905	4,899	4,902	4,905	4,906	4,782	4,903
2020	5,230	5,230	5,353	5,230	5,219	5,225	5,227	5,216	5,011	5,233
2030	5,429	5,428	5,594	5,416	5,410	5,421	5,426	5,428	5,148	5,435
2040	5,529	5,527	5,727	5,510	5,514	5,527	5,525	5,532	5,231	5,543
	Hardwood Rockies harvest									
1986	32	32	32	32	32	32	32	32	32	32
2000	52	52	52	52	52	52	52	52	52	52
2010	66	66	66	66	66	66	66	66	66	66
2020	67	67	67	67	67	67	67	67	67	67
2030	61	61	61	61	61	61	61	61	61	61
2040	58	58	58	58	58	58	58	58	58	58
	Hardwood Pacific Coast harvest									
1986	279	279	279	279	279	279	279	279	279	279
2000	331	331	331	331	331	331	331	328	327	331
2010	415	415	416	415	415	415	415	390	392	415
2020	426	426	430	426	426	426	426	426	393	426
2030	409	410	416	409	409	409	410	420	376	409
2040	389	389	397	389	389	389	389	389	353	389
	Softwood North Inventory									
1986	38,175	38,175	38,175	38,175	38,175	38,175	38,175	38,175	38,175	38,175
2000	42,301	42,301	42,278	40,603	43,152	42,263	42,275	42,300	42,316	42,301
2010	44,190	44,199	44,094	41,648	45,943	44,872	44,078	44,197	44,345	44,190
2020	44,366	44,387	44,124	41,009	47,001	45,960	44,153	44,383	44,769	44,362
2030	44,393	43,424	42,935	39,274	46,985	45,890	43,069	43,406	44,092	43,370
2040	42,029	42,060	41,308	37,243	46,480	45,352	41,583	42,040	43,070	41,969
	Softwood South Inventory									
1986	91,417	91,417	91,417	91,417	91,417	91,417	91,417	91,417	91,417	91,417
2000	86,894	86,986	86,623	79,703	87,326	87,476	86,673	86,620	87,341	86,897
2010	92,718	92,903	92,005	82,571	94,590	94,585	92,264	92,496	94,680	92,713
2020	100,160	100,182	98,880	88,408	103,287	102,040	99,837	100,065	102,811	100,141
2030	101,107	101,280	98,462	88,436	106,268	102,823	100,589	101,095	106,494	100,703
2040	98,967	98,997	95,125	84,595	106,312	100,290	98,183	98,802	104,441	97,974

Table 124.—Continued

	Base	Increased solidwood recovery	Higher exports	Reduced growth	Increased forest management	Surplus cropland	Reduced USFS harvest	Spotted owl protection	Increase recycle fiber	Higher housing starts
Softwood Rockies Inventory										
1986	18,967	18,967	18,967	18,967	18,967	18,967	18,967	18,967	18,967	18,967
2000	18,617	18,701	18,622	18,560	18,622	18,630	18,586	18,540	18,639	18,616
2010	17,374	17,575	17,394	17,209	17,405	17,420	17,253	17,230	17,489	17,380
2020	15,848	16,001	15,829	15,434	15,925	15,931	15,522	15,651	16,124	15,780
2030	14,614	14,773	14,447	13,980	14,756	14,758	14,171	14,371	15,158	14,439
2040	13,832	13,994	13,561	13,087	14,117	14,061	13,313	12,902	14,817	13,536
Softwood Pacific Coast Inventory										
1986	57,022	57,022	57,022	57,022	57,022	57,022	57,022	57,022	57,022	57,022
2000	58,747	59,066	58,958	58,538	59,032	59,232	58,310	58,344	58,867	58,767
2010	59,591	60,105	60,044	59,101	60,261	60,273	58,625	59,430	59,905	59,600
2020	60,491	60,822	60,761	59,693	61,772	61,164	59,649	56,778	61,227	60,424
2030	62,140	62,182	61,933	60,901	64,273	63,029	61,426	62,038	64,429	61,828
2040	63,359	63,535	62,738	62,254	66,541	64,706	62,735	57,307	65,368	62,392
Total Softwood Inventory										
1986	205,581	205,581	205,581	205,581	205,581	205,581	205,581	205,581	205,581	205,581
2000	206,559	207,053	206,481	197,403	208,131	207,600	205,843	205,804	207,154	206,580
2010	213,873	214,781	213,537	200,530	218,199	217,150	212,220	213,353	216,418	213,882
2020	220,865	221,391	219,594	204,543	227,984	225,094	219,160	216,877	224,931	220,707
2030	221,254	221,659	217,776	202,591	232,282	226,500	219,255	220,910	229,993	220,341
2040	218,188	218,585	212,733	197,179	233,449	224,409	215,814	211,050	227,696	215,871
Hardwood North Inventory										
1986	119,748	119,748	119,748	119,748	119,748	119,748	119,748	119,748	119,748	119,748
2000	137,985	137,986	137,924	134,378	137,495	138,854	137,933	137,982	137,943	137,985
2010	145,130	145,171	144,873	139,795	144,311	150,203	144,946	145,162	145,226	145,130
2020	147,789	147,872	147,129	140,814	146,778	157,224	147,454	147,857	148,377	147,770
2030	148,101	148,212	146,809	139,540	146,851	161,159	147,594	148,153	149,414	148,016
2040	147,311	147,419	145,226	137,269	145,761	163,455	146,599	147,352	149,456	147,108
Hardwood South Inventory										
1986	115,184	115,184	115,184	115,184	115,184	115,184	115,184	115,184	115,184	115,184
2000	120,299	120,298	120,136	115,216	119,392	121,316	120,251	120,298	119,979	120,298
2010	110,319	110,319	109,543	103,521	108,361	113,833	110,094	110,305	110,265	110,332
2020	96,297	96,312	94,472	87,890	93,109	101,306	95,916	96,258	98,126	96,300
2030	83,167	83,193	79,977	73,127	78,612	89,326	82,626	83,127	87,902	83,086
2040	73,252	73,307	69,555	63,478	68,854	80,363	72,626	73,223	80,561	73,063
Hardwood Rockies Inventory										
1986	2,199	2,199	2,199	2,199	2,199	2,199	2,199	2,199	2,199	2,199
2000	2,803	2,803	2,803	2,802	2,803	2,802	2,800	2,802	2,803	2,803
2010	3,144	3,146	3,145	3,143	3,145	3,144	3,134	3,143	3,145	3,144
2020	3,411	3,412	3,411	3,409	3,411	3,410	3,392	3,410	3,412	3,410
2030	3,633	3,678	3,632	3,631	3,678	3,678	3,654	3,633	3,677	3,632
2040	3,873	3,947	3,873	3,877	3,947	3,947	3,920	3,858	3,940	3,873
Hardwood Pacific Coast Inventory										
1986	12,894	12,894	12,894	12,894	12,894	12,894	12,894	12,894	12,894	12,894
2000	15,845	15,854	15,849	15,840	14,998	16,858	15,832	15,836	15,843	15,845
2010	16,029	16,043	16,042	16,013	14,694	17,345	15,980	15,075	16,058	16,029
2020	16,162	16,170	16,171	16,152	14,617	17,780	16,101	16,154	16,228	16,161
2030	16,716	16,714	16,711	16,711	14,939	18,678	16,660	16,710	16,818	16,713
2040	17,368	17,356	17,349	17,358	15,335	19,690	17,313	17,358	17,502	17,357
Total Hardwood Inventory										
1986	250,024	250,024	250,024	250,024	250,024	250,024	250,024	250,024	250,024	250,024
2000	276,931	276,941	276,711	268,236	274,687	279,831	276,816	276,917	276,567	276,931
2010	274,622	274,678	273,602	262,472	270,510	284,526	274,154	273,686	274,694	274,635
2020	263,659	263,766	261,182	248,264	257,914	279,720	262,863	263,680	266,142	263,642
2030	251,617	251,798	247,130	233,009	244,080	272,841	250,534	251,622	257,811	251,447
2040	241,804	242,028	236,002	221,981	233,896	267,455	240,458	241,792	251,457	241,402

of softwood lumber and plywood is up in most producing regions, particularly in the later projection years. Consumption of softwood roundwood pulpwood is also higher in the South because improved product recovery in the West shifts some lumber and plywood production from the South to the West, reducing the volumes of byproducts from mill operations available to southern pulpmills.

Lower harvests early in the projection period result in reductions in softwood stumpage and softwood lumber prices relative to the base projections in the near term. In the longer term, lumber prices remain lower than in the base Assessment projection but stumpage prices outside of the Pacific Coast region rise slightly because of increased product production in those regions.

The effects of industry adoption of the technologies identified by Haygreen and others (1986) have been estimated by Skog and Haynes (1987). They found that, just as this future suggests, the outlook for timber could be changed by actions that improved processing efficiency. The effects of a variety of specific technological changes are explored in Chapter 10.

Higher Exports

In the last 3 years, exports of forest products have been at near record levels, reawakening interest in the potential of export markets (see Chapter 5 for details). Realizing the potential for expanded trade also depends on the willingness of domestic firms to enter new markets, elimination of currently restrictive trade barriers (in importing countries), and the ability of U.S. producers to capture a larger export market share in the face of price and other kinds of competition from other world supplies.

In this future, the projected exports of lumber, plywood, and pulp products (including pulpwood and the roundwood equivalent of pulp, paper, and board) are assumed to increase by 20% per decade for the next five decades. Exports of lumber and plywood start to rise after 2010 when domestic product prices start to stabilize. Log exports in the Douglas-fir subregion are assumed to fall as lumber and plywood exports rise.

A doubling of exports of the major timber products (except softwood logs) over the projection years has the obvious effect of increasing demands and harvests (timber supplies) over the base projections for softwoods and hardwoods (see table 124). After 2010, softwood log exports in the Douglas-fir subregion were assumed to be replaced by exports of softwood lumber and plywood. The impacts vary by product, however, because doubled exports of some products are small in comparison to production. Impacts also vary by region because of the location of export markets and comparative cost differences. For example, production of softwood lumber and plywood drops below the base Assessment projection in the South, but rises substantially above them in the Pacific Northwest where reductions in log exports increases the availability of logs for domestic processing. Consumption of softwood roundwood pulpwood shows the reverse pattern, much above the base in the South (650 million cubic feet above the base by 2040), and below it in the Pacific Northwest.

There are also regional differences in the impact of this future on timber inventories. Softwood inventories in the South are lower in this future because of higher pulp production than those in the base Assessment projection. Hardwood inventories drop below the base Assessment projection in both the North and South because of increases in hardwood pulpwood use.

Prices for softwood stumpage and/or products made from softwoods are generally higher than those in the base. This reflects the volumes involved. There are large increases in pulpwood consumption while doubled lumber exports are still small relative to total lumber production. Hardwood sawtimber stumpage prices are not impacted as there is little change in hardwood lumber production and prices.

Lower Rates of Timber Growth

This decade of the 1980s has seen the emergence of a number of concerns centered first around declining forest growth possibly caused by acid rain or other air pollutants, and more recently due to global climate change. These concerns have evoked public apprehension and led to large scale research programs such as the Forest Response Program (FRP) (Schroeder and Kiester 1989) and the National Acid Precipitation Assessment Programs (NAPAP).[35]

The purpose of this future is to illustrate the economic impacts associated with the types of growth declines found by deSteigner and Pye (in press). They summarized a survey of expert opinion about quantitative estimates of the damage caused by air pollutants to major U.S. forest ecosystems, and found in general that eastern hardwood types would experience a 5% decline while eastern softwood types would experience a 10% decline. These growth reductions were simulated by lowering both current and future yield functions by the specified percentages for all stand age classes. This approach lowers what growth stands can attain. Because of stocking-level adjustments and growth of softwood components of hardwood stands and hardwood components of softwood stands, however, the simulated reductions in aggregate stand growth differ somewhat from the initial adjustments in yields.

Inventories change more slowly. By 2000, inventories in the Northeast and Southeast (except for softwoods in the Southeast) are only 3–4% less than in the base Assessment projection (table 125). Softwood inventories in the Southeast, for example, are 9% lower than in the base Assessment projection. This reflects the strong markets for softwood stumpage in the Southeast and the close balance between harvest and growth in the base Assessment projection. Hardwood inventories decline

[35]*The final NAPAP Assessment is due in 1990 (NAPAP 1988). This assessment includes the causes and effects of acidic deposition and related control and mitigation strategies.*

Table 125.—Growth, inventory, and harvest reductions.[1]

	Growth		Inventory		Harvest[2]	
	Hardwood	Softwood	Hardwood	Softwood	Hardwood	Softwood
			Northeast			
2000	.94	.90	.97	.96	1.00	1.00
2020	.94	.91	.95	.92	1.00	1.00
2040	.95	.92	.94	.89	1.00	1.00
			Southeast			
2000	.94	.91	.97	.91	1.00	.94
2020	.94	.92	.91	.85	1.00	.82
2040	.92	.92	.90	.79	1.00	.79

[1]*Measured as the ratio of the growth reduction future divided by the base Assessment projection.*
[2]*Sawtimber harvest only.*

by 2040 to 6% less than the base in the Northeast and 10% less in the Southeast (see table 125). Changes in harvest reflect shifts in product markets. In the South, there are changes in both softwoods and hardwoods but sawtimber harvest impacts are only large for softwoods. Softwood sawtimber harvest in the Southeast, for example, drops 6% by 2000 and 21% by 2040. This harvest trajectory is the consequence of the market model including the specification of the stumpage supply functions that relate harvest to inventory and price levels.

The market determines the economic impacts. These vary between species, regions, product and stumpage markets, and over time. Impacts in the near term are modest except for softwoods in the South where stumpage prices increase by 27% by 2000. They rise most rapidly in the near term as slow, downward capacity adjustments (modeled as a function of profitability) lead to tight stumpage markets. Overall, the price impacts for this future are the most severe of all of the futures in the softwood sector.

The biological and economic impacts associated with growth declines differ. The biological impacts, other than for growth, are slow to develop. Reduced growth rates eventually lower timber inventories (which lower harvests) and could, in the longer term, affect the mix of species. The most severe economic impacts are in the South, and especially in the Southeast where declines in growth further aggravate expected declines in softwood inventories shown in the base Assessment projection. Economic impacts for both the North and for hardwoods, in general, are more modest.

Another way to gauge the economic impacts is to look at which groups (consumers, producers, and stumpage owners) gain or lose because of growth reductions associated with acidic deposition. Sample impacts are shown as follows:

	Consumer expenditures	Southeast lumber producers' revenues*	Southeast stumpage owners' revenues
		billion 1982 dollars	
2000	.57	−.15	.03
2020	2.82	−.06	—
2040	2.16	−.03	.06

*Computed as profit per thousand board feet times production.

As a group, consumers are the most impacted as increased lumber prices due to reduced growth raise consumer expenditures. Changes in consumer expenditures for softwood lumber average $15 (1982 dollars) per household by 2040. In the near term (during the next two decades), potential changes in consumer expenditures are partially reduced by increased production in other regions including those in Canada. By 2020, the opportunities for this offsetting production are exhausted, increasing total impacts. Producers generally lose revenue as stumpage prices increase in affected regions faster than final product prices. In the South, these losses are greatest in the next decade but fall after 2000 as producers reduce lumber capacity in response to lower harvest levels and higher stumpage prices. One interesting note is that reduced growth leads to increased plywood profits and production levels in the Southeast. As less timber becomes available, there is a shift from lumber to plywood production in the Southeast resulting from the availability of alternative sources for lumber relative to those for plywood.

In spite of lower harvest levels (because of reduced timber inventories), stumpage owners see increased revenues in the long run derived from the sale of sawtimber because of higher stumpage prices.

Greater Forest Management

As described in Chapter 9, there are economic opportunities to increase timber inventories on private timberlands. In this future, the impact of increasing investment levels above those in the base Assessment projection were analyzed. Specifically, investment levels were increased to include those economic opportunities whose average rates of return were 10% or greater.

As shown in table 124 the impacts of increased investments on private timberlands are substantial. Softwood timber harvests, net annual growth, and inventories are all higher than in the base projection. Softwood timber inventories are 8.1% greater in 2040 for private timberlands in the South. This pattern in growth, inventories, and harvests illustrates how timber markets function. Growth increases are noticeable first. These lead to increases in inventories and finally (in later decades) to increases in harvest. The impacts on the softwood forest resource are primarily felt in the South where the bulk of private timberland is located.

The economic impacts associated with this future are explained in Chapter 9.

Reforestation of Surplus Cropland

Important factors that influence the amount of cropland—such as changes in the domestic and international demand for agricultural products and changes in agricultural production technologies—are difficult to project and result in uncertainties regarding their possible impact on future land reallocation. These factors may have unanticipated effects on the amount of land needed for agricultural production. This future examines the effect of reducing the acres of cropland in production on the availability of timberland acres. This future assumes that all surplus cropland[36] projected by the Second RCA Appraisal (USDA SCS 1987) will revert to natural vegetation, either range or forest. It tests the sensitivity of future natural resource production to changes in the agricultural land base.

Idle cropland area was determined from the 2030 intermediate scenario projections in the 1988 RCA Appraisal (USDA SCS 1987). The Second Appraisal projects the availability of 386.8 million acres of cropland in 2030. Of this total, 218.5 million acres are assumed to be used for crop production, 39.8 million are assumed to be enrolled in the Conservation Reserve Program, and 128.5 million acres are assumed to be idle (land that will not be needed for agricultural production).

Of the 128.5 million idle acres, most is projected to revert to range (96 million acres). An additional 15.6 million acres is projected to revert to hardwoods, 15.4 million to hardwood/softwood, and 1.5 million acres to softwood types. Roughly 40% of the idle cropland available for reversion to forest was accounted for in the initial base timberland assumption. The remaining acres are expected to add 19.1 million acres to the timberland base over the next 20 years. In this future most of these acres consist of hardwood and hardwood/softwood types and occur primarily in the North and the South.

The effect of these increases in timberland area by 2040 is to raise private timberland inventories 2.9% and 10.8%, respectively, for softwoods and hardwoods (table 124). The largest increases are for hardwoods in the North and in the Pacific Coast. While these changes in timber inventories are large, they have limited market impacts since most of the increase involves hardwood types where there is already abundant supplies. Stumpage prices, by 2040, in the North are 6% less and in the South 11% less than those in the base run. These lower stumpage prices lead only to a small (less than 1%) change in hardwood timber demand.

[36] *Surplus cropland as defined in the RCA Appraisal are those acres that are currently cropped that would be in surplus (i.e., not needed to meet projected demands) in the future if a least cost method is used to meet food and fiber demands in the United States, under "intermediate" supply and demand assumptions.*

Changes in National Forest Timber Harvests

In the last two decades, it has become increasingly clear that the future of timber production on the national forests depends in part on (1) success in finding suitable ways to integrate timber production with other uses of forest land, and (2) the need to protect and maintain the forest environment, including endangered and threatened species. The controversy surrounding habitat protection for the spotted owl illustrates the increasing constraints on timber production on the national forests. In this section, two futures are presented to address these two issues. The total national forest harvest levels for each case are shown as follows:

	Base assessment projection	Reduced national forest harvest	Spotted owl
		billion cubic feet	
1986	2.07	2.07	2.07
2000	2.00	1.70	1.86
2010	2.17	1.85	2.03
2020	2.23	1.90	2.09
2030	2.28	1.95	2.13
2040	2.32	1.99	2.18

The reduced national forest harvest level was initially specified to be a 20% reduction, but in the actual simulations the reduction is roughly 15% because of the difference between sales offered and sold in the Rocky Mountains. In this simulation, some of the reduction in national forest harvest is assumed to come from those sales that while offered, would not be sold. Consequently, harvest reductions come primarily in the Pacific Coast states and in the South.

Reduced National Forest Harvest

The first future illustrates a future where national forest harvest levels are reduced from 2.3 billion cubic feet per year to 2.1 billion. This decrease in national forest harvest is partly offset by changes in harvests of other owners or in other regions. In regions, where there are sufficient private timber supplies, decreases in national forest harvest lead to higher stumpage prices that, in turn, increase timber harvests from private timberlands. For example, the national forest harvest in the Douglas-fir subregion is reduced by 96 million cubic feet per year. Total harvest, however, is reduced by only 40 million cubic feet by 2000—private harvests having increased by 56 million cubic feet per year. In the Douglas-fir subregion, these offsetting changes cannot be sustained after 2000 because of a worsening timber inventory situation. In other sections, such as the Rocky Mountains, the reduction in national forest harvest is partly offset throughout the projection period.

Under this future, declines in timber inventories are reflected in intensified competition for the available timber and higher prices for softwood stumpage prices. Those in the Pacific Northwest, for example, are 17% above the base by 2040.

Softwood lumber prices are 2.4% higher in 2040 than in the base Assessment projection (table 124). Because of the lumber price increases, total lumber consumption is down 1.2% and lumber imports from Canada are up 21% by 2040. The increase in lumber imports comes progressively after 2000 because domestic production is reduced as a consequence of the lower timber inventories and the associated higher prices. By 2040, domestic lumber production is 5.2% less than the base Assessment projection. There are different impacts among regions. The largest impacts are in the western states, particularly the Pacific Northwest with its large national forest resources.

There are no significant impacts on the hardwood resource associated with this future, further illustrating the small role of national forests in the hardwood sector.

The Northern Spotted Owl

The recent national forest and Bureau of Land Management controversy over old-growth retention and proper forest management practices has centered in the Douglas-fir subregion. This issue concerns further retention of old-growth forests than was planned to ensure survival of species such as the Northern Spotted Owl.[37] Exact acreage reductions and the affects on timber harvest are unclear until a protection policy is adopted. However, a mid-range harvest level from the Spotted Owl Environmental Impact Statement (USDA FS 1988a) suggests that national forest harvest in the Douglas-fir subregion could be reduced by 25%, assuming that 25% of the region's harvest came from old-growth stands.

Figure 62 shows the total harvest. National forest harvest was reduced over the next 3 years by 150 million cubic feet in the Douglas-fir subregion leading to roughly a 5% reduction in the total harvest for the subregion. This leads to higher stumpage prices and higher harvest on private lands. In 2000, harvest increases of 49 million cubic feet on forest industry timberlands and 20 million cubic feet on nonindustrial timberlands offsets the 150 million cubic feet decline. The actual harvest decline in 2000 following these changes is 73 million cubic feet.

[37]*The various viewpoints are summarized in publications such as "Pacific Northwest Lumber and Wood Products: An Industry in Transition" (Olson 1988) and "Spotted Owls, Old Growth and the Economy of the Northwest" (Northwest Forest Resource Council 1989).*

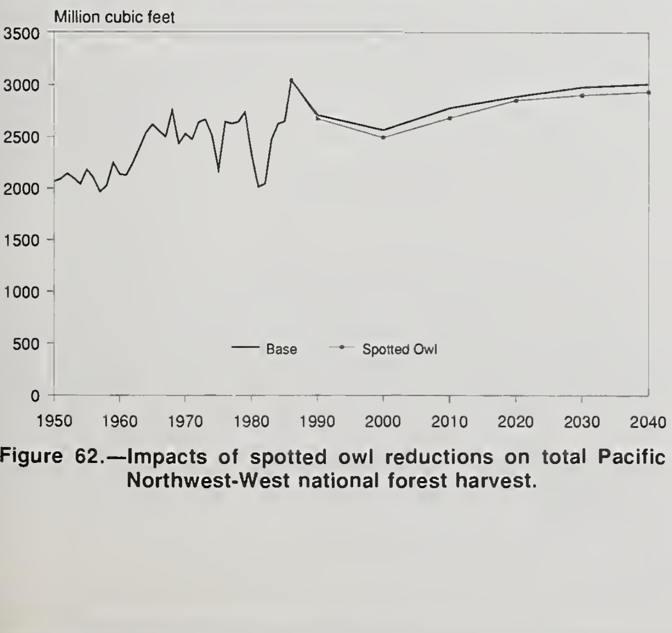


Figure 62.—Impacts of spotted owl reductions on total Pacific Northwest-West national forest harvest.

Nationally, the effects of this future are modest relative to other futures (see table 124). It raises softwood product and stumpage prices and lowers U.S. consumption and production. Its impacts are most severe in the Douglas-fir subregion where higher stumpage prices lead to lower harvest and production levels.

Increased Recycling

This future examines the impacts of further increases in recycling in the forest sector. There is a growing interest in the impact of increased use of wastepaper as raw material for paper and board production. Producers in other developed countries (e.g., Japan and European countries) use about twice as much wastepaper as raw material for the production of paper and board as U.S. producers. In the United States this recent interest seems to stem largely from concerns about waste disposal rather than concerns about raw material availability. In this future, the impacts of increasing wastepaper use to 39% of total fiber furnish are examined (see table 91 for the assumptions used in the base projection).

Increased recycling leads to a 3.7% reduction in total demand for forest products by 2040 (table 124). Consumption by sawtimber and pulpwood is shown in the following tabulation:

	Sawlogs		Pulpwood	
	Base	Recycle	Base	Recycle
	billion cubic feet			
1986	9.0	9.0	5.8	5.8
2000	8.2	8.2	7.4	7.1
2020	9.5	9.6	9.6	8.4
2040	9.6	9.9	10.8	8.9

By 2040, we are using 17.6% less pulpwood as a result of increased use of wastepaper. Some of the wood that would have been used as pulp is being used for the manufacture of other products especially lumber (note that sawlog consumption is increased). U.S. softwood lumber consumption rises 2.7%, imports of softwood lumber from Canada drop by 57.6%, and U.S. softwood lumber production rises by 14.3%.

Table 124 shows the reductions in harvest for both softwoods and hardwoods. The largest harvest reductions are for softwoods, particularly in the Pacific coast states where harvest falls both because of lower pulpwood use and because lumber and plywood production falls as a result of increased product production in the South. Reductions in the South are larger for hardwoods than for softwoods. Another way to look at this is in terms of reductions in acres harvested because of increased recycling. As the use of wastepaper increases, fewer acres are harvested each year (440,000 acres less in 2010). The bulk of these acres are in the South and are evenly split between hardwoods and softwoods.

Changes in wood prices are another way to gauge the impact of increased use of wastepaper. In the South, the reductions in harvest have fairly substantial price impacts. By 2010, sawtimber stumpage prices are expected to be reduced by 21.5%. This makes the region more competitive compared to, say, Canada and raises lumber production by 36% by 2040. Hardwood sawtimber stumpage prices, on the other hand, are reduced by only .5% reflecting the relatively abundant supplies of hardwood pulpwood and the limited interaction between hardwood pulpwood and sawtimber markets.

Higher Housing Starts

The last alternative future deals with higher housing starts due to a higher level of replacement home starts. The base projection assumed that replacement rates (new housing starts that replace units discarded from the housing stock) remain at roughly their current level[38] leading to a progressive aging of the housing stock.

If the average age of the single-family housing stock is roughly 50 years and if replacement rates continue at their current levels, then the average age of the housing stock can be expected to increase to roughly 100 years over the projection period. The plausibility of such a future is questionable but one issue of interest is the affect on housing starts (and the forest sector) of altering the replacement rate assumption after 2010 in an attempt to reduce the rate of increase in the average age of the housing stock by 2040. Such a future would also increase the demand for solid-wood products in the later half of the projection period.

In this future, the replacement rate (fraction of the stock replaced) assumption for single-family homes was increased from .35% per year to .68% per year by 2040. The impact of this change on housing starts is shown as follows:

	Base		Alternative	
	Replacements	**Total**	**Replacements**	**Total**
		millions of starts		
2010	.815	1.678	—	—
2020	.846	1.850	.960	1.964
2030	.886	1.691	1.120	1.925
2040	.919	1.545	1.320	1.945

All of the increase is in single-family starts that rise 32% over the base by 2040. This increase in construction activity raises lumber consumption by 5.3% in 2040 (table 124) over the base projection and leads to increases in stumpage prices in all regions during the last two decades of the projection period.

Most of the increased lumber consumed is imported from Canada. U.S. production increases after 2010 by only 578 million board feet. Plywood consumption and production increases by 1.6%. Plywood production increases after 2010 by 377 billion square feet. Most of this increment comes from the Douglas-fir and Southern regions.

IMPLICATIONS

There are a number of implications that can be drawn from these alternatives for the future of the forest sector. In general, they all portray a future for the next two decades that is consistent with past assessments (USDA FS 1958, 1965, 1973, 1982, 1988b). That is, a future where there is continued growth in consumption, less rapid growth in timber inventories, and rising real prices for stumpage and products. After 2010, these projections diverge from the traditional view of the future in that slowing consumption and increasing timber inventories reduce and/or stabilize the rate of price growth. Individual alternatives alter this pattern by changing timber supplies or product demands.

The implications of these alternative futures can, in general, be divided into four groups: increases in product demand, changes in private timber inventories, reductions in demand, and changes in national forest harvest levels. In addition, there are implications for three special situations of current or emerging interest: the hardwood sector, timber supply in the Douglas-fir subregion, and a transition in timber inventories.

Increases in Demand

The demand for forest products increases faster than available timber supplies for the next several decades. Only a severe economic downturn could reduce this near-term increase in demand. Some of the events leading to the expected near-term increases in stumpage and product prices have already occurred such as the age class problems that are embedded in the current timber inventory. In the longer term, however, growth in demand for solid-wood products slows to about that for timber supplies. This results in stable to declining stumpage prices and slower growth in solid-wood product prices. The changes embodied in the alternative futures do not alter these basic prospects for the next two decades.

Two futures involve long-term increases in demand for various forest products. The increased exports and higher housing starts futures both increase product demand in the longer term and have similar impacts on aggregate product production and prices. Regional impacts differ, however, because in the increased export future, rising timber demand for lumber exports is partially offset by declining log exports in the Pacific Coast Region. Both futures demonstrate that only small changes in quantities are necessary to alter the long-term price projections in the base assessment projection. They also demonstrate that by 2040 ample timber supplies reduce potential price increases to about a fifth of what might have been in the near term.[39]

Changes in Private Timber Inventories

Three of the alternative futures deal with changes in private timber growth and inventories. Two deal with increases (surplus cropland and increased forest management investment) and one deals with lower rates of

[38] *Current replacement rates for single-family units are .35% per year, i.e., .35% of the housing stock is retired and replaced each year.*

[39] *The implied price elasticity for softwood lumber in the higher housing start simulation is 2.4 in 2040, about 5 times as large as the near-term elasticity.*

timber growth. These futures illustrate several points. Foremost is that changing growth or adding unstocked land to the timber base does not have an immediate impact on forest markets. The effect is delayed, in some cases for several decades, until timber inventories (particularly available inventory in older age classes) have changed sufficiently to alter the behavior of private timber supplies.

The projections of hardwood sawtimber markets are relatively insensitive to change in timber inventories and conditions as portrayed in both the surplus cropland and lower rate of timber growth futures. Although private hardwood supplies are dependent on inventory levels, as is the case for softwoods, the inventory changes brought about by these futures are small relative to the total stock so that the supply and price impacts are minimal.

Reductions in Demand

Two futures involve reductions in the demand for timber: first, improved recovery lowers the demand for roundwood (mostly sawtimber) used in solid-wood products; second, increased use of recycled fiber lowers the demand for roundwood (mostly nonsawtimber) used for pulp products.

The current level of recycling is 20.4% of fiber furnish. While this reflects a slight increase over the last decade (up from 19.7% in 1976), it is still less than the 29.9% used in 1952. One reason for this long-term decline has been relative costs. Unlike Japan and most European countries (where use of wastepaper is much higher), virgin fiber costs in the United States are low relative to recycled fiber in a variety of paper grades and are expected to remain low in the future.

Changes in National Forest Harvests

After 2010, harvest increases on private timberlands reduce the role of the national forests in the overall timber supply outlook. That is not to say that national forest harvest flows become less important in all regions. The western regions maintain their dependence on national forest harvest flows but increases from private timberlands in the North, South, and in the Douglas-fir subregion alter the national mix of timber harvests. This shift in harvest patterns mirrors a shift in production of solid-wood products to those regions with a large private timberland base.

While changes in national forest timber supply have their greatest effects in western regions, all regions must compete in what are essentially national markets for wood and fiber products. Through these product/market interactions, shifts in national forest supply potentially influence producers and consumers in all parts of the United States and in Canada. In deliberating the merits of draft forest plans and proposals for expanded old-growth reserves, policymakers and those who wish to influence policy must address an array of questions relating to the interregional and national impacts of potential national forest supply shifts. How will proposed changes alter regional patterns of development and employment in the forest sector? What will be the impact on trade in commodities such as softwood lumber that is a major product from national forest timber? Finally, how will supply changes affect consumers of forest products?

Viewed from the national level, market changes in the reduced national forest harvest future appear modest, though predictable in terms of direction. Wood products prices increase, consumption and domestic production fall, and softwood lumber imports rise. Substitution effects, both of timber harvest among forest owners and of product supply across regions, play a central role in limiting aggregate changes. At the regional level, however, there are major shifts in the geographic concentration of national forest harvest and far larger impacts on output and employment. In effect, losses in the Pacific Coast regions are redistributed to the Rocky Mountains and eastern regions. Though total national forest system harvest falls, there are significant interregional trade-offs.

Further harvest reductions in the Douglas-fir subregion under the spotted owl future have only modest impacts on other domestic regions. While there is some response to higher product prices, the bulk of the long-term adjustment is born within the Douglas-fir subregion and by lower domestic consumption and expanded lumber imports. Private lands in the Douglas-fir subregion have limited capability to expand harvest in substitution for reduced national forest supply. Unlike other regions, the net harvest change in the Douglas-fir subregion would exceed the change in national forest cut alone within a decade of the initiation of the spotted owl future. In this instance, trade-offs involve the diverse benefits of expanded old-growth reserves, some of which may not be geographically constrained, against relatively localized economic and employment losses.

The Hardwood Sector

In all of these futures, the impact on the hardwood sector is much the same. Perceptions of the sector have been largely set by the notion that sawtimber of select species is declining in availability. This quality issue dominates most discussion of the hardwood sector. In this Assessment, hardwood demand is portrayed as increasing as a result of increases in pallet production and substitution of hardwoods for softwoods in solid-wood applications and in fiber for pulp and paper. These expected changes differ from the situation familiar to many where hardwood consumption remains relatively stable. The last decade, in fact, has seen hardwood harvest from growing stock sources increase by 40%. Increases as large as these, but at a diminishing rate, are expected to continue for the next several decades and hardwood harvests are expected to increase faster than softwood harvests. Changes are expected in how hardwood harvest are used. For example, the share of harvest used as

A logger on a national forest sale in the Douglas-fir subregion.

sawlogs declines as the pulpwood share increases. By 2040, the share of harvest being used as pulpwood has increased to nearly 50%. The proportion of harvest used as fuelwood is expected to continue increasing for the next several decades before stabilizing late in the projection period.

In terms of traditional forestry concerns, several questions evolve from this expected future for the hardwood sector. First, there are the prospects for impacts associated with the expected increases in the harvest of hardwoods especially for low-valued products such as fuelwood and pulpwood. Second, hardwood timber supplies are expected to grow fast enough to prevent stumpage price increases except in the case of sawtimber, especially in the North. Third, new products, such as OSB-waferboard, are not expected to impact the sector except as a user of lower quality material. Lastly, hardwood lumber production may experience some locational instability as comparative production costs shift.

The Douglas-Fir Subregion

Of special interest is the future for the Douglas-fir subregion where reductions in public timber harvest have large impacts. One question of importance is where will the timber come from that will supply the forest products industry in this subregion. A related question deals with the extent to which the industry in the subregion will be forced to restructure. This Assessment presents one view of where the timber will come from in the next several decades.

As a matter of perspective, timber harvests in the Douglas-fir subregion for the last 3 years (1986–1988) were at all time highs. The 1988 harvest is estimated to have been 2.73 billion cubic feet, down slightly from the 1987 estimated harvest of 2.78 billion cubic feet. Figure 63 shows harvest by owner. The smallest ownership (in terms of harvest) has been the nonindustrial (other private) timberland owners. Harvest on this ownership has been stable to declining since the early 1950s until the last several years when harvest has started to increase. Changes have also taken place in the mix of products produced in the subregion. The most important product continues to be lumber, while the second most important product has been veneer until recently when the volume harvested for export logs exceeded that for veneer. In 1988, 25.2% of the harvest is estimated to have been exported from the region as logs. The future industry in the region is expected to be closely related to the current industry as little change is expected in the mix of industry. The drop in plywood production is the consequence more of competition from OSB-waferboard than from timber supply problems. Finally, the regional differences in wage rates that once accounted for differences in manufacturing costs have rapidly disappeared in the last 15 years as employers have moved in the direction of low wages. This movement has led to a convergence of wage rates and consequently processing costs between former higher and lower cost producers.

Total harvests in this subregion are projected to fall 12% in the near future as a consequence of declines on forest industry lands and public timber harvests (fig. 63). This decline is no longer expected to be as severe is it was a decade ago. After 2000, harvests stabilize at around 2.7 to 2.8 billion cubic feet per year. In the perspective of the past several decades, future harvest levels are expected to be like those seen in the past decade. These projections depend, however, on the assumption that national forest harvest levels will remain at the levels observed over the past 15 years. In terms of sawtimber size material, however, harvest declines continue.

While the Douglas-fir subregion and the other western regions are expected to maintain recent harvest levels, they collectively lose market share to the eastern regions in the next two decades. In the longer term the market share of western regions stabilizes at roughly 40%. Much of the loss in market share has already taken place. The most rapid time of change was during the period 1976–84 when the western market share decreased on the average of 2% per year.

Returning to the original question of where will the timber come from?—if the national forest harvest stays at recent levels, than expected declines on forest industry timberlands can be partially offset by increases from the nonindustrial ownership. This process has already started and will peak just after 2000. After 2010, managed stands on forest industry timberlands will support increasing timber harvests. This transition in the Douglas-fir subregion is expected to stabilize harvest.

Transition from Natural to Managed Stands

These projections (especially the base Assessment projection) show that the transition from natural stands to managed stands on forest industry timberlands is completed after 2000 in the South (fig. 64) and 2010 in the Douglas-fir region (fig. 65). In both figures 64 and 65, this is shown by the shift in the age class distribution to younger stands. By 2010, both regions have forest industry timber inventories that are relatively balanced across a narrow range of age classes.[40] In the Northwest, the timber available for harvest will range from 40–60 years old. In the South, specifically the Southcentral subregion, the harvest ages will range from 20–30 years.

This transition is not smooth because of age class imbalances in both the South and in the Douglas-fir subregion. Both regions presently have extensive volumes of areas of young stands that are expected to reach merchantable sizes (ages) soon after 2000. Until then, most harvest is expected to come from stands of natural origin that have only recently been subject to management practices. The availability of these stands are expected to diminish rapidly by the mid 1990s, leading to stumpage price increases.

These projections show an inventory changing rapidly over the next two decades. Older stands are completely harvested and the future inventory represents an ownership that has been implicitly regulated. Harvest currently comes from a broad spectrum of age classes now but in

[40]*Five-year age classes are used in the South while 10-year age classes are used in all other regions.*

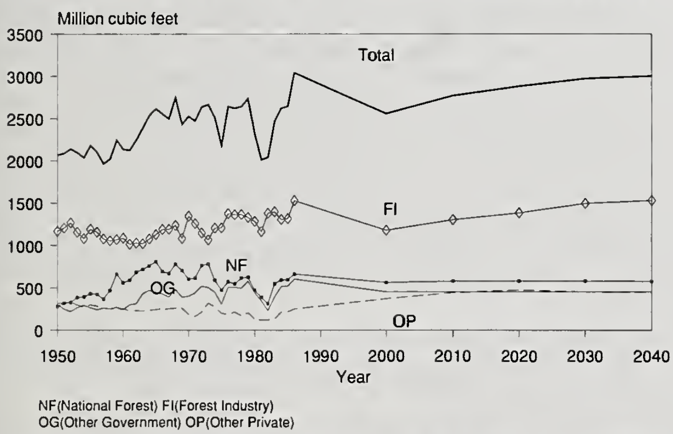


Figure 63.—Pacific Northwest-West total harvest, by ownership, 1950–1986, with projections to 2040.

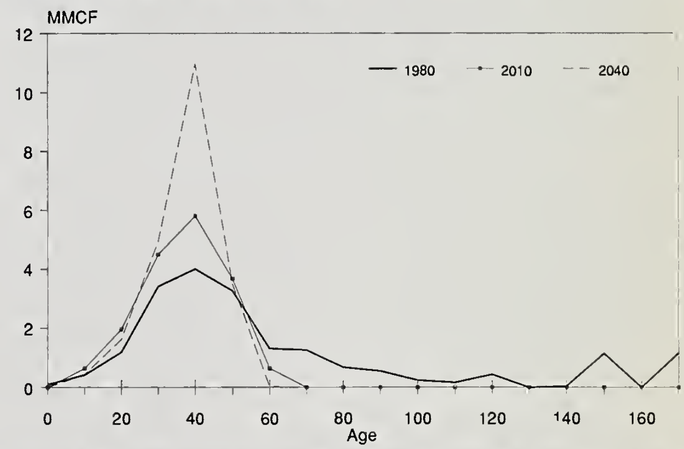


Figure 65.—Pacific Northwest-West forest industry inventory volume by age.

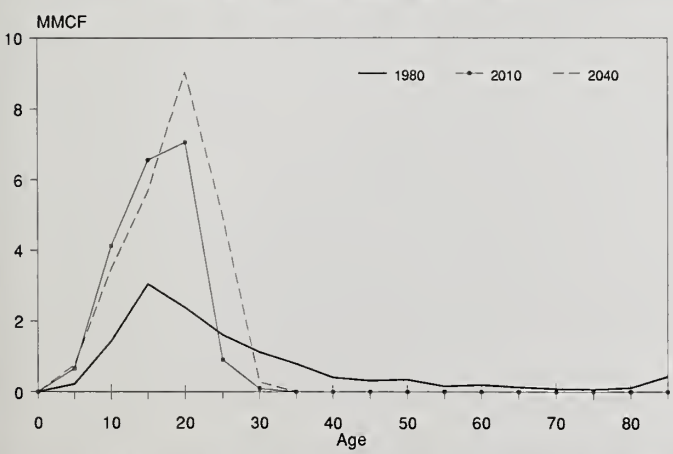


Figure 64.—South Central forest industry inventory volume by age.

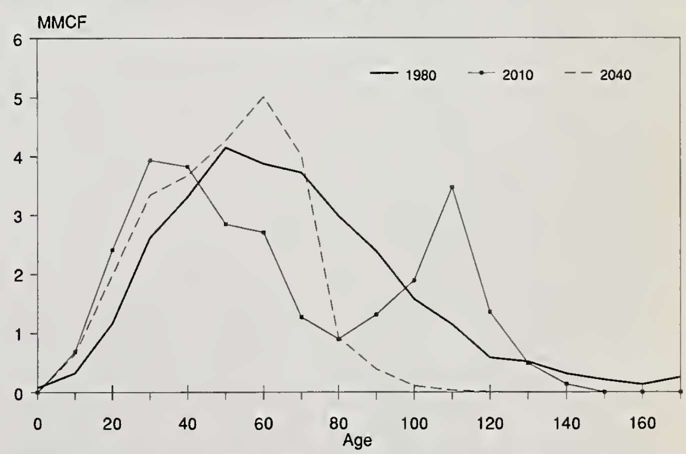


Figure 66.—Southeast other private inventory volume by age.

two decades it will almost entirely come from stands that are now considered to be at minimum harvest age. This raises questions about the quality of that timber and the ability to supply markets that have specific size, ring count, and limb size requirements.

Projections for the nonindustrial ownership show a different future (as illustrated for the Southeast in fig. 66). No forest regulation scheme will characterize this ownership and the change in harvest age is not expected to be as severe. Consequently, this ownership will still hold older and presumably more valuable timber. The nonindustrial ownership also faces a problem of age class imbalance but it is not expected to be resolved until late in the projection period (see the plots of 2010 and 2040 in fig. 66).

SUMMARY

The softwood lumber price index is often used as a general measure of the overall economic situation in the U.S. forest sector. In the base Assessment projection, it is projected to increase at an annual rate of 1.2% between 1986 and 2010 and .2% between 2010 and 2040. In the sense of an overview, which future affects the softwood lumber price index most? Figure 67 shows the softwood lumber price index from the base Assessment projection and four other futures that trace the bounds of the effects on the index. Two futures result in lower projected increases in the softwood lumber price index: increased

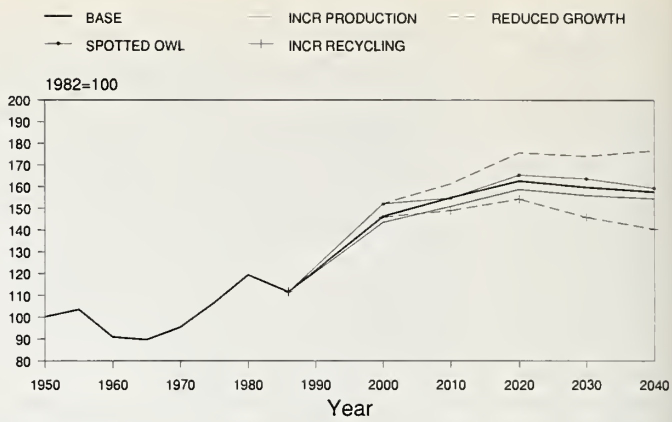


Figure 67.—Softwood lumber price index, 1950–1986, with projections to 2040.

productivity through improvements in processing efficiency, and increased recycling. Both of these futures reduce the demand for roundwood, lower wood costs, and finally total costs. The Spotted Owl and reduced growth futures lead to higher rates of projected price increases. The Spotted Owl future affects timber supplies immediately while the lower growth rates future impacts timber inventory levels only in the longer term. Both of these futures also illustrate how regional issues (the Spotted Owl issue is centered in the Douglas-fir subregion and lower rates of timber growth focuses on the East) can impact the entire forest sector.

CHAPTER 9. OPPORTUNITIES FOR INCREASING PRODUCTIVITY ON TIMBERLANDS

Existing timberlands have the potential to produce much larger quantities of timber, with positive economic returns, than they do today. In addition, in some regions there are large areas only marginally productive in crop or pasture use that would be suitable for growing trees. Only a part of this potential increase in productivity on timberlands is reflected in the projections discussed earlier. If more of the opportunities to increase timber supplies were used, it would be possible to produce greater quantities of timber products at lower costs. Achieving this increase in productivity would require time and substantial investments in a variety of research, forest management, and landowner assistance programs. It would also require accommodation of timber production and other benefits derived from timberland, such as recreation, wildlife habitat, and water quality.

This chapter takes a look at several measures of the productivity of the Nation's timberlands over the past three and a half decades. It reviews recent trends in research and timber management activities that have increased the productivity of timberlands, and it quantifies the opportunities that currently exist to achieve further increases in timber growth through investments in forest management on private lands other than forest industry lands. Finally, it discusses some of the policies and programs that have encouraged investments in timber management by private owners in the past and some of the economic and institutional factors that could determine whether the needed investments are made in the future. The following chapter will review other means to increase timber supplies and improve productivity in forestry by increasing the efficiency of harvesting, processing, and end use of timber.

FOREST PRODUCTIVITY TRENDS FOR TIMBER IN THE UNITED STATES[41]

Measures of Forest Productivity

Productivity, in economic terms, is defined as real output produced per unit of input employed in production. Productivity measures describe the quantitative relationship between inputs and outputs. They are different, therefore, from either measures of the quantity of production alone or measures of economic efficiency, which take into account the value of the inputs and outputs. Although measures of productivity for farm production have been in use for many years, similar measures for forestry have not been available. The forest productivity measures discussed here pertain to only one of the many important outputs from forests—timber. Forest productivity for timber is calculated as the ratio of the physical or real quantity of timber produced to the physical or real quantity of forest inputs employed in its production.

[41]*Most of the material in this section is taken from Ince and others (1989).*

Many inputs are employed in production of timber. The primary forest input of economic value is capital in the form of the timber growing stock resources of the forest. Timber growing stock volume (or "inventory") serves as a real measure of timber capital input employed in the production of timber. Another important forest input in production of timber is land. Timberland acreage serves as a real measure of forest land input employed in production of timber.

Real measures of timber output include timber growth and timber removals. Timber growth represents a purely biological measure of timber output. It is the amount of timber produced in the forest and stored on the stump for both present and future consumption. Timber removals are more of an economic measure of timber output and represent mainly the quantity of timber removed in commercial timber harvesting for present consumption. Whereas timber growth reflects the biological timber output of the forest, timber removals reflect wood market requirements and trends in harvesting and wood utilization technology.

Tables 126 and 127 contain data on timberland area, net annual growth, annual removals, and growing stock inventory in the United States, by ownership and section, for the years 1952, 1962, 1970, 1977, and 1987. These data are derived from the continuous forest surveys conducted by the USDA Forest Service. Growth, removals, and inventory are shown separately for softwoods (table 126) and hardwoods (table 127), since management and utilization of softwood and hardwood species have been very different over time. These tables also include three measures of forest productivity for timber, by ownership and section: (1) timber growth per acre, (2) the ratio of timber growth to inventory (growth/inventory), and (3) the ratio of timber removals to inventory (removals/inventory).

The ratios of growth to inventory and removals to inventory are displayed as indexes. The data value for growth, removals, or inventory for a given year is divided by the data value for 1977, and then multiplied times 100 to provide an index with 1977 = 100. 1977 was chosen as a base year for comparability with other USDA statistics and to provide a benchmark measure of change since the 1980 Assessment. The growth/inventory index is calculated by dividing the growth index by the inventory index. The removals/inventory index is calculated by dividing the removals index by the inventory index. The indexes highlight the magnitude and direction of change over time within each ownership class or each section. The indexes do not, however, allow direct comparisons of the absolute levels of inputs or outputs between ownership groups or sections. It should also be remembered that, although these productivity measures are developed in relation to a single input (timber capital or timberland), timber outputs are affected by a number of interrelated inputs, including the inputs of labor and forest management.

Table 126.—Timberland area, timber growth, removals, and inventory, growth per acre, and forest productivity indexes (1977 = 100) for softwoods in the United States, by ownership and section, specified years 1952–1987.

		Softwoods					
						Productivity indexes	
Year	Timberland area	Net annual growth	Annual removals	Total inventory	Annual growth per acre	Growth/ inventory	Removals/ inventory
	Million acres	*Billion cubic feet*			*Cu. ft.*		
United States, all owners and sections							
1952	509	7.7	7.8	430	15.2	67	83
1962	515	9.6	7.6	448	18.7	80	79
1970	504	11.3	9.3	458	22.5	92	94
1977	491	12.5	10.0	465	25.5	100	100
1987	483	12.9	11.4	451	26.6	106	117
Forest industry							
1952	59	1.9	2.8	77	31.7	61	74
1962	61	2.3	2.3	76	37.9	77	62
1970	68	2.6	3.1	75	38.9	88	85
1977	69	2.9	3.6	74	42.8	100	100
1987	71	3.2	4.2	72	45.5	112	119
Other private							
1952	297	3.5	3.5	94	11.7	78	131
1962	301	4.3	3.0	103	14.4	88	102
1970	286	5.2	3.3	114	18.3	96	102
1977	278	5.9	3.5	124	21.2	100	100
1987	276	5.5	4.2	135	19.8	85	109
National forests							
1952	95	1.7	1.0	204	17.6	69	53
1962	97	2.0	1.7	214	20.6	79	85
1970	95	2.4	2.2	212	25.0	94	106
1977	89	2.5	2.0	208	27.8	100	100
1987	85	2.8	2.1	186	33.0	127	116
Other public							
1952	58	0.7	0.4	55	12.6	66	52
1962	56	1.0	0.6	56	17.2	85	69
1970	56	1.1	0.8	57	20.0	96	89
1977	56	1.2	0.9	59	21.4	100	100
1987	51	1.4	0.9	57	27.0	120	105
South							
1952	205	3.6	3.1	59	17.8	97	117
1962	209	4.7	2.8	73	22.5	101	86
1970	203	5.6	3.7	87	27.8	102	95
1977	198	6.3	4.4	99	31.8	100	100
1987	195	5.8	5.7	104	29.9	88	123
West[1]							
1952	150	3.1	4.0	344	20.8	63	77
1962	150	3.7	4.3	341	24.7	75	82
1970	146	4.4	5.0	332	29.8	91	99
1977	139	4.6	4.9	322	33.2	100	100
1987	133	5.7	4.9	300	43.0	133	108
North							
1952	154	1.0	0.6	27	6.3	101	148
1962	157	1.2	0.5	34	7.7	101	101
1970	154	1.3	0.6	39	8.7	97	95
1977	153	1.6	0.7	44	10.2	100	100
1987	155	1.3	0.7	47	8.3	76	97

[1]*The West includes the Rocky Mountains and Pacific Coast.*
Source: Ince et al. 1989. Data have been revised slightly since publication of the earlier report.

Table 127.—Timberland area, timber growth, removals, and inventory, growth per acre, and forest productivity indexes (1977 = 100) for hardwoods in the United States, by ownership and section, specified years 1952–1987.

		Hardwoods					
						Productivity indexes	
Year	Timberland area	Net annual growth	Annual removals	Total inventory	Annual growth per acre	Growth/ inventory	Removals/ inventory
	Million acres		*Billion cubic feet*		*Cu. ft.*		
United States, all owners and sections							
1952	509	6.2	4.1	180	12.1	95	139
1962	515	7.1	4.3	211	13.8	93	127
1970	504	8.5	4.2	236	16.8	99	111
1977	491	9.4	4.2	260	19.2	100	100
1987	483	9.7	5.1	305	20.0	87	103
Forest industry							
1952	59	0.7	0.5	20	11.7	90	139
1962	61	0.8	0.7	25	13.5	87	142
1970	68	1.1	0.6	29	15.8	97	106
1977	69	1.2	0.6	32	17.7	100	100
1987	71	1.2	0.8	35	16.4	86	124
Other private							
1952	297	4.6	3.3	131	15.5	95	139
1962	301	5.1	3.4	149	17.0	93	127
1970	286	6.1	3.3	164	21.3	100	112
1977	278	6.7	3.2	181	24.1	100	100
1987	276	6.9	3.9	214	25.0	87	102
National forests							
1952	95	0.4	0.1	13	4.2	96	142
1962	97	0.5	0.1	17	5.2	96	121
1970	95	0.6	0.1	19	6.1	98	126
1977	89	0.7	0.1	21	7.4	100	100
1987	85	0.6	0.2	25	7.3	81	107
Other public							
1952	58	0.5	0.1	16	8.5	94	107
1962	56	0.6	0.2	21	11.4	96	89
1970	56	0.7	0.2	24	13.4	98	99
1977	56	0.8	0.2	26	15.1	100	100
1987	51	1.0	0.2	31	19.0	97	81
South							
1952	205	3.0	2.6	84	14.9	84	153
1962	209	3.4	2.7	95	16.3	83	150
1970	203	4.3	2.3	104	21.1	96	119
1977	198	5.0	2.2	116	25.2	100	100
1987	195	4.6	3.0	134	23.4	79	114
West[1]							
1952	150	0.4	0.0	19	2.6	80	44
1962	150	0.5	0.1	22	3.3	87	63
1970	146	0.6	0.1	25	4.1	94	93
1977	139	0.6	0.1	25	4.5	100	100
1987	133	0.9	0.1	31	6.4	108	76
North							
1952	154	2.7	1.5	77	17.8	112	126
1962	157	3.2	1.5	95	20.5	107	106
1970	154	3.6	1.7	107	23.3	106	106
1977	153	3.8	1.8	119	24.7	100	100
1987	155	4.2	2.0	140	27.3	95	94

[1]*The West includes the Rocky Mountians and Pacific Coast.*
Source: Ince and others 1989. Data have been revised slightly since publication of the earlier report.

Forest Productivity Trends, 1952–87

Timber growth per acre shows the trend in real biological timber output per unit of land area available for production of timber. This area, of course, includes many acres where production of timber is not the primary objective of the landowner. The growth/inventory index shows the trend in real biological timber output per quantity of timber capital employed in production of timber. The removals/inventory index shows the trend in timber output primarily for market per quantity of timber capital employed in production of timber.

These productivity measures reflect some of the major changes in the timber resource situation discussed in Chapter 3. The growth per acre trends for all owners (fig. 68) indicate that the biological productivity for timber of U.S. forests has increased substantially since 1952. Growth per acre has increased substantially and continuously for both softwood and hardwood timber. The growth/inventory index has increased substantially for softwood timber, but has declined recently for hardwood timber (fig. 69). It is evident that timberland is being used increasingly more efficiently for biological timber production, while timber capital is being used increasingly more efficiently for biological production of softwood timber but not for biological production of hardwood timber.

Forest productivity measures within ownership categories generally follow the same trends. An exception occurs in the other private ownership category, where softwood growth per acre and growth per unit of inventory have declined in the last decade (table 126). Most timberland in other private ownership is in the South and the North. Both these sections experienced significant gains in softwood growth and inventory from the 1950s until the late 1970s. Over the past decade, softwood inventories have continued to increase but net annual growth per acre has declined.

The net annual growth decline in the South has been the subject of much interest and study in recent years (USDA FS 1988b). Causes for the decline include inadequate regeneration of pine stands following harvest on other private lands, a significant increase in the volume of mortality and cull trees over the last decade, and a

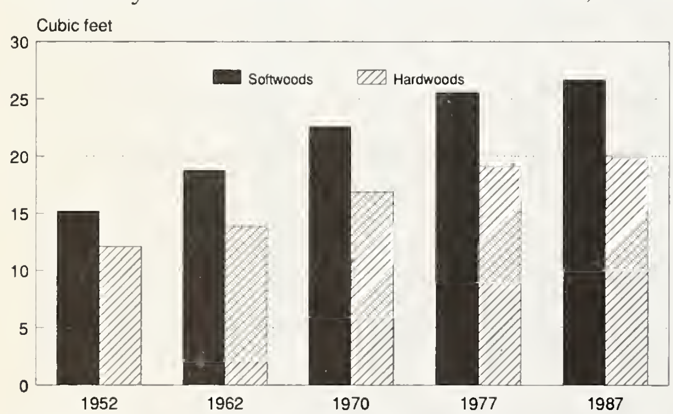


Figure 68.—Trends in net annual growth per acre in the United States, all ownerships.

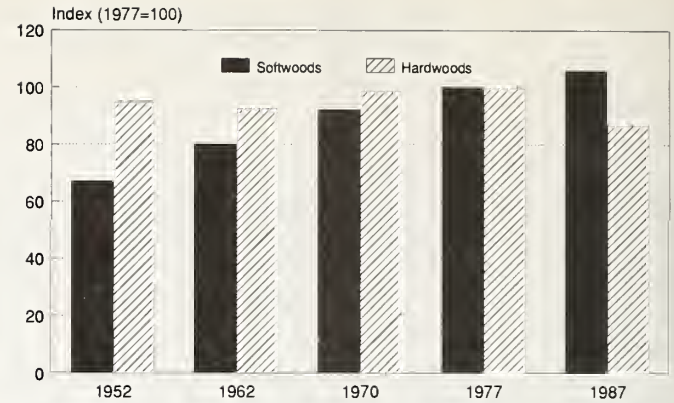


Figure 69.—Trends in growth/inventory productivity indexes in the United States, all ownerships.

decline in average annual radial growth of natural pine in some areas for reasons that are not yet understood. In the North, spruce budworm outbreaks have resulted in a dramatic drop in growth for balsam fir in Maine (Maine Department of Conservation 1988). In addition, much of the spruce-fir forest in this area was regenerated after severe budworm outbreaks in the early 1900s, and stands are reaching an age where growth is slowing down.

In contrast, softwood growth per unit of inventory has continued to make major gains in the West. In Pacific Coast areas especially, softwood inventories have been declining and net annual growth increasing as old-growth timber is harvested and replaced by vigorous young stands.

The decline in growth per unit of inventory for hardwoods reflects the continuing accumulation of hardwood growing stock on all ownerships as noted in Chapter 3. Net annual growth for hardwoods has been fairly stable in recent years or even declined in some areas as stands age and mortality increases.

The removals/inventory indexes for all owners (fig. 70) show that forest productivity for timber in the United States, as influenced by timber markets and utilization technology, has improved substantially for softwood timber. For hardwood timber, this measure of productivity has declined in previous decades and then, except for the other public ownership, increased in just the last decade, especially on forest industry ownerships (table 127). The indexes show that timber capital has been used increasingly more efficiently for commercial production of softwood timber while timber capital has been used less and less efficiently for commercial production of hardwood timber. The downward trend for hardwoods shows a small reversal in the last decade associated with increased utilization of hardwood timber.

Because timber removals are mainly commercial timber harvest volumes, the trend in forest productivity according to the removals/inventory index is influenced strongly by the market requirements for timber and the technology of wood use. The indexes reflect rising demands for softwood timber products over the past several decades which have generated large increases in softwood removals. In the late 1970s and early 1980s, technological advances in the manufacture of

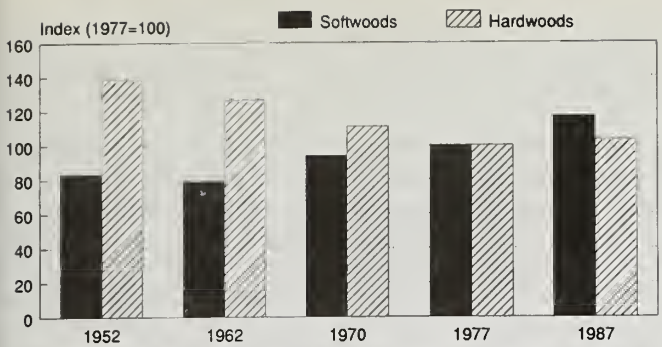


Figure 70.—Trends in removals/inventory productivity indexes in the United States, all ownerships.

pulp, paper, and board products and high demands for fuelwood stimulated greater utilization and harvest of hardwood timber.

Implications for the Future

The forest productivity measures presented here are by no means a complete measure of the productivity of U.S. forests. They do, however, highlight significant trends in timber production capabilities nationwide and across ownerships and geographical sections.

Over the past three decades, timber harvests from all ownerships have increased in response to rising demands for timber products. At the same time, total timberland area has gradually declined. Softwood net annual growth per acre of timberland and per unit of inventory, however, have also increased on all lands (with the exception of other private ownerships) in the last decade. The hardwood productivity indexes, on the other hand, reflect inventory accumulations that until recently have far outpaced harvests for market.

The projections in this Assessment indicate that demands for timber products will continue to rise in the future and that the timberland base will continue to decrease. Increasing timber growth would be one way to sustain higher levels of timber harvests in the next century. The increases in productivity on timberlands described earlier have come about in large part as a result of substantial public and private investments in forest research, management and protection, and education and technology transfer. Trends in these programs, especially over the last decade, are reviewed later in this chapter. The projections of timber supplies in Chapter 7 were based on the assumption that investments in timber management would continue at current levels or in some cases accelerate, especially on forest industry lands. Although substantial opportunities exist to increase timber growth on other private lands as well, the outlook for increases in productivity on these ownerships is more problematic.

RECENT TRENDS IN FOREST RESEARCH AND TIMBER MANAGEMENT

Forest Research

Research provides the knowledge and technology needed by forest managers to improve the productivity of their timberlands. Most forest management research is conducted by the USDA Forest Service and by forestry schools located at land grant colleges and universities, other state-supported and "1890" schools, and several private universities. Timber management and utilization research is also conducted by a few of the larger forest product companies. Some companies that do not maintain a staff of scientists or laboratory facilities still participate in research activities through university cooperatives and small staffs devoted to in-house problem-solving. Expenditures for forest management research, including primarily silviculture, genetics, economics, and mensuration, were approximately $30 million for the USDA Forest Service, $19 million for forest industry, and $17 million for universities in 1985 (Hodges et al., in press).

Major research efforts include development of cost effective and reliable silvicultural alternatives and timber management guidelines to improve forest growth, quality, and composition; genetic improvement for superior tree growth, quality, and resistance to forest pests; and mathematical models and computer programs to predict more accurately the growth and yield of forest stands. Research is also providing technology to prevent or reduce the impact of insects or disease on the timber supply; methods of preventing and controlling wildfire and prescribing fire to enhance production; assessments of the effects of atmospheric deposition on terrestrial and aquatic ecosystems; information and analyses of the timber resource; and technology to harvest and utilize timber more efficiently.

Most studies of economic returns on investments in forestry research have found high rates of return. Increases in the productivity potential of forest stands due to the development of new management technologies have been estimated at up to 70% for Douglas-fir and more than 200% for loblolly pine (Joint Council 1988). Genetic improvement in planting stock has been credited with increasing annual growth for some conifers by 20% to 40%, as well as improving other traits such as specific gravity, straightness, and disease resistance. Research has also advanced an understanding of the complex interrelationships at work within forest ecosystems, which is essential for multiple-use planning and management of timberlands.

Despite a continuing role for advances in knowledge and technology to meet the increasing demand for goods and services from forest lands, investments in forestry research generally declined between the late 1970s and early 1980s. Declines in funding paralleled reductions in the number of scientists engaged in forestry research and student enrollments in undergraduate and graduate forestry programs (Giese 1988).

Total appropriations for USDA Forest Service research fell by almost 25% in constant dollars between fiscal years 1977 and 1986. In the following fiscal years, this downward trend turned around somewhat as funding levels increased. In fiscal year 1989, appropriations for Forest Service research in all areas totaled $137.9 million.

Funding for university-based research comes primarily from state and private sources with significant support from McIntire-Stennis and other federal funds. Nonfederal funding for forestry research has increased by nearly 30% in the past decade, compensating in part for a decline in federal contributions. Expenditures from all sources for forestry research at universities was approximately $88 million in fiscal year 1986 (Joint Council 1988).

Information on expenditures by forest industries is not readily available, and much of the research accomplished is proprietary in nature. The American Forest Council estimates that research investments by forest industry have declined by more than 30% since 1982 (Joint Council 1988).

Sustaining the significant gains in forest productivity for timber achieved over the last several decades would require continuing development and implementation of new knowledge on the biological and economic factors affecting timber growth and harvest balances. Opportunities exist, for example, to improve productivity on timberlands over the long run through basic research on the fundamental physiological and biological processes of tree growth, through development of new and improved timber management techniques, and through accelerated implementation of technologies as they are developed. Realizing the potential gains in productivity made possible by research requires on-the-ground actions by public and private forest land managers. Recent trends in putting available timber management technology into practice are discussed in the next section.

Timber Management

Timber management encompasses a wide variety of land and stand management activities that are designed to increase timber growth and protect against losses. Such activities include stand regeneration after timber harvesting or on nonstocked land, conversion of acres with offsite species to a preferred forest type, improved scheduling of harvest for mature timber, intermediate stand treatments to improve tree growth or quality, and management of fire, insects and disease to reduce losses. Investments in timber management result in substantial increases in timber growth over time on the growing stock and land base available for timber supplies.

Regeneration Trends

Most forest regeneration occurs naturally or through harvest practices designed to encourage natural regeneration. Natural regeneration of softwoods following logging may require 3 to 5 years in the South and 5 to 10 years in the West. Lack of adequate regeneration to desired species may result in changes in forest type. Over large areas of the South, for instance, a natural succession to hardwoods occurs after harvest of pine stands unless action is taken to encourage regeneration of pine. In contrast to softwoods, hardwoods usually regenerate rapidly and easily, mostly from stump and seedling sprouts. To alter the species mix on a site to favor preferred species, however, special silvicultural systems and site preparation treatments may be necessary (Burns 1983).

Artificial regeneration—planting and direct seeding—requires an initial investment, but generally gives faster and more certain results than natural regeneration. It provides better control of species, spacing, and stocking levels and allows the use of genetically improved stock. Most regeneration through planting and seeding is with commercially important softwood species, chiefly southern pines and Douglas-fir.

Planting of seedlings raised in nurseries accounts for nearly all artificial regeneration. Both industry and government are increasing their efforts to plant superior trees by improving the quality of such seedlings. Currently 68% of state-produced tree seedlings (Risbrudt and McDonald 1986) and 99% of federal nursery stock (USDA FS 1987a) are of genetically improved quality. Forest industry has also made major advances in the use of genetically improved seedlings.

Nationwide data on acres regenerated naturally are not available. Since 1982, however, new records for acreage regenerated by planting and direct seeding have been set each year. In 1988, nearly 3.4 million acres were artificially regenerated nationwide (USDA FS 1988c). Four-fifths of the acres regenerated were in the South (fig. 71). Virtually all artificial regeneration is accomplished through tree planting rather than direct seeding. Direct seeding was used on 40,000 acres in 1988, only 1% of the total acres artificially regenerated.

Nationwide in 1988, other private ownerships accounted for 47% of artificial regeneration accomplishments; forest industry ownerships accounted for 40%. Less than 15% of the acres planted or direct-seeded were on public ownerships—9% on national forest lands and 4% on other public lands.

Peak years of tree planting prior to 1982–88 occurred during the era of the Soil Bank Program from the mid-1950s to the early 1960s (fig. 72). The Soil Bank Program made payments to farmers to retire land from crop

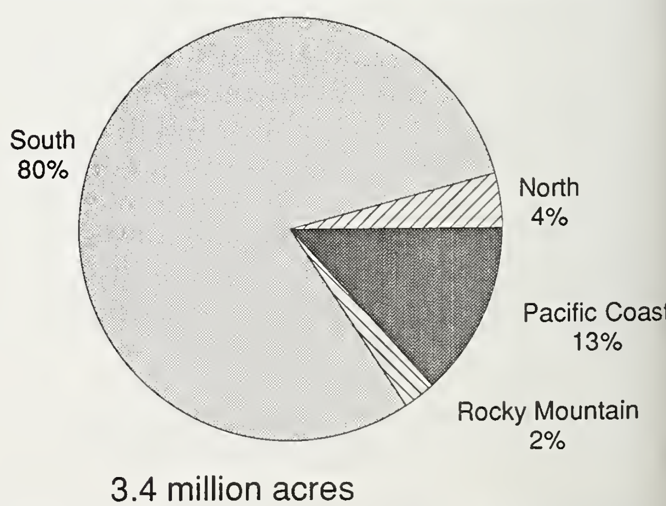


Figure 71.—Area planted and direct-seeded in the United States, by section, 1988.

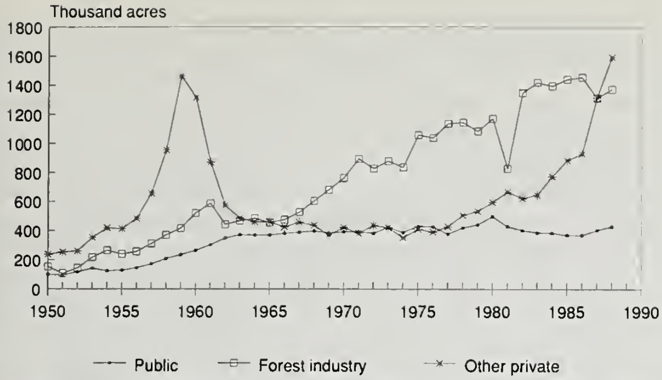


Figure 72.—Area planted and direct-seeded in the United States, by ownership, 1950–1988.

production, with most planted tracts remaining in trees after the program expired (Alig et al. 1980). Planting and direct seeding on farmer and other private ownerships accounted for nearly 70% of the artificial regeneration activity in 1959.

Following the end of the Soil Bank Program, artificial regeneration on forest industry lands surpassed planting and direct seeding on other private lands. During the 1960s and 1970s, most of the increase in artificial regeneration occurred on forest industry ownerships in the South and the Pacific Coast. During the 1980s, forest industry planting and direct seeding have averaged about 1.3 million acres per year, about half the total.

In 1987, for the first time in 20 years, artificial regeneration reported on other private ownerships surpassed tree planting and direct seeding on forest industry lands. This increase in artificial regeneration on other private ownerships has coincided with the implementation of a number of policies and programs designed to stimulate investments in forestry. These policies and programs include restructured educational and technical assistance programs under the Renewable Resources Extension and Cooperative Forest Management Acts, the reforestation tax credit and amortization provisions enacted in 1980, direct financial assistance for reforestation under the federal Forestry Incentives Program, a variety of state cost-share programs, and most recently the Conservation Reserve Program. These programs are discussed in more detail in a later section.

In recent years, tree planting in the South has exceeded 2 million acres per year. Other private owners planted nearly 1.5 million acres in 1988, and forest industry planted over 1 million. Artificial regeneration in the Pacific Coast section has involved around 400,000 acres per year, primarily on public and forest industry lands. Although planting activity in 1988 surged to 454,000 acres, this amount is still down somewhat from peak years in the late 1970s, when planting occurred on a half million acres per year, over 20% of the national total. Tree planting in the North has also declined from a peak of over 300,000 acres per year during the Soil Bank era to an average of 150,000 acres per year over the last 5 years. Other private and public ownerships reported the most activity. Tree planting in the Rocky Mountain section has always represented a minor portion of the national total. In recent years, artificial regeneration has run about 100,000 acres per year, a modest increase since the 1970s. Three-fifths of the acres regenerated in 1988 in this section were public lands.

Intermediate Stand Treatments

Management practices during the period between regeneration and harvest cuts can increase timber supplies by changing the composition of stands in favor of desired species, reducing the number of defective trees, increasing growth on favored residual trees, and releasing desirable seedlings on recently regenerated areas. In addition, fertilizing stands and draining areas where excess moisture slows growth can increase growth rates. In recent years, intermediate treatments have been reported on about one and a half million acres per year, with over half on forest industry lands, primarily in the South, and another quarter on national forest lands, especially in the West (USDA FS 1988c).

The most widespread intermediate treatment is thinning stands to remove low-value timber, to speed growth of desirable species and trees, and to shorten timber rotations by concentrating growth on residual trees. Pruning the lower branches on young trees that are expected to be part of the final crop can also increase the quality and value of timber growth. Although pruning has little effect on total timber supplies, it can increase supplies of high-quality timber. Overall, pruning has not been widely used in the past.

Fertilization of forests can increase timber supplies where experience and research show that lack of soil nutrients is limiting plant growth. The biggest opportunities seem to be on the nitrogen-deficient soils of the Douglas-fir region and the poorly drained phosphorus and nitrogen-deficient soils of the Coastal Plains of the South. In the Douglas-fir region, addition of nitrogen fertilizer typically results in a range of response from 200 to 800 gross cubic feet over a 10-year period, with the higher levels of response coming from low-quality sites. The use of phosphorus fertilizers in newly planted pine forests on poorly drained sites on the southern Coastal Plain is generally expected to increase yields in 25-year-old stands by around 15 cords. The use of nitrogen fertilizer in these stands when they are from 10 to 25 years old also increases harvest yields substantially.

Although the use of fertilizers on commercial timberlands outside the Coastal Plain of the South and the Douglas-fir region has so far been limited, there may be opportunities in other regions. There are also some specialized uses. For example, research has shown that with fertilization black cherry seedlings and sprouts can, in one season, outgrow the reach of browsing deer.

Reduction of Losses

The growth of timber can be reduced by poor harvesting practices, wildfire, insects, and diseases. Management practices that reduce losses from these causes and result in rapid salvage of dead and dying timber can add substantially to net annual growth and the volume of timber available for use. Harvesting activities often damage residual trees and may increase the risk of insect attacks, windthrow, and fire on adjacent timber stands. Improvements in logging practices to minimize damage and the protection of residual trees against destructive agents such as wind, insects, and disease could significantly reduce the mortality and growth loss associated with harvesting.

Fire management trends.—The most effective timber management effort in the United States has been the control of forest fires. Although recent years have brought several exceptionally severe fire seasons, the long-term results of fire management programs have been remarkable. The area burned annually declined from 30 to 40 million acres at the beginning of the century to 3 to 5 million acres between 1980 and 1986. Almost all timberland and large tracts of nonforested watershed are now protected by federal, state, and private organizations. Federal expenditures for fire protection on national forest lands averaged about $250 million annually in the 1980s. Federal and state expenditures to protect state and private lands have historically exceeded the levels expended for national forests. The improvement in protection has contributed in a major way to the increases in net annual growth and timber inventories which have been taking place in eastern forests in recent decades.

The rate of reduction in the area burned annually, however, has slowed significantly in recent years. Increasing fire management efforts have been offset by greater risks associated with improved access to and increased use of forest lands as well as the natural accumulations of fuels on unburned protected areas. Accumulation resulting from management practices such as harvesting and thinning, along with air quality constraints on burning such material, contribute to the problem.

Another factor is the expansion in areas where wildlands intermingle with residential development. In wildland and urban interface areas, the encroachment of structures in and about the forests has increased fire hazards. Fire suppression forces must protect human life and residential property in the interface areas—often at the expense of allowing increased acreage of forest land to burn. Accelerated research to improve technology of fire prevention, presuppression and suppression, and other measures such as closer timber utilization could reduce fire risks on timberlands.

Insect and disease management trends.—Insects and diseases take a heavy toll of timber by killing trees and by reducing timber growth and quality. A few major pests such as the western bark beetle, southern pine beetle, and root rot account for much of the mortality. Other insects and diseases such as spruce budworms, dwarf mistletoes, and gypsy moths also cause tree mortality, but they cause considerably more damage in the less spectacular form of killing branches, shoots and terminals; reducing the rate of growth; and stunting, deforming, or degrading the value of trees and wood products.

Forest pests can cause widespread outbreaks resulting in extensive tree mortality, deformity, growth reduction, decay, and reproduction failure. The actual consequences of these effects, however, depend largely on specific management objectives and forest resource values. As a result, forest pest management considerations are closely linked to forest management objectives and operations that define the need and provide the means for preventing or reducing pest-caused losses.

Annual federal and state expenditures for forest insect and disease protection were $38.2 million in 1987. This amount represents a moderate decline (in constant dollars) over the past decade. Throughout the 1980s, about 40% of the total expenditure has gone to the North, 25% to the South, and 35% to the West. About 80% of North and South expenditures was used to suppress pests on private and other public lands. The expenditures in the West were largely to suppress pests on federal lands.

During the late 1970s and early 1980s, private and other public expenditures averaged about 70% of total expenditures. From 1983 to 1988, private and other public expenditures averaged about 55%. This change began when federal expenditures increased in response to southern pine beetle, mountain pine beetle, and western spruce budworm outbreaks on federal land. The change also coincided with the end of federally supported spruce budworm suppression in Maine and a collapse of gypsy moth populations in parts of the North.

In the Pacific Coast and Rocky Mountain regions, most losses from insects and diseases have been caused by western spruce budworm, mountain pine beetle, dwarf mistletoe, and root disease. Since 1982, approximately $14.0 million has been spent for western spruce budworm suppression, $15.3 million for mountain pine beetle suppression, and $5.8 million for dwarf mistletoe suppression. Root diseases are a particular concern because they not only cause outright tree mortality, butt rot, and growth loss, but they also predispose trees to insect attack and windthrow. By affecting the growing site, root diseases remove large areas of productive forest land from full timber production. Management strategies which limit stand disturbance and exploit differences in tree species susceptibility can be used to reduce losses from root disease.

In the South, a large portion of the expenditure—$17.9 million since 1982—has been for the suppression of the southern pine beetle, the most damaging insect pest in that region. Fusiform rust, a botanical curiosity before 1900, is a disease that now flourishes across the South killing or deforming millions of slash and loblolly pines each year. Increased use of genetically resistant planting stock coupled with wider application of improved management strategies may help slow the increasing trend of this disease.

In the North, recent suppression efforts have been mainly concentrated on the gypsy moth in Maryland, New Jersey, Pennsylvania, Rhode Island, and West Virginia. Since 1982, approximately $38.4 million has been expended for gypsy moth suppression. In 1982, $8.6 million was spent on spruce budworm suppression in Maine.

Improvements in pest management technology such as stand risk rating, pest outbreak and damage prediction models, biological pesticides and pesticide application techniques, geographic information systems, and pest-complex prevention and control strategies have expanded the opportunities for increasing timber supplies by reducing pest-caused losses. Rapid salvaging of dead or damaged timber following wildfires, insect and disease outbreaks, and wind storms can also reduce losses of timber. Since a large part of the losses to destructive agents are comprised of individual or small groups of trees, the development of more cost effective harvesting systems could facilitate salvage operations.

More complete integration of forest pest considerations in the forest planning process and in resource management operations will be needed, however, to better realize recent technological gains. Such integration would permit more timely application of effective prevention and suppression strategies for forests where economic and other values permit treatment.

ECONOMIC OPPORTUNITIES FOR ACHIEVING INCREASES IN PRODUCTIVITY ON TIMBERLANDS

Significant gains in productivity of U.S. timberlands have been achieved over the past three decades. Still, many opportunities to enhance productivity on existing timberlands remain. Nationwide, many acres could be managed to grow higher wood volumes per acre, more preferred species, and/or higher valued products. These opportunities to increase timber growth exist on stands that are poorly stocked, have competing vegetation, have offsite species, are financially overmature, or are in some other less productive condition. Although implementing these opportunities would require substantial investments, many of these investments would yield a return of 4% or more in constant dollars (net of inflation or deflation). The 4% rate approximates the average long-run opportunity cost of capital in the private sector (Row et al. 1981).

Opportunities to increase productivity exist on all ownerships, but the greatest potential is on private ownerships. Decisions on future management of private timberlands tend to be less constrained by institutional factors and freer to respond to economic opportunities than management choices for public lands. Currently, over 84 million acres of private timberland are suitable for investments in regeneration or stocking control to increase timber growth or produce higher valued timber products (fig. 73). Seventy-nine percent of these potential timber investment opportunities occur on private ownerships other than forest industry. These other private ownerships control the largest area of timberland, 57% of all timberland in the United States, and their lands are less likely to be intensively managed at present than forest industry lands.

On forest industry lands, stand management to enhance productivity is essential to maintain competitive wood supplies for mills. Scheduling of stand treatments

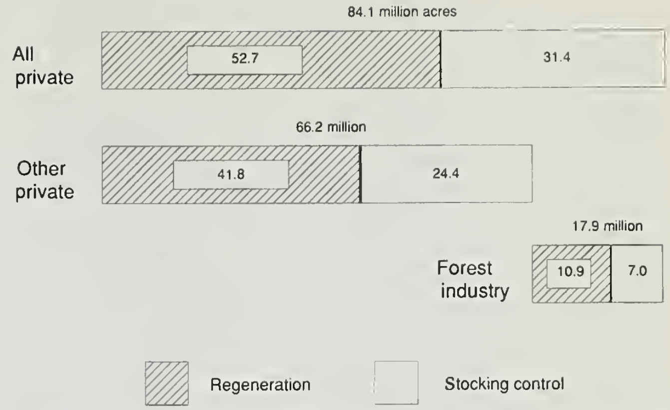


Figure 73.—Acres of private timberland with economic opportunities to increase timber growth, by ownership and type of treatment, with 4% return.

is likely to depend on annual cash flow and profitability considerations; and, even on industry lands, sites with low productivity or high treatment costs, small tracts, sites with environmental limitations, or areas with development potential for nontimberland use may remain untreated. By and large, however, forest industry lands are highly productive sites and are actively managed to increase their productivity. Therefore, most of the economic opportunities currently existing on forest industry lands are likely to be implemented.

On public lands, treatment opportunities are often constrained by site characteristics and multiple-use management objectives. As discussed in Chapter 3, the origins of the national forests resulted in large areas of relatively inaccessible and unproductive timberland being incorporated in the national forest system. Furthermore, on national forest lands the implementation of timberland investment opportunities is determined by forest plans. Although timber production is emphasized for some areas, emphasis for others is on nontimber outputs which may require longer rotations, more diverse stands, and less intensive management than would be appropriate for maximizing wood production. Decisions on whether or not to implement opportunities to increase timber growth or financial returns from timber production are subject to public policy determinations as well as economic analysis and must then be incorporated in forest plans.

A similar process applies to forest management decisions on many other public lands. Some of these lands are highly productive, such as the revested Oregon and California railroad grants lands in western Oregon administered by the Bureau of Land Management. Others, such as many of the county lands in Minnesota that were obtained as tax delinquent lands in the 1930s, have low productivity. Many of these public ownerships are managed for multiple purposes with important constraints on timber management and harvest. In some cases, however, such as state lands in Washington, public managers are expected to maximize income from their timberlands. Opportunities to increase returns from timber production then become an important consideration in the planning process.

The following analysis of economic opportunities to increase the productivity of timberlands concentrates on nonindustrial private ownerships because these ownerships have the largest share of opportunities for investment. It is recognized that nontimber outputs are often an important management objective for nonindustrial private landowners. Many of these other private lands, however, have not been managed to achieve their potential for timber or nontimber benefits. The joint production of timber and other outputs may require somewhat lower management intensity than reflected by the treatments described in this chapter. Still, on many sites, goals for increased wildlife and recreation outputs can be achieved more effectively by management of stand stocking, harvesting, and regeneration in a manner that will simultaneously improve timber outputs.

Acres on other private ownerships that are suitable for more intensive timber management, the expected return from the recommended treatments, and the additional timber volumes that could be produced are described below. These economic opportunities were identified using analytical techniques and information on stand responses to management developed for previous assessments of timber resources (USDA FS 1982, 1988b). Data on the timberland area suitable for treatment were the most recently available for each state.

Methods and Assumptions

Timberland Area Suitable for Treatment

The primary statistical base for identifying opportunities to increase timber supplies consisted of data on areas of timberland suitable for treatment compiled for each state by USDA Forest Service, Forest Inventory and Analysis units. Timber stand conditions on each sample plot were evaluated to determine treatments that could increase productivity. In many cases, stands were judged to be sufficiently productive so that no specific treatment was warranted at the time.

Forest treatments were separated into broad treatment classes for the purpose of analyzing economic opportunities. Regeneration treatments were prescribed where stand conditions indicated that a newly regenerated stand would be significantly more productive than the existing stand. Stocking control treatments were aimed at correcting timber stocking conditions that were impairing growth and development of commercial stands.

Regeneration treatments include:

- **Regeneration with or without needed site preparation.**—These acres lack manageable timber stands because of inadequate growing stock. Examples include poorly stocked land, recently harvested stands, failed plantations, and similar stands with insufficient stocking. Treatment of these stands involves immediate natural regeneration or planting. Site preparation may be required to assure adequate stocking and limit competing vegetation on some sites.
- **Conversion to a preferred management type for acres with offsite species.**—These are stands with chronic disease or pest problems, undesirable or offsite species, high proportions of cull trees, or high stress with trees of poor vigor. Conversion involves planting to a different management type or natural regeneration to favor a more desirable species distribution.
- **Harvest of financially mature timber followed by regeneration.**—These are financially mature or overmature sawtimber stands with sufficient volume to justify a commercial harvest. Most stands contain valuable sawtimber and could be held, but the volume and value growth rate of a replacement stand would be higher. These stands need to be harvested and regenerated naturally or planted.
- **Partial harvest of merchantable timber with natural regeneration.**—These are typically poletimber and sawtimber stands with enough merchantable volume for a commercial thinning or regeneration harvest. Stands have a favorable species composition and may be even- or uneven-aged. Treatments such as commercial thinning, seedtree or shelterwood regeneration cuts and selection harvest are appropriate.
- **Salvage of damaged timber followed by regeneration.**—These stands are excessively damaged due to fire, insects, disease, wind, ice, or other causes. These stands have unproductive areas where timber has been killed, trees have broken tops, or trees are threatened with additional damage from insects or diseases unless harvested. Average growth and yields of higher valued products are significantly reduced in these stands and harvest or removal of damaged or threatened timber is recommended, followed by regeneration.

Stocking control treatments include:

- **Control stocking of undesirable trees.**—These stands have adequate growing stock mixed with competing vegetation limiting crop tree development. Deadening or removal of stems that will not yield an adequate return is needed to release overtopped trees, to prevent stagnation and/or improve composition, form, or growth of the residual stand.
- **Precommercial thinning of overstocked seedling and sapling stands.**—These densely stocked stands include plantations with many volunteer stems, overstocked natural stands, hardwood thickets, and similar young stands with too many trees per acre. These stands are likely to stagnate and need precommercial thinning to help crop trees attain dominance.
- **Commercial thinning of dense poletimber stands.**—These poletimber stands are overstocked and need thinning to reduce stocking, prevent stagnation, and confine growth to fewer high-quality crop trees.

Acres were also classified by site class and forest management type for economic analysis. Three site classes based on potential productivity of well-stocked timber stands were used: high sites are capable of growing more than 85 cubic feet per acre per year; medium sites are capable of growing from 50 to 84 cubic feet annually; and low sites can grow from 20 to 49 cubic feet per acre per year.

Broad forest management types appropriate for each region were used for analysis. The forest management types in the southern states include planted pine, natural pine, mixed pine-hardwoods, upland hardwoods, and bottomland hardwoods. The forest management types in northern states are red, white, and jack pine; loblolly-shortleaf pine, spruce-fir, swamp conifers, oak-pine, aspen-birch, lowland hardwoods, maple-beech-birch, and oak-hickory. The forest management types in western states are coastal Douglas-fir, inland Douglas-fir, hemlock, fir-spruce, ponderosa pine, lodgepole pine, mixed conifers, larch, redwood, red alder, and aspen.

Management Options

Although many management options are possible for each stand condition, one preferred option was selected for each class of acres. In general, selected options favored more intensive regeneration treatments, stocking control, and treatments to produce shorter rotations and higher valued or larger crop trees. Natural stand management was preferred in cases where artificial regeneration was considered inappropriate or uneconomic.

Separate options were developed for managed and unmanaged stands to compare incremental gains resulting from treatments. The treated option was used to project results if specific management practices were applied to increase productivity. Treated stands were assumed to be kept highly productive with continued treatments for the analyses. The untreated option was used to determine foregone timber harvests for untreated stands. Minimal custodial management was assumed to continue for these cases indefinitely. All management options were carried out for a minimum of 150 years to assure a consistent investment period for comparison of treated and untreated stands.

Timber Yields

Harvest timber volumes were based on empirical yield tables for fully stocked stands. Yield tables included growing stock volume, percent softwood stocking, and percent of growing stock volume in sawtimber for each forest type and site class. Yields reflected average stocking and growth conditions for all stands in each group rather than site specific yields.

Economic Assumptions and Analysis

Management options were combined with treatment costs, yields, and stumpage prices to project cash flows for each investment opportunity (USDA FS 1987a). Stumpage prices used for the analyses were projected to rise over the investment period, in keeping with the trend for rising prices in the base case projection discussed in Chapter 7. Constant dollars were used for all stumpage prices and costs so that the effects of inflation or deflation were excluded. Only direct costs for treatments, such as stand establishment or stocking control, and costs associated with harvesting or selling timber were included. Costs that would accrue regardless of the treatment, such as ad valorem taxes, were excluded from financial analyses. Land costs and income taxes were also excluded.

For treated stands, opportunity costs due to foregone revenues from untreated stands were included. These opportunity costs were based on revenues that would have been earned if stands were not treated. Similarly, expected future costs for untreated stands were included as avoided costs for treated stands. Because of the large number of possibilities, it was not possible here to examine the dynamics of how opportunities for investment might change over time if scheduled treatments are actually postponed or otherwise adjusted.

A 4% real rate of return was used for discounting all costs and revenues. Although 4% approximates the average long-run rate of return on investments in the private sector, it is an average, and many management options yield higher rates of return. Some investments in stand treatments can earn rates of return in the range of 10% or higher.

Economic Opportunities by Region

There are economic opportunities to increase timber growth and/or financial returns from growing timber on over 66 million acres of other private timberland nationwide (table 128). This area represents about one-quarter of the timberland in other private ownership in the states included in the analysis. About two-thirds of these opportunities involve some form of regeneration activity (fig. 73). About one-third of the opportunities require stocking control measures in existing stands.

Approximately three-quarters of the opportunities are in the two southern regions, the Southeast and South Central. Nearly one-fifth of the opportunities are in the two northern regions, the North Central and Northeast. The small percentage of opportunities in the western states reflects in part the relatively small proportion of timberland held by other private owners in the West.

Within sections, the South also has the largest percentage (36%) of timberland in other private ownership with opportunities for management that would yield 4% or more return on the investment (table 128, fig. 74). Approximately 30% of the timberland in the Pacific Coast section and only 12% of the timberland in the North hold similar opportunities. Opportunities in the Rocky Mountain section are very limited, not only because of the relatively small area of timberland in other private ownership, but also because of the generally lower productivity of these lands compared to areas in the Pacific Coast.

Table 128.—Economic opportunities yielding 4% or more[1] for increasing forest productivity for timber on other private ownerships[2] in the contiguous United States, by region and treatment opportunity, in 1987.

Region and treatment opportunity	Area of timberland	Area with treatment opportunities	Cost of treatment	Net annual growth increment
	Million acres	*Million acres*	*Million dollars*	*Million cubic feet*
Northeast				
Regeneration[3]		([4])	0.8	0.5
Stocking control[5]		6.7	233.2	181.6
Total	57.7	6.7	234.0	182.1
North Central				
Regeneration		4.4	584.2	340.5
Stocking control		1.8	57.7	78.8
Total	49.0	6.2	641.8	419.4
Southeast				
Regeneration		18.1	1,965.5	835.4
Stocking control		6.7	318.6	268.7
Total	59.0	24.8	2,284.1	1,104.1
South Central				
Regeneration		16.8	2,442.9	865.0
Stocking control		7.9	372.5	333.7
Total	78.4	24.7	2,815.3	1,198.7
Rocky Mountain[6]				
Regeneration		0.1	21.0	4.5
Stocking control		0.1	3.3	2.8
Total	4.9	0.2	24.3	7.3
Pacific Northwest				
Regeneration		1.3	423.0	329.4
Stocking control		0.8	33.9	34.2
Total	6.9	2.1	456.9	363.6
Pacific Southwest				
Regeneration		1.1	178.0	160.4
Stocking control		0.3	6.9	11.0
Total	4.7	1.4	184.9	171.4
Contiguous States				
Regeneration		41.8	5,615.3	2,535.8
Stocking control		24.4	1,026.1	910.7
Total	260.6	66.2	6,641.4	3,446.5

[1]*Includes those opportunities which would yield 4% or more in constant dollars (net of inflation or deflation) on the investment.*
[2]*Private ownerships other than forest industry.*
[3]*Regeneration includes opportunities to reforest inadequately stocked stands, to convert off-site species to more productive forest management types, and to harvest mature timber and regenerate.*
[4]*Less than 50,000 acres.*
[5]*Stocking control includes commercial and noncommercial thinning, cleaning, and release.*
[6]*Includes only the economic opportunities in Idaho and Montana. Other states in the Rocky Mountain and Great Plains regions are excluded.*
Note: Data may not add to totals because of rounding.

Implementation of the opportunities on other private lands would increase net annual growth by close to 3.5 billion cubic feet, primarily from investments in regeneration of nonstocked and understocked sites, conversion of areas to preferred species, and harvest of mature timber followed by regeneration. Almost all of this increase would be softwood growth. Current net annual growth of softwoods would increase by about 55% (fig. 75). There are also economic opportunities to increase hardwood growth by 470 million cubic feet, a 7% increase over current net annual growth.

Investments of over $6.6 billion dollars would be needed to implement all of these opportunities. Over 75% of these funds would be needed in the South Central and Southeast regions (table 128).

Nearly 30% of the economic opportunities nationwide would yield rates of return of 10% or higher. Implementation of these opportunities would increase total net annual growth on other private ownerships by over one billion cubic feet. The investments required for these treatments would be around $1.6 billion. Most of these

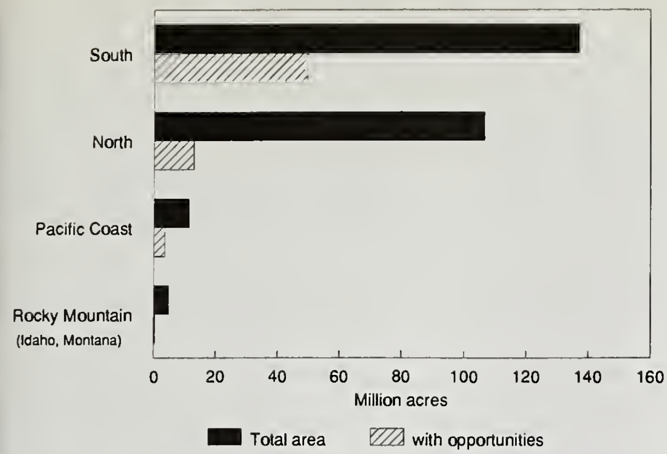


Figure 74.—Area of timberland in other private ownership, total area and area with economic opportunities, by section.

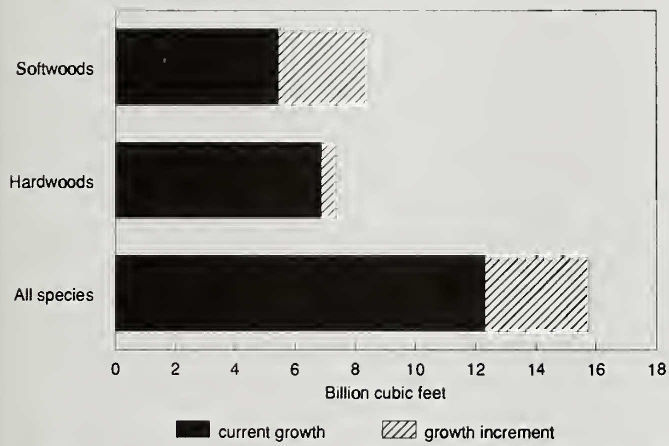


Figure 75.—Current economic opportunities to increase net annual growth on other private timberland, for softwoods and hardwoods, with 4% return.

opportunities are also in the two southern regions and involve some form of reforestation.

North

Close to 70% of the timberland in the North is in other private ownership. The analysis of economic opportunities in the North included treatments for softwood stands, especially red pine, white pine, and spruce/fir, and for hardwood stands, primarily oak-hickory and maple-beech-birch forest types. The forest resource and the associated opportunities are quite distinct between the Northeast and the North Central regions.

Northeast.—There are economic opportunities to increase timber growth on approximately 6.7 million acres of timberland in other private ownership in the Northeast. Unlike other regions, the bulk of these opportunities consists of stocking control treatments for hardwoods. Economic opportunities to reforest or convert to preferred species are limited in the Northeast. Stocking control treatments on 5 million acres of oak-hickory and maple-beech-birch stands would increase net annual growth for hardwoods by over 112 million cubic feet. Another 70 million cubic feet of softwood growth could be obtained by intermediate stand treatments on 1.5 million acres of red and white pine and spruce/fir.

Implementation of all opportunities would increase current net annual growth in the Northeast by about 8%. The cost for all treatments would be approximately $234 million. Economic returns from these investments generally range between 4% and 9%. None of the treatment options analyzed had an average rate of return of 10% or higher.

North Central.—In the North Central region, approximately 6 million acres have economic opportunities to increase timber growth, or about 13% of the timberland in other private ownership. About 70% of these opportunities involve regeneration treatments. Net annual softwood growth could more than double with an addition of 300 million cubic feet of growth. Hardwood growth could be increased by 8% with 116 million cubic feet of additional growth per year. Investments of $642 million would be needed to implement all of the opportunities.

Most of the opportunities are found in the Lake States (Michigan, Minnesota, and Wisconsin). Large opportunities exist to increase softwood growth by converting jack pine and hardwood stands on low sites to red pine. Commercial thinning of red pine plantations also offers favorable returns. Hardwood growth could be increased by clearcutting and regenerating aspen-birch stands on high sites. The largest opportunities for increasing hardwood growth, however, consist of commercial thinning of oak-hickory and maple-beech-birch stands on better sites. Opportunities in the central part of the region are limited primarily to stocking control treatments of oak-hickory and maple-beech-birch stands.

As in the Northeast, none of the treatment opportunities analyzed had an average rate of return of 10% or higher. Most of the treatments had an average rate of return of 5% to 7%.

South

Approximately 70% of the timberland in the South is in other private ownership. For the evaluation of economic opportunities in the Southeast and South Central regions, the selected management option in most, but not all, cases was to establish pine plantations. Bottomland hardwood stands were not converted to pine except in cases where stand conversion was recommended as the needed treatment by forest inventory data. Natural regeneration was evaluated for bottomland hardwood stands on high-quality sites. Natural pine, mixed pine-hardwood, and upland hardwood forest management types on low-quality sites were assumed to be managed by natural regeneration methods in most instances. Only in cases where site preparation was required for regeneration, salvage, or type conversion of low sites for these types did management options include artificial regeneration to pine plantations.

In addition to the opportunities on timberland discussed below, the South is in a unique position compared to other sections in the opportunities that exist to augment timber growth through tree planting on marginal cropland and pasture. Because of the minimum site preparation costs involved, tree planting on unused cropland and pasture offers a relatively high rate of return. A recent study estimated that nearly 22 million acres of marginal cropland and pasture in the South would yield greater returns as pine plantations than in crop or pasture use (USDA FS 1988b). If planted to pine, these acres could add about 2.1 billion cubic feet of timber growth per year. A similar analysis in the North and West, comparing potential returns from tree-planting and crops on idle cropland, estimated that investments in forestry would be more profitable than crops on less than 2 million acres (Parks et al. 1988). The more profitable investments were limited to planting high-valued species in specific areas, such as black walnut in parts of the Allegheny Plateau and Catskill Mountains and redwood in the California Coastal Redwood Belt.

Southeast.—There are economic opportunities for increasing forest productivity for timber on about 25 million acres of other private timberlands in the Southeast, over two-fifths of the timberland area in this ownership category. Treatment of this area would increase net annual growth by 1.1 billion cubic feet, primarily for softwoods. This additional growth represents a 58% increase over current net annual growth for softwoods on other private lands and a 31% increase for all species. Achieving this additional growth would require an investment of $2.3 billion.

On an area basis, almost three-quarters of the economic opportunities consist of some form of reforestation or stand conversion. Opportunities exist, for example, to clear, site prepare, and plant pine on 2.2 million acres of nonstocked timberland and over 7 million acres of timberland occupied by poorly stocked oak-hickory, oak-pine, or natural pine stands. Net annual growth could be increased on another 4 million acres if mature stands and stands severely damaged by insects, disease, or other elements were harvested and regenerated to pine. Opportunities also exist to increase net annual growth through regeneration on nearly 3 million acres of bottomland hardwood lands. Most of this increase would come from natural regeneration of bottomland hardwoods on high-quality sites that are poorly stocked or occupied by mature or overmature stands. If all of the opportunities for reforestation and stand conversion on other private ownerships were implemented, net annual growth in the Southeast would increase by over 835 million cubic feet. Most of this growth would be from softwoods.

Opportunities to increase net annual growth by intermediate stand treatments such as stocking control exist on close to 7 million acres in other private ownerships in the Southeast. Net annual growth would increase by 270 million cubic feet, primarily from treatments such as removing competition from hardwood trees in pine stands and competition from trees of less desirable species or form in hardwood stands. This increase in growth also includes gains from precommercial thinning of seedlings and saplings and commercial thinning of poletimber. Most of these opportunities are found in natural pine and mixed pine-hardwood stands.

Nearly half of all the economic opportunities to increase forest productivity on other private lands in the Southeast would yield rates of return on the investment of 10% or greater. The largest opportunities with this rate of return involve the harvest of mature stands followed by the establishment of a new stand with higher rates of growth in terms of volume and value. Only about a fifth of the economic opportunities for regeneration following site preparation on nonstocked or poorly stocked sites had rates of return of 10% or greater. In particular, treatments to establish pine plantations on sites occupied by a large component of upland hardwoods and to naturally regenerate bottomland hardwood stands tended to have lower rates of return than other treatments. Nonetheless, there are over 2.3 million acres of other private lands that could be planted to pine after site preparation for a return on the investment of 10% or greater. Only a small proportion of current economic opportunities are found on pine plantations because of the intensive management already practiced in most of these stands. Of the opportunities that do exist, approximately 75% have rates of return of 10% or greater. Commercial thinning of poletimber accounts for the largest share of these opportunities.

South Central.—Economic opportunities to increase productivity on other private timberland in the South Central region are similar to the opportunities in the Southeast. Around 25 million acres, one-third of the timberland in this ownership, could be treated to increase productivity and yield 4% or more return on the investment. In total, these investments would amount to $2.8 billion. If these investments were made, an additional 1.2 billion cubic feet of net annual growth would be produced. Most of the increase would be in pine growth. This amount equals 68% of current net annual softwood growth and one-third of the net annual growth for all species on other private ownerships.

As in the Southeast, the majority of opportunities are for some form of reforestation or stand conversion. There are, for example, economic opportunities for regeneration following site preparation on 11.9 million acres on other private ownerships. These treatments would add 590 million cubic feet of net annual growth at a cost of $1.8 billion. Most of this area is characterized by cutover oak-hickory stands on sites suitable for pine. High-quality bottomland hardwood sites suitable for natural regeneration represent about 14% of the total economic opportunities.

If all stocking control opportunities on other private ownerships, including commercial and precommercial thinning, were implemented, they would add 330 million cubic feet of net annual growth for an investment of $370 million. Opportunities for release treatments exist primarily on upland hardwood sites and oak-pine sites where growth on crop trees would be enhanced by removal of competition from undesirable vegetation.

One-fourth of the economic opportunities on other private ownerships in the South Central region have rates of return on the investment in forest productivity of 10%

or greater. Although only about a fifth of the area with opportunities to clear, site prepare, and plant has rates of return this high, such opportunities do exist on over 2.5 million acres. Over half of the opportunities in natural pine and mixed pine-hardwood management types have a rate of return of 10% or greater. Most of these opportunities involve either release treatments or other stocking control.

Rocky Mountains/Great Plains

Only about one-quarter of the timberland in the Rocky Mountain and Great Plains regions is in other private ownership, and over half of that area is in the lowest productivity class. Steep slopes, fragile soils, and other environmental factors preclude intensive management practices over large areas of the Rocky Mountain states. Consequently, economic opportunities to increase timber growth on other private lands in these two regions are quite limited.

Idaho and Montana are two states, however, with significant acreage in other private ownership and suitable for commercial timber production. In these two states, approximately 200,000 acres have opportunities to increase timber growth. About half of the opportunities result from reforestation of nonstocked acres. The other half call for release and commercial thinning treatments for suppressed ponderosa pine, Douglas-fir, lodgepole pine, and spruce-fir. Total cost for these treatments would be $24 million. The result would be over 7 million cubic feet of additional softwood growth per year.

Prospective rates of return for these investments are in the range of 4% to 5%. Although there are undoubtedly additional economic opportunities to increase timber supplies in other Rocky Mountain states, more data than was available for this analysis would be needed on areas needing treatment, timber responses to management, and stumpage prices in the region.

Pacific Coast

The Pacific Coast has some of the most productive timberlands in the United States. Only about 20% is in other private ownership. Alaska and Hawaii are excluded from this analysis.

Pacific Southwest.—For this analysis the Pacific Southwest encompasses the state of California. There are economic opportunities to increase net annual timber growth on 1.4 million acres of other private lands. Net annual softwood growth could be increased by over 170 million cubic feet, a 70% increase, at a cost of $185 million. Most of the growth increment would come from harvesting mature redwood and mixed conifer stands and regenerating these stands. Substantial opportunities also exist to rehabilitate Douglas-fir sites overgrown with hardwoods. Commercial thinning or other stocking control of redwood, Douglas-fir, and mixed conifer stands would contribute to the net annual growth increment on about one-fifth of the acres with economic opportunities.

Most recommended treatments for Douglas-fir and redwood stands have average rates of return of 10% or greater. Overall, about 40% of the acres with economic opportunities in the region would earn rates at this level. The net annual growth increment from these treatments would be over 100 million cubic feet.

Pacific Northwest.—The Pacific Northwest has two distinct subregions marked by differences in the timber resource. In the humid and highly productive lands west of the Cascade Mountains in Washington and Oregon, coastal Douglas-fir is the predominant commercial species. In the drier, less productive subregion east of the Cascades in those states, the inland variety of Douglas-fir and ponderosa pine provide most of the timber supplies.

Regionwide, there are economic opportunities on 2.1 million acres of other private timberland. A net annual growth increment of about 364 million cubic feet, almost entirely softwoods, could be obtained with investments totaling $457 million. Virtually all of this increase would be in the coastal Douglas-fir subregion, and 90% of the opportunities in this subregion involve some form of regeneration treatment. These opportunities include planting Douglas-fir on nonstocked sites, sites poorly stocked with hardwoods, or following harvest of overmature stands. Stocking control measures, such as commercial thinning of stands currently overstocked followed by fertilization and precommercial thinning of young stands, also have favorable rates of return. In the ponderosa pine subregion, economic opportunities include planting nonstocked acres, commercial thinning of Douglas-fir poletimber stands, and harvesting mature softwood stands with subsequent artificial regeneration of the site.

Rates of return for treatments in the ponderosa pine subregion tend to average between 5% and 7%. Rates of return in the Douglas-fir subregion run several percentage points higher. Average rates of return are 10% or higher on about one-quarter of the acres in the Douglas-fir subregion. Most of these opportunities relate to commercial thinning and fertilization of Douglas-fir stands.

Prospective Impacts of Implementing Economic Opportunities for Management Intensification

Implementing all of the current investment opportunities on 66 million acres of other private timberlands would greatly impact the age structure, volume, growth rate, and species composition of these forests. A portion of these impacts is already reflected in the baseline projection discussed in Chapter 7. The baseline projection assumes a modest increase in the level of management intensity on other private timberlands over the projection period. To examine the impacts of greater levels of investment on other private lands, an alternative analysis was conducted.

The following sections discuss the investment opportunities already captured in the baseline and the effects of increasing investment levels above those in the baseline. These effects include changes in the forest resource itself and the associated economic impacts, such as changes in stumpage prices and timber product prices and production. There is also an overview of how increased timber production may affect the environment and other forest resources.

Assumptions on Timber Management in the Baseline

Overall, about one-fifth of the current economic opportunities described in this chapter for other private ownerships are already captured in the base projection (fig. 76). Most of the investments in more intensive forest management practices are assumed to occur in the South. This assumption is consistent with the location of the bulk of potential treatment opportunities in the Southeast and South Central regions. Increases in management intensity are also assumed in the Pacific Northwest Douglas-fir subregion because of its inherent productivity for timber and to a lesser extent in the North Central Lake States subregion.

The base projection provides for continuing increases over the projection period in the area of timberland managed as softwood plantations in the regions and subregions mentioned above. Investments above current levels in the management of softwood species in other regions are not expected to occur. Management of hardwood species is expected to continue at low, essentially custodial levels. The following sections describe in more detail the regeneration opportunities that are reflected in the base projection and the difficulty of capturing the effects of stocking control treatments.

Regeneration.—The baseline projection assumes that nonindustrial private owners will plant trees at a rate comparable to that for the recent decade. In total, the acreage of planted pine on nonindustrial private ownerships in the South is projected to rise from 8 million acres in 1987 to 20 million acres by 2040. This increase in area represents a net change. The total number of acres

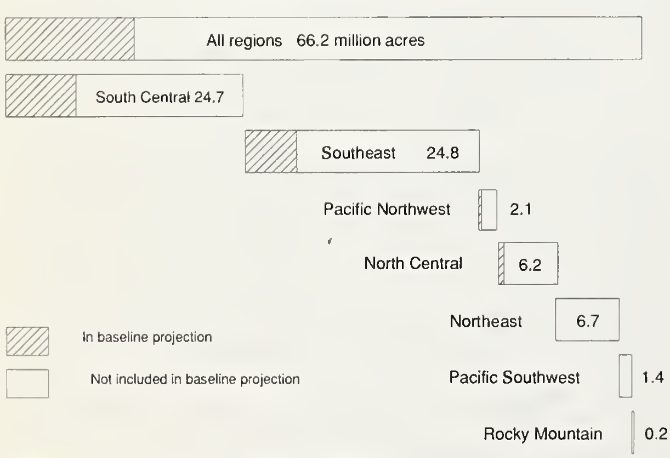


Figure 76.—Acres of other private timberland with investment opportunities and opportunities included in the baseline, by region, with 4% return.

planted to pine in the South is larger than the net increase in planted pine acreage because some pine plantations are harvested over the projection period and other planted pine acres are projected to revert to other forest types or be converted to other land uses.

Part of the increase in acreage of pine plantations is due to lands being converted from agriculture and other rural land uses. The remainder represents the projected enrollment of approximately 30% of the 35 million acres of regeneration investment opportunities on existing timberlands in the South.

In comparison to the South, relatively small changes in levels of other private reforestation are projected for other regions of the country. In the Pacific Northwest, about 20% of all regeneration opportunities are projected to be undertaken, resulting in about 300,000 acres of new plantations. In the North Central Lake States subregion, about 10% of the regeneration opportunities are projected to be undertaken. Implementation of these opportunities would result in about 400,000 acres of new red and white pine plantations.

Stocking Control.—Stocking control includes precommercial and commercial thinning and other forms of timber stand improvement. An estimated 24 million acres of stocking control opportunities currently exist on nonindustrial private timberlands. These treatments would increase the proportion of merchantable volume in a stand, alter the species composition, or release growing stock from undesirable competing vegetation. Although stocking control treatments increase the economic returns from timber management, they may have only a minor effect on total stand volume at final harvest. Consequently, the effects on timber supplies of changes in acreage receiving stocking control treatments are difficult to quantify.

The base projection does assume that large areas of softwood plantations on other private ownerships, especially in the South and the Pacific Northwest, will be more intensively managed than they are now. By the end of the projection period, the area of softwood plantations where thinning is part of the management regime will double in the Pacific Northwest Douglas-fir subregion and increase fourfold in the South. In the opportunities analysis, part of the growth increment attributed to stocking control treatments is based on a similar assumption that existing stands are regenerated after final harvest and receive appropriate stocking control treatments through subsequent rotations. Thus, for purposes of this analysis, it was not practical to separate the effects of stocking control treatments from regeneration treatments in the base projection or the alternative analysis of increased levels of investment.

Increasing Investment Levels above the Base Projection

As described in preceding sections, there currently exist substantial economic opportunities to increase timber growth on timberland in other private ownership. Much of the discussion focused on the opportunities with average rates of return of 4% or higher.

For many reasons, it is unlikely that all of these opportunities will be implemented. Some are likely to be implemented, however, if current management trends on other private lands continue. This portion of the opportunities has been incorporated in the base projection. Capturing all of the remaining opportunities would require investments far beyond the investment levels common today and would have significant impacts on timber product markets and production.

Analyzing the impacts of implementing additional timber management opportunities presents several difficulties. First, the analysis of economic opportunities was made with the base projections of stumpage prices (see table 111). As additional investments are implemented, timber inventories increase, causing stumpage prices to fall. This reduces the economic incentive for implementing opportunities. Second, as discussed earlier, the effects on timber supplies of intermediate stand treatments are essentially excluded. Finally, although the opportunities to increase timber growth are defined in terms of current stand conditions, regeneration and/or stocking control treatments would in all likelihood be implemented over an indeterminate number of years in the future.

To provide some indication of the impact of increased investments in forest management despite these limitations, an alternative scenario was structured which assumed that regeneration opportunities with a rate of return of 10% or greater were implemented uniformly over the projection period. Investments in forest practices beyond what is in the base will need to be extremely attractive (or highly subsidized) in order to be adopted (Brooks 1985, Cubbage and Haynes 1988). Opportunities with a 10% rate of return are likely to remain attractive even if prices do not rise to the levels in the base projection. Almost all of these opportunities are in the South. These investments would increase the net gain in pine plantations in the South in the base projection by about 50%.

Forest Resource Impacts

The impacts of increased investments on other private timberlands are substantial. Softwood timber supplies (harvests), net annual growth, and inventories are all higher than the base projection. Softwood inventories are 8.1% greater in 2040 for private timberlands in the South. The pattern for growth increases, inventories, and harvests illustrates how timber markets function. Increases in investment first result in larger growth increments. This leads to increases in inventories as industrial capacity slowly responds. Finally (and in later decades) harvest increases as capacity rises and shifts to the South to take advantage of the increase in raw materials. The impacts on the softwood forest resource are primarily located in the South where the bulk of the private timberland investment opportunities are located. Additional impacts occur in other regions as industrial capacity shifts to the South. In general the economic impacts are associated with increases in softwood harvests (see table 124). By 2040, harvests in the South have increased by 2.2% but stumpage prices have fallen by 20%. Lower stumpage prices lead to higher solid-wood production and consumption. By 2040, increased lumber production also leads to a 20% reduction in softwood lumber imports from Canada.

Economic Impacts

As a result of the increase in inventories and harvests, stumpage prices for sawtimber are reduced below those for the base in all regions. This is most evident in the South where stumpage prices are 10% lower in 2010 and 20% lower in 2040. Stumpage prices in the Pacific Northwest Douglas-fir subregion are reduced by 12% by 2040. These lower stumpage prices lead to lower lumber prices (3.9% by 2040).

In response to lower lumber prices, softwood lumber production rises and by 2040 is 5% higher. This increase in production comes at the expense of softwood lumber imports from Canada which drop by 2 billion board feet. Softwood plywood production and softwood plant byproduct consumption are also increased.

A majority of the economic opportunities in the South involve the conversion of oak/pine and upland hardwood stands to pine plantations. Implementation of the regeneration opportunities in the alternative scenario results in a 38 million cubic feet decline in the hardwood inventory in the South by 2040.

Impacts on the Environment and Other Renewable Resources

Intensification of timber management would be expected to have wide-ranging effects on the forest environment and other renewable resources. Because of the vast differences in timber types and local environmental conditions, along with the wide variety of timber management activities, it is not possible to specify or quantify all of the positive or adverse effects. These impacts, however, may be discussed in a general way. Most adverse impacts can be mitigated through careful planning and faithful execution of the plan.

Timber management activities, in particular timber harvesting, provide the means to greatly alter not only the trees but the understory vegetation for a forested area. Any type of timber removal will alter the amount of light and moisture reaching the forest floor, which in turn will have an effect on the understory vegetation. The resulting changes may be either positive or negative depending upon the viewpoint of the landowner or forest user. Manipulation in the form of intensive management will generally improve the health of the forest vegetation, since reduction of stand densities and regeneration of stands before they begin to lose vigor will help minimize insect and disease losses.

For harvest activities, as well as some slash disposal and site preparation activities, the potential exists for considerable soil disturbance. The degree to which this disturbance occurs depends upon many factors, such as the silvicultural operation, the soil type, topography, precipitation amount, and the type of skidding equipment used. Roadbuilding to provide access to harvest areas can be a major source of soil movement and potential erosion. Eroded soils frequently end up in streams, raising the turbidity of the water and leading to sediment deposits in other locations.

Access becomes easier for hunting, fishing, and many other types of recreation with road construction for timber harvesting. Adverse recreational impacts may occur, primarily as a reduction in the esthetic quality of the forest area for viewing, hiking, or camping. In many instances, landscape vistas can be improved by manipulation of some of the vegetation.

Vegetation removal can have a major effect on the water resource both directly and through its effects on the soil. Water yields are increased with harvesting activities, but the amount and duration of the increase depends upon site characteristics, precipitation, and the vegetation removed. Stream temperatures can be raised by the removal of the riparian cover that provides shade. In most instances, an increase in water temperature is not a favorable impact on either the fisheries resource or on water quality for human domestic consumption. Fish are also very sensitive to dissolved oxygen concentrations in streams. Severe reductions in oxygen concentrations due to soil particles from erosion and accumulation of slash or other forest residue in streams may be fatal to fish, even if the reductions occur for only brief periods.

Herbicides used in timber management activities involve special water pollution and safety concerns. Many of the herbicides used in forestry are the same as those used in the agricultural community, but the quantity applied per acre and the frequency of application is almost insignificant when compared to the agricultural community.

Changes in vegetative type inevitably affect the kind and amount of habitat available for different wildlife species and thus influence the wildlife community composition. Species dependent on climax forests will become less common following harvest while species dependent on early seral plant communities will become more common. Many species are dependent on a mosaic of plant communities which will provide their needs for both cover and forage. A forest composed of a mosaic of habitats will provide for the largest diversity of wildlife species, and this mosaic may be created through carefully prescribed timber harvest.

Invertebrates are also affected by management activities. Soil disturbances, such as compaction and altered infiltration rates, can cause habitat changes that dramatically affect the invertebrate populations of forest soils. This population, in turn, affects the availability of food for amphibians, reptiles, small mammals, and birds.

Concern about the environmental impacts of forest management activities has led to an increase in state forest practice regulation over the past two decades. Federal water pollution control statutes have been a major impetus behind efforts to control timber harvesting activities and other activities near streams. Controls range from voluntary compliance with guidelines developed as "best management practices" to mandatory legal restrictions. In addition to water quality, forest practice regulation may address areas such as reforestation of harvested lands, prescribed burning and treatment of slash, pesticide and herbicide applications, and occasionally management of wildlife habitat and esthetic quality (Henly and Ellefson 1986). Mitigation measures to avoid adverse environmental impacts will continue to be an increasingly important aspect of forest management as forest practices regulation becomes more widespread and comprehensive.

FACTORS AFFECTING INVESTMENTS IN FOREST MANAGEMENT ON OTHER PRIVATE LANDS[42]

The preceding section of this chapter described the substantial opportunities that currently exist to increase timber growth through investments in forest management, in particular on other private lands. Although this analysis indicates that landowners and society can expect positive financial returns on these investments—in many cases returns of 10% or more—the portion of these investments that will actually be made is open to speculation. An array of ownership objectives and institutional factors affect decisions by other private landowners on how to manage their forests.

Management Objectives of Owners

Private individuals and organizations other than forest industry own roughly three-fifths of the Nation's timberland and number more than 7 million. Seventy percent of these owners have less than 10 acres of timberland, but these small acreage holdings account for only about 4% of the total acreage in this ownership (Birch et al. 1982). Holdings larger than 100 acres encompass about 75% of total nonindustrial private forest land and are the source of most of the timber harvests from this ownership category.

Nonindustrial private owners are a very heterogenous class of forest owners. Many of these owners manage their forest land for resources or benefits other than timber. Timber management may be perceived as secondary to or in conflict with other benefits, such as recreation, wildlife, or scenic beauty. Nonetheless, nonindustrial private owners are often considered to hold the key to increasing the productivity of the forestry sector and thereby increasing the Nation's timber supply. Over the past three decades, the proportion of total national timber supplies from these lands has declined slightly, from around 57% to just over one-half. Other private owners, however, accounted for almost two-thirds of the large increase in harvests over the last decade (tables 118 and 119).

[42]*Material in the sections on management objectives of other private owners, market incentives and barriers to forestry investments, and tax policies is based on Yoho (1988).*

Other private owners who do not rule out timber management as an objective still cover a wide spectrum of interest in making investments toward that end. The least interested owners could be classified as custodial owners or sideline investors. Custodial owners would include individuals or groups simply holding timberland pending some further disposition, such as heirs waiting to sell forest property. Sideline investors typically own forest land as an appendage to another asset, such as a farm or residential property. Both types of owners are unlikely to give much attention to the investment opportunities on their forest land.

Some forest property may be acquired by individuals or organizations with an interest in speculative investment. Speculators usually try to acquire forest land with good chances for a windfall appreciation in property value in excess of increases due to timber growth. Typically, investment strategies for speculators do not call for increased investments to promote growth.

On the other hand, many other private owners are interested in investments in timber management. For some, managing their timberland is a hobby or second vocation. These owners may be motivated to maintain a well-managed forest as much for the personal satisfaction and recognition associated with stewardship as for economic returns. Finally, there is some fraction of other private owners who will behave as true investors and who could be expected to respond to opportunities based on economic criteria alone.

At any given point in time, only a portion of other private timberland owners are managing their lands for timber production. In addition, ownership tenures for forest land are often quite short in relation to the time it takes for trees to grow to maturity. A 1978 survey of landowners nationwide, for instance, found that over 40% of the forest land had been acquired by the present owners within the previous 20 years (Birch et al. 1982). Control of individual forested tracts during the course of a rotation, therefore, may pass into or out of the hands of individuals or organizations with an interest in timber management.

For forest land owners willing to consider timber management, the likelihood of investment may be affected by their perceptions of market incentives and barriers to timberland investments.

Market Incentives and Barriers to Forestry Investments

Expectations for Financial Returns and Liquidity

Most forest owners appear to have realistic but vague and rather conservative expectations as to the financial returns they can expect from their forest properties. It seems to be widely recognized that forests generally represent long-term, modest yielding and generally low liquidity investments.

Many forest owners, however, would have great difficulty in translating their expectations of growth, harvest and stumpage values into an anticipated rate of return on investment. Generally, only the most sophisticated owners, such as those who seek the help and advice of professional foresters, have rate of return estimates in mind.

Forest owners often have low to modest financial expectations for their forest properties partly as a result of overestimating prospective losses due to natural risks. Most owners perceive the risk from fire, insects and disease to be considerably greater than national studies have shown. Also, many nonindustrial private owners are only vaguely aware of the possibilities of partially recovering losses of forest capital by salvage.

Institutional investors, on the other hand, who are accustomed to handling client accounts with investments in equities (common stock), bonds (government and corporate), commercial real estate and farm land, appear to be quite demanding and exacting in terms of the rate of return outlook they would require before investing their client's money in a commercial forestry venture. Institutional investors look for a premium for higher perceived risk and lower apparent liquidity in comparison with the return they would expect to earn on other investments, such as commercial real estate.

Forests normally represent very long-term investments and require planning horizons far beyond those employed by average investors. Forest investors often must plan on investment paybacks beyond their own life expectancy. Given such long time periods, the cost of capital becomes even more significant as the deciding factor in evaluating the profitability of forestry investments.

The low liquidity problem is particularly acute in the first half of the life of the investment. This situation discourages established owners and prospective new investors from developing young forests because significant losses could result if they had to be sold before about mid-rotation age. Wider acceptance of the discounted cash flow method of valuing forestry investments might result in better recognition of the value of young stands.

Portfolio Balance

Forestry investments, however, may have other attributes which make them attractive to large investors and investment managers. On the basis of a few and not very exhaustive studies using portfolio analysis, forestry investments appear to be somewhat countercyclical to the earnings performances of bonds (corporate and public) and corporate stocks. This results in lower overall risk for an investment portfolio of which timber is a part, thereby improving total portfolio returns. If further investigation demonstrates this to be the case, it would go a long way in offsetting forestry investments' modest rates of return, long payback periods, and lack of liquidity.

Capital Requirements

Many owners acquired their forest properties by gift, inheritance or other passive means and, thus, are not likely to view their forest as a package of investment opportunities. Such owners are often land rich and capital poor; hence, they are not financially able to respond to incremental investment opportunities on their own lands.

Risk and Uncertainty

The long-term aspect of forestry investments tends to magnify the real and perceived risks and uncertainties associated with them. The prospects envisioned by forest investors for loss due to fire, insects, and disease constitute powerful deterrents to increased private investment in forestry. But, the availability of better information on losses from such factors and the development of diversification strategies by forestry investors could, in time, lessen the seriousness of this problem.

Prices

Future price trends for forest products and standing timber always have been, and will continue to be, one of the basic worries of forestry investors. In recent years great strides have been made by forest economists in formulating price projections through the development of sophisticated national and regional models by which timber supply and demand can be projected many years into the future. But these models are not yet capable of fully incorporating rest-of-the-world impacts on the United States. Possible impacts of foreign competition, both in domestic and overseas markets, on timber prices in general are a continuing concern.

The other price problem for many forest owners and investors is the matter of local prices. Projections of regional and national price trends may not be applicable to local markets where tree farmers sell the timber stumpage they produce. Studies have shown timber stumpage prices are strongest in areas with the most active competition among buyers. Interest in investment in timber growing also tends to be strongest in areas with active markets and with prices in line with, or above, regional averages. Often, however, forest owners sell in local markets where only one or two buyers are active. One mechanism for making the markets for standing timber behave more competitively has been to have better market and price information more readily available to all timber sellers.

Landowner Assistance and Incentive Programs

Providing assistance to nonindustrial private forest land owners to encourage production of timber and other benefits from their lands has long been recognized as an important objective for both public and private policies and programs (Cubbage and Haynes 1988). A substantial portion of the activities in regeneration, improvement, and protection of timber stands, as well as improvements in harvesting and utilization, on farm and other private ownerships is a result of a range of educational, technical assistance, and financial incentive programs. In addition, many private forest land owners have benefited from federal and state tax policies that reduce tax liabilities associated with owning and managing timberland.

In 1978, Congress passed three related acts to improve management of timber and other forest resources through better coordination among existing programs of education, technical/financial assistance, and research. These acts are: the Renewable Resources Extension Act (P.L. 95–30), the Cooperative Forestry Assistance Act (P.L. 95–313), and the Forest and Rangeland Renewable Resources Research Act (P.L. 95–307).

Education

Educational programs inform landowners of opportunities for protecting and managing their lands and of sources of assistance that are available. The Renewable Resources Extension Act (RREA) resulted in expanded programs by the Cooperative Extension Service and associated colleges and universities in forest land management and four other areas (rangeland management, fish and wildlife management, outdoor recreation, and environmental management and public policy). Federal RREA funds act as seed money for these programs; two-thirds of the total funding comes from state and local contributions. In 1986, about 68% of the $2.4 million appropriation for RREA went for forest land management (USDA Extension Service, n.d.). Forest land management programs include not only education of forest owners, but also programs for improved harvesting, continuing education for forestry and related professionals, improved utilization by forest product manufacturers, and increased public awareness and understanding. Extension programs have been one of the primary channels for disseminating new research findings to forestry professionals, landowners, and wood processors.

In addition to extension programs, there are also a growing number of public and private programs that publicize the benefits of forest protection and management by providing recognition to landowners who adopt sound forestry practices. Forests selected by these programs often serve as examples or demonstrations of management opportunities for other landowners and the community. The American Tree Farm System, a program of the American Forest Foundation administered by the American Forest Council, is one example. Nationwide there are more than 61,000 tree farms encompassing 89 million acres certified for the program. Most of the tree farms are in the South and in the North. The TREASURE Forest program operated by the Alabama Forestry Planning Committee, a coalition of state and federal agencies, with cooperation from forest industry, environmental and landowner groups, is another example.

Various studies have shown that forestry education and technical assistance for nonindustrial private landowners have resulted in adoption of improved management techniques, increased returns to landowners from their timberlands, and favorable benefit-cost ratios for society.

Technical Assistance

Technical assistance programs, usually concerned with the preparation and implementation of management plans, provide direct on-the-ground assistance to landowners on how to manage their forests to achieve a variety of objectives. These objectives may include not only timber production but also wildlife habitat improvement, esthetics, and soil and water protection.

State foresters perform the field work for state programs and for programs administered by the Forest Service in cooperation with state forestry agencies. The Soil Conservation Service also cooperates with state forestry agencies and extension personnel when developing management plans for conservation practices on farms that involve forest practices. Private sector programs include landowner assistance programs provided by individual companies in the forest products industry and a wide range of services provided to landowners by consulting foresters.

In 1978, authorizations for a variety of cooperative programs between the Forest Service and state forestry agencies were consolidated by the Cooperative Forestry Assistance Act. The Rural Forestry Assistance section of the act authorizes federal financial and technical assistance to state forestry agencies for nursery production and tree improvement programs; reforestation and timber stand improvement activities on nonfederal lands; protection and improvement of watersheds; and programs to provide technical forestry assistance to private landowners, vendors, forest operators, wood processors, and public agencies.

In the private sector, the largest share of technical assistance is provided by consulting foresters. In return for fees paid by the forest landowner, consulting foresters provide detailed management advice, market forest products, and arrange for equipment and labor to get forestry work done. According to the Association of Consulting Foresters, there are some 2,500 consulting foresters in the United States, nearly double the number in 1976.

Landowner assistance programs provided by individual companies in the forest products industry have also been growing rapidly. This assistance is usually provided in return for the opportunity to bid on the landowner's timber when he decides to sell. Technical assistance is usually free and other practices provided at cost. Over the past decade these programs have been increasing in the South, declining somewhat in the West, and are stable in other sections.

Financial Assistance/Incentives

Federal funding for forest management assistance peaked in the years immediately following passage of the 1978 Cooperative Forestry Assistance Act. In recent years, this funding has declined sharply. Federal contributions (in constant 1982 dollars) between 1983 and 1988 averaged only half the level for the period 1978–82. Federal funding for forest management and utilization programs in 1987 was approximately $10 million.

In general, state funding for the programs authorized by the Cooperative Forestry Assistance Act has far exceeded the requirements for matching federal funds. In recent years, for example, $9 out of every $10 expended for nursery production, tree improvement, and forest management assistance have come from state sources. State appropriations have not increased sufficiently in many areas, however, to make up for the decline in federal support (Lickwar et al. 1988).

Most financial assistance programs for forestry involve cost sharing, whereby federal or state governments pay a portion of the cost of establishing and maintaining timber stands on private lands.

The Forestry Incentives Program (FIP) is the principal federal cost sharing program aimed at increasing timber production by assisting nonindustrial private landowners with planting, site preparation for natural regeneration, and timber stand improvement. Agricultural Stabilization and Conservation committees for each state and county, in consultation with state forestry agencies, establish a cost share rate up to a maximum of 65%. In counties not designated for FIP or where all FIP assistance has been allocated, cost sharing may be available under the Agricultural Conservation Program (ACP). Although the primary purpose of this program is soil and water conservation, cost shares of up to 75% (80% for low-income participants) may be authorized for reforestation and stand improvement. Actual cost shares are set by state and county committees in the same manner as FIP. Actual cost shares for FIP and ACP are often around 50%.

In 1986, FIP paid out $11.3 million in cost shares for treatments on over 228,000 acres (USDA Agricultural Stabilization and Conservation Service 1988a). Over three-quarters of this assistance went to landowners in the South. Another 12% went to landowners in the North. Under ACP, approximately $6.4 million in cost shares were spent for forestry practices on 126,000 acres (USDA Agricultural Stabilization and Conservation Service 1988b). Slightly over half of this assistance went to private landowners in the South, 28% to the North, and 16% in the West.

In the late 1970s and early 1980s, between 40% and 50% of all tree planting on other private ownerships was cost-shared by FIP or ACP. Although around 250,000 acres per year are being planted with financial assistance from FIP and ACP, these acres now represent a smaller proportion of reforestation activity on nonindustrial lands.

A number of states also have cost share programs, supported with state and/or industry funds, or provide other assistance to landowners for reforestation, such as free seedlings. Many of these programs have been established within the last 10 years and are serving an increasing number of landowners. Between 1981 and 1985 in the

South, for example, the number of acres planted with aid from state cost share programs more than doubled and accounted for more than one-third of all acres regenerated with cost share assistance in 1985 (Royer 1988).

Cost sharing has been found in a number of studies to encourage investments in forestry practices. An evaluation of the 1979 Forestry Incentives Program (Risbrudt and Ellefson 1983) attributed to the program an additional 1.3 billion cubic feet of timber growth over the first rotation and an average real internal rate of return of over 8% for public and private investments under the program. An analysis of reforestation decisions by landowners in the South who had harvested timber concluded that awareness of cost sharing programs increased the likelihood of reforestation by 19% (Royer and Moulton 1987).

Some of the increases in reforestation on other private lands since 1985 are attributable to the Conservation Reserve Program, established under the Food Security Act of 1985. Under this program, farmers receive annual rental payments (established by bid) for 10 years and payments of up to 50% of the costs of establishing trees or grass on the highly erodible acreage placed in the reserve. This financial assistance, combined with the often favorable returns from planting pine on marginal cropland in the South (discussed earlier in this chapter), greatly enhances the economic incentive for farmers to convert highly erodible cropland to forestland. Landowners are able to stock the growth that occurs on the trees during the 10-year establishment period while they are receiving the annual rental payment. In some cases, the trees are ready for harvest with only 5 more years of growth. From first acceptance of bids in 1986 through mid-1988, over one and a half million acres had been approved for tree planting under the Conservation Reserve Program, with over 90% of these acres in the South.

Tax Policies

Tax incentives, perhaps more correctly called special tax benefits, have been applied in forestry for three basic purposes from which it is presumed that society as a whole will gain:

1. To encourage private forest landowners to invest in activities to increase timber supply and to encourage the movement of capital from outside sources into forestry, thereby overcoming an inherent investor bias.
2. To compensate forest owners for the nontimber values which society derives from the maintenance and management of private forest holdings.
3. To provide equity to forest owners for the biases that the tax system imposes on them essentially due to the long-term nature of such investments.

Tax incentives applicable to forestry investment are found in two general categories of the tax system—the ad valorem general property tax and the income tax system, mainly the federal income tax. General property taxes are levied on forest ownerships by local jurisdictions under the authority of the states in which the properties are located. Such taxes may be levied on the land and timber together, or separately. Income taxes, on the other hand, are levied on forest owners, be they corporate, individual or other, and are based on the income derived from the harvest of timber and other products. Forestry income tax incentives are mainly concerned with the classification of income and the rate at which income is taxed, plus the handling of costs associated with generating that income.

Property taxes.—The general property tax as ordinarily administered is thought by many forest economists to be very discouraging to the maintenance of intensive investments in forestry on private lands. The reason for this concern is the fact that the tax is levied annually against the timber growing asset which is not likely to produce a significant income until harvested, usually after a period of many years.

Various tax deferral alternatives for the annual property tax on standing timber have been developed to neutralize the forest disinvestment incentives which have been mentioned above. Under a forest yield tax, for example, owners in effect are permitted to defer the annual ad valorem taxes on the standing timber until it is harvested. However, the land on which the timber is growing continues to be taxed annually according to the ordinary provisions of the general property tax or, in many states, under one of several special modified tax systems applicable to the land, such as use value taxation or differential rate taxation.

Many private forest owners, however, have shied away from electing to place their properties under a tax deferral arrangement on the assumption that such action would tend to cloud the title to the property and thereby impair its liquidity. In addition, some recent studies have shown that the most prevalent reason for nonindustrial landowners not enrolling their properties under special tax deferral programs is their refusal to accept the accompanying restrictions on use and management of their properties, such as permitting open access for hunting, etc. Surveys have also shown that a substantial portion of nonindustrial forest owners in states with optional forest yield tax laws are likely to be unaware of the fact that such an alternative is available to them.

In contrast to the optional yield tax programs, in most states the majority of eligible owners have enrolled their properties under the special modified property tax systems available for forest land when these are operated apart from yield tax systems. These modified property tax schemes apparently provide more forest investment incentive than optional yield tax laws.

Income taxes.—Prior to passage of the Tax Reform Act of 1986, forest owners and investors had come to rely on the ability to classify income originating from timber growth, as well as income which arose from appreciation in the value of other capital assets over an extended period, as long-term capital gains. Individuals were allowed to exclude 60% of long-term capital gains from taxable income. Likewise, forestry investors had grown accustomed to writing off current forest operating, maintenance and protection costs incurred in growing new stands of timber, against current ordinary income from any source. Initial stand establishment costs had to be capitalized and, thus, could only be recovered over a period of years and perhaps not until the stand was harvested.

With the advent of the Tax Reform Act of 1986, the above described economic climate for long-term, modest yielding forestry investments has changed significantly. Differential tax rates for all types of long-term capital gains income have now been completely phased out. Tax reform and the ensuing ''passive loss'' rules, as developed by the Internal Revenue Service, have restricted forest owners who do not qualify as an ''active business'' from charging annual forest management costs against certain types of current income. Forest owners still have the attractive option of using 10% of the first $10,000 of qualifying reforestation expenditures per tax year as a tax credit. They may also amortize 95% of the total qualifying amount as a series of annual deductions against income over a period of 84 months.

Other tax policies.—In addition to the limited tax credit, other advantageous tax provisions, which are not restricted to forestry-related activity, still remain as important considerations to forestry investors.

One provision has to do with estate building. When a forest owner or investor dies, the estate, after exemptions and deductions, is taxed on its fair market value under provisions of the federal estate tax laws. However, gains in the value of the estate, including the forestry portion, as measured between the owner's investment basis in the property and its fair market value at the time of death, are not taxed as gains for income tax purposes to the deceased. This is extremely important to many individual nonindustrial forest owners who make large investments in forestry because their primary motive for doing so is to build an estate for their heirs.

Many of these tax advantages which benefit forestry estates under the federal provisions, however, tend to be offset by state death tax laws. This is due to the liberal exemptions and credits at the federal level which are not available in quite a few states.

Another advantageous tax provision for timber owners, which still remains after further changes made by the 1987 Tax Act, permits any forest owner to utilize the installment sale method of leveling timber sale income over a period of tax years. This act precludes the tax reporting advantages of installment sales by sellers of real property who are considered to be in such a trade or business, but an exception is made for sellers of farm property and timber.

The long-term impact on forestry investment activity resulting from the substantial changes made in the tax code in 1986 is not yet apparent. Some analysts believe that forest investors will adjust to the changes so the impact will be minimal. Others are finding that owners are cutting back on the extent of their investments in intensive practices because many such investments have been made submarginal by the impact of the tax code changes on after-tax income. Since investments in forestry must be based on long-term considerations, concern about possible changes in the tax laws creates an uncertainty that affects investor confidence regarding the economic outlook for such investments.

CONCLUDING OBSERVATIONS

In summary, programs of education, technical assistance, and financial incentives have been designed over the years to encourage investments in timber management by nonindustrial private owners. It remains to be seen whether the investments made over the past decade, including the substantial increases in tree planting, are sufficient to turn around the recent decline in productivity on other private lands noted at the beginning of the chapter. Due to the large area of timberland held by other private owners, future gains in productivity for the Nation's timberlands as a whole will continue to be heavily influenced by the status of management on these lands. Although many broad generalizations about stand conditions, costs, prices, and other factors affecting timber management decisions had to be made for the analysis in this chapter, it is clear that substantial opportunities to increase forest productivity on other private lands exist today. These investments, if made, would generate significant increases in timber growth at a favorable rate of return.

CHAPTER 10. OPPORTUNITIES TO CHANGE TIMBER DEMAND THROUGH ALTERED TIMBER UTILIZATION

Opportunities to meet rising demands for timber products by increasing net annual timber growth are discussed in the preceding chapter. Utilization improvements can also aid in meeting rising demands by increasing the efficiency of harvesting, processing, and end use of wood and fiber products. But utilization improvements may also increase demand for timber by reducing wood product cost relative to the cost of nonwood products or by developing new products or end uses. These improvements, in general, increase the economic contribution wood-using industries can make to the economy when using a limited timber base.

This chapter discusses opportunities for utilization improvement that will (1) increase efficiency of wood use, (2) reduce the cost of wood products and the cost of using wood in applications, and (3) provide new or improved wood products or wood use applications. A key purpose here is to propose and explain technology-influenced projections of (1) costs for harvesting, softwood lumber processing, plywood processing, nonveneered structural panel processing, and paper/paperboard processing; and (2) product recovery factors for softwood lumber, panels, and paper/paperboard. Projections of processing costs and product recovery are shown in Chapter 6. These projections are used in the various projection systems to project timber consumption and prices shown in Chapter 7. In this chapter, the first section reviews recent trends in improving wood utilization technology. The second discusses and projects the impact of prospective improvements in wood utilization. These technology projections are used in the base timber market projections discussed in Chapter 7. The third section discusses and evaluates the role of research in changing wood utilization technology.

RECENT TRENDS IN IMPROVING WOOD UTILIZATION

Improvements in Timber Stand Utilization

In recent years there has been substantial improvement toward greater utilization of all timber on a harvest site and greater utilization of sources other than growing stock (table 76). This greater utilization of growing stock[43] has been aided by improvements in harvesting, use of a broader range of wood quality in products, and new products that can be made from timber sources other than growing stock. Use of other sources of timber other than growing stock sources has also improved with greater use of whole tree chipping, integrated harvesting, and increases in fuelwood harvesting. Despite the considerable improvement in use of growing stock and other timber sources for products, logging residue left on sites (including growing stock and other logging residue sources[44]) is still one-quarter as large as the amount of roundwood removed. Opportunities for increased utilization of timber on harvest sites still exist.

Improvements in Product Recovery from Roundwood and Residue

Improvement in utilization of timber sources has been accompanied by improvement in product recovery from roundwood and from residue. Between 1952 and 1976 the residue left unused at mills declined from 13% to 4% and declined to 2% in 1986. By 1986 virtually all roundwood was made into products or converted to energy. The percentage of roundwood and mill residue converted to solid products or delivered to pulpmills increased from 68% to 90% between 1952 and 1976 due to increased sawmill and plywood/veneer mill product recovery, and increased use of mill residue for pulp, and panels. But the proportion declined to 88% in 1986 partially as a consequence of increased demand for fuelwood.

There are three trends that explain the improvement in roundwood conversion. First, product recovery has improved for lumber and plywood processing. Second, products with higher average recovery have replaced those with lower recovery. That is, plywood has replaced lumber in many uses, nonveneered panels are challenging plywood in structural uses, and composite lumber products are replacing lumber in selected applications. Third, there has been progressively more complete use of mill residue for composite products and pulpwood.

The relative importance of recovery improvements is greater for processes that consume more wood material. Sawmills and pulpmills process roughly the same amount of wood material—7.1 and 7.6 billion cubic feet in 1986 (fig. 77, table 129). Pulpmill furnish includes both roundwood and mill residue. Sawmill input is 24% hardwood. Homes and industries burn 4.5 billion cubic feet of wood for energy. Plywood and veneer mills process 22% as much as sawmills. Their input is 7% hardwood. Particleboard mills, oriented strand board/wafer board mills and miscellaneous industries use about 16% as much wood as sawmills, much of which is residue.

The degree of improvement in these process categories is suggested by specific statistics. Many sawmill studies have shown improved lumber recovery factors (LRF). For example, in the Pacific Northwest-West softwood LRF is estimated to have improved from 6.67 to 7.87 board feet per cubic foot between 1952 and 1985 (table 88). Table 129 suggests that in 1986 sawmills required 2.36 cubic feet of timber to be harvested for each cubic foot

[43] *Other sources includes salvable dead trees, rough and rotten cull trees, trees of noncommercial species, trees less than 5 inches dbh, tops and roundwood harvested from nonforest land (e.g., fence rows).*

[44] *Other logging residue sources include material sound enough to chip from downed dead and cull trees, tops above the 4-inch growing stock top and trees smaller than 5 inches. It excludes stumps and limbs.*

of lumber produced—an overall conversion efficiency of 42%. In preparing projections of timber consumption and prices in Chapter 7, the TAMM model used an estimate of 2.04 cubic feet of timber for each cubic foot of lumber produced—an overall conversion efficiency of 49%. The 49% estimate is more in line with estimated sawn wood conversion efficiencies for Canada and European countries (UNECE/FAO 1987).

Softwood plywood recovery factor in the Pacific Northwest-West is estimated to have improved from 12.5 to 14.5 square feet (3/8 inch basis) per cubic foot between 1952 and 1985 (table 89). Table 129 and estimates used in the TAMM model indicate that in 1986 softwood and hardwood plywood/veneer mills converted 50% of veneer log volume to plywood or veneer. Of all roundwood going into lumber and plywood/veneer production the proportion going into plywood production increased from 5% in 1952 to 19% in 1976 and then declined to 18% in 1986.

Nonveneered structural panel production, which currently recovers 55% to 60% of wood input, has grown from 0.8% of structural panel production in 1976 to 15% in 1986. Not only do nonveneered structural panels recover more of wood input, they use a larger proportion of more abundant hardwoods and smaller diameter logs than the average logs required to make lumber or plywood.

This is only a partial list of the process and product trends that are improving the proportion of wood input

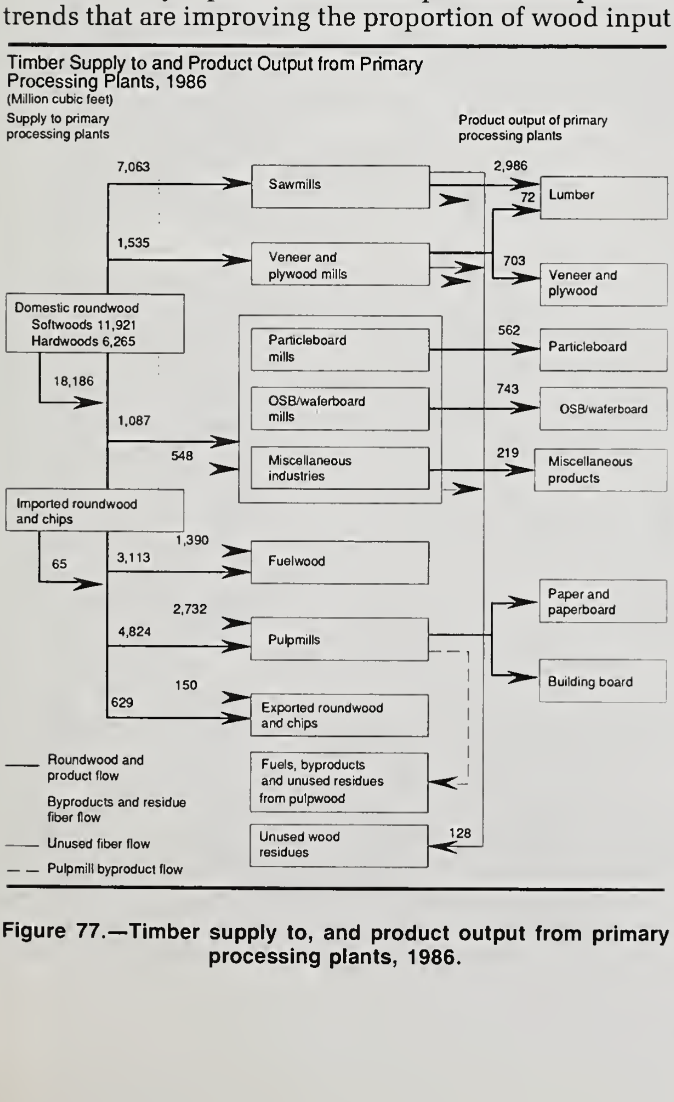


Figure 77.—Timber supply to, and product output from primary processing plants, 1986.

that ends up in solid-wood products. There are also improvements that increase the quality of lumber and panels from given timber or retain quality when using lower cost timber.

The use of wood (both hardwoods and softwoods) in making all paper, paperboard and related products increased from 1.08 to 1.21 cords per ton of paper between 1952 and 1986. This overall trend masks four important underlying trends. First, use of pulpwood per ton of paper and board has increased largely because of greater use of woodpulp and less use of waste paper attendant with the production of a greater proportion of high strength and lightweight paper and board products. Between 1952 and 1986 woodpulp use per ton of paper and board increased 14% and wastepaper use decreased 36% (table 91). Second, pulpwood use per ton of pulp actually declined between 1952 and 1986 from 1.6 cords to 1.5 cords. Third, use of mill residue as part of the pulpwood mix has increased from 25% in 1962 to 36% in 1986. Fourth, the proportion of hardwood in the pulpwood mix has increased from 14% in 1952 to 25% in 1976 and 31% in 1986. The shift to hardwoods has occurred because of technology developments allowing greater use of shorter hardwood fibers.

Changes in the End Use of Wood Products

Improvements in recovery of products from roundwood and residue have been accompanied by improvements in the efficiency of wood use in construction, manufacturing and shipping, as well as development of new wood products or applications for wood that have replaced nonwood products (Bowyer et al. 1987). Examples of end-use efficiency improvements include prefabricated roof trusses which save up to 30% of wood requirements over conventional roof systems. Roof trusses have expanded from less than 1% of residential roofing in 1952 to 77% in 1976 and more than 90% in 1986. Long spans are possible and reduce the need for interior load bearing walls, costs can be held down on assembly lines in manufacturing plants, and erection time is reduced at construction sites. An example of one wooden product being used to replace another wooden product has been the use of medium density hardboard siding in place of softwood lumber. This product has also replaced plywood and aluminum siding. The market share of hardboard siding peaked in 1983 at 31% and has declined to 25% in 1985. Finally, vinyl siding is an example of a nonwood product competing with a wood product. Vinyl siding was first introduced in 1957 but did not exceed 1% of the siding production until 1963. By 1985, improvements in quality, particularly regarding the fading of the finish, and reduction in cost increased its market share to 16% of siding production.

An example of a new use for wood has been the development and use of residential wood foundations. Since the building of a number of demonstration homes in 1969–71 the number of new homes using wood foundations increased to about 20,000 per year in 1984 or about 1% of new homes.

Table 129.—Source and utilization of roundwood in primary processing plants in the United States, by softwoods and hardwoods, 1986.

Product	Total	Residue[1] from solid products	Sawlogs	Veneer bolts and logs	Pulpwood, roundwood and whole-tree chips	Pulpwood chip imports	Miscellaneous industrial	Fuelwood
			Million cubic feet, solid-wood basis, excluding bark					
Supply to primary processing plants								
Roundwood products from U.S. forests								
Softwoods	11,921	—	5,980	1,433	3,095	—	868	545
Hardwoods	6,265	—	1,668	127	1,683	—	219	2,568
Total	18,186	—	7,648	1,560	4,778	—	1,087	3,113
Imported roundwood and chips								
Softwoods	58	—	10	0	12	36	—	—
Hardwoods	7	—	0	5	2	1	—	—
Total	65	—	10	5	14	37[2]	—	—
Exported roundwood								
Softwoods	599	—	595	0	4	—	—	—
Hardwoods	30	—	0	30	0	—	—	—
Total	629	—	595	30	4	—	—	—
Total supply to domestic mills								
Softwoods	11,380	—	5,395	1,433	3,103	36	868	545
Hardwoods	6,242	—	1,668	102	1,685	1	219	2,568
Total	17,622	—	7,063	1,535	4,788	37	1,087	3,113
Output from primary processing plants								
Lumber								
Softwoods	2,238	—	2,167[3]	72[4]	—	—	—	—
Hardwoods	819	—	819[5]	0	—	—	—	—
Total	3,038	—	2,986	72	—	—	—	—
Plywood and veneer								
Softwoods	677	—	—	677[6]	—	—	—	—
Hardwoods	26	—	—	26[6]	—	—	—	—
Total	703	—	—	703	—	—	—	—
Pulpwood delivered to U.S. mills								
Softwoods	5,408	2,270[8]	NA	NA	3,103	36	NA	—
Hardwoods	2,147	462[9]	NA	NA	1,685	1	NA	—
Total	7,556	2,732	NA	NA	4,788	37	NA	—
Pulpwood chip exports								
Softwoods	150	150	150	—	—	—	—	—
Hardwoods	0	0	0	—	—	—	—	—
Total	150	150	150	—	—	—	—	—
Particleboard and OSB/waferboard								
Softwoods	566[9]	NA	NA	NA	—	—	NA	—
Hardwoods	216	NA	NA	NA	—	—	NA	—
Total	781[10]	NA	NA	NA	—	—	NA	—
Miscellaneous industrial								
Softwoods	618	NA	NA	NA	—	—	NA	—
Hardwoods	125	NA	NA	NA	—	—	NA	—
Total	743	NA	NA	NA	—	—	NA	—
Total particleboard, OSB/waferboard and miscellaneous industrial								
Softwoods	1,183	396[7]	NA	NA	—	—	787	—
Hardwoods	343	151[8]	NA	NA	—	—	190	—
Total	1,524	548	NA	NA	—	—	976	—
Fuelwood								
Softwoods	1,648	1,103[7]	NA	NA	—	—	NA	545
Hardwoods	2,855	287[8]	NA	NA	—	—	NA	2,568
Total	4,503	1,390	NA	NA	—	—	NA	3,113
Total of all products								
Softwoods	11,305	—	NA	NA	3,103	36	NA	545
Hardwoods	6,189	—	NA	NA	1,685	1	NA	2,568
Total	17,494	—	NA	NA	4,788	37	NA	3,113

Table 129.—Continued.

Product	Total	Residue[1] from solid products	Sawlogs	Veneer bolts and logs	Pulpwood, roundwood and whole-tree chips	Pulpwood chip imports	Miscella-neous industrial	Fuelwood
Unused manufacturing residues								
Softwoods	75	75[7]	NA	NA	0	0	NA	—
Hardwoods	54	54[8]	NA	NA	0	0	NA	—
Total	128	128	NA	NA	0	0	NA	—
Total output								
Softwoods	11,380	—	5,395	1,433	3,103	36	868	545
Hardwoods	6,242	—	1,668	102	1,685	1	219	2,568
Total	17,622	—	7,063	1,535	4,788	37	1,087	3,113

NA—Indicates detailed data on residue or roundwood use for this column is not available.

[1]*The residue column shows total residue used in a product which came from sawmills, veneer/plywood mills or miscellaneous industries, except that for particleboard, OSB/waferboard and miscellaneous industrial products this column is total residue from sawmills and veneer/plywood mills only. The sawlog column contains residue from sawmills except for the lumber products row where it contains roundwood contents in lumber. The veneer log column contains residue from veneer/plywood mills except for the plywood/veneer product row where it contains roundwood contents in plywood/veneer. The miscellaneous industrial column contains residue from miscellaneous industrial mills except for the particleboard, OSB/waferboard, and miscellaneous industrial products rows were it contains amounts of roundwood contained in byproducts.*

[2]*Total roundwood and chip imports (630,000) times 79.2 cubic feet per cord.*

[3]*Lumber volume in 1,000 board feet times 64.50 cubic feet per 1,000 board feet.*

[4]*Lumber volume from cores of peeled veneer logs is estimated at 5% of veneer log volume.*

[5]*Lumber volume in 1,000 board feet times 79.47 cubic feet per 1,000 board feet.*

[6]*Plywood/veneer volume in 1,000 square feet 3/8-inch basis times 31.25 cubic feet per 1,000 square feet.*

[7]*Residue use in bone dry tons times (2,000 pounds/27.35 pounds per cubic foot).*

[8]*Residue use in bone dry tons times (2,000 pounds/34.34 pounds per cubic foot).*

[9]*Softwood furnish estimated at 72.4% of total.*

[10]*Volume of particleboard and OSB/waferboard in 1,000 square feet 3/4-inch basis times 62.5 cubic feet per 1,000 square feet.*

Note: Numbers may not add to totals due to rounding.

Sources: Roundwood products from U.S. Forests: Waddell et al. 1989: table 30. Imported and exported sawlogs and veneer logs and pulpwood chip exports: USDA FS 1988e: tables 4–7. Imported and exported roundwood and whole tree chips: USDA FS 1988e: tables 5, 6, and 27. Residues from solid wood products for making pulp products, fuelwood, and other products (particleboard, OSB/waferboard and miscellaneous industrial): Waddell et al. 1989: table 31.

PROSPECTIVE IMPROVEMENTS IN WOOD UTILIZATION TECHNOLOGY

There are at least three techniques and associated rationales to use in preparing forecasts of technological capabilities (Bright 1978): (1) extrapolate trends—assume a steady pace of technological change; (2) project change based on change in technological determinants; and (3) project change based on identifying emerging innovations, their capabilities and possible pace of adoption—assuming a certain pace of adoption for promising innovations. The evaluation method here rests primarily on the third technique and to a lesser degree on the second technique.

Technological innovations will change the competitiveness of wood sources and products by (1) increasing the recovery and decreasing costs for making lumber, panels, paper and paperboard; (2) developing processes/products that expand the use of underutilized species, mill residue and residue left on harvest sites; (3) decreasing the cost of harvesting; (4) increasing the efficiency of end use of wood products; and (5) developing new/improved products and end-use application methods to expand markets for wood. This section identifies many of these technological developments and focuses on projecting costs and/or product recovery for harvesting operations, lumber processing, plywood and nonveneered structural panel processing, and pulp and paper processing. This section also discusses prospective technological changes in construction and manufacturing and the resultant projections of wood product use rates in various end uses.

The next several subsections present an assessment of the effects of technological change in harvesting and processing of softwood lumber/composite lumber, softwood plywood, nonveneered structural panels and paper/paperboard. Each begins with a discussion of possible technological developments in processing. The assessment includes the following steps: (1) identifying likely changes in technology, (2) formulating current and future mill designs which incorporate innovations and have specific recovery and cost characteristics, (3) developing projections of the mix of mill designs used for production through 2040, and (4) calculating recovery and costs resulting from the projected mix of mill designs.

In addition to the assessment of harvesting and softwood lumber, panel and paper/paperboard processing, we present more general assessments of technology change in hardwood lumber processing, wood use in construction, wood use in manufacturing, and wood use for energy. Included in these assessments are an explanation of the technology assumptions used to make the timber consumption and price projections that are shown in Chapter 7.

Harvesting

Timber harvest and transport includes machines and processes whose application varies widely by region, season, terrain, tree species, tree size, stand density, portion of the stand removed, and distance to market. Timber harvesting involves a wide range of equipment tailored to the unique problems posed by each stand. The characteristics of the harvest system used are determined by the major product of each stand (pulpwood, saw logs, veneer logs, tree length logs, whole trees, or chips), stand and species characteristics, expected weather conditions, and the terrain (flat, mountainous, or swamps). Many stands include several product/terrain combinations. To cover the range of conditions encountered, each timber producing region has developed several distinct sets of equipment and procedures. These "solutions" may not necessarily result from a least-cost calculation but from practical adjustments to the highly seasonal and otherwise unpredictable nature of the business, local labor shortages or surpluses, industry purchase policies, and agency/landowner harvest schedules.

In general, for a given harvesting system, costs per unit volume are inversely related to the square of average tree diameter and inversely related to trees per acre. This is because stands are harvested one tree at a time and tree volumes increase with the square of diameter.

Technology Developments

Future timber harvest equipment will closely resemble today's. Tomorrow's logging machines, regardless of improved efficiency, will still have to move over rough surfaces, sever and maneuver heavy trees or logs, and carry them considerable distances in all kinds of weather. Within these constraints, equipment and system designers seek to improve: (1) load capacity, (2) travel and process speed, (3) reliability and longevity, (4) species and product versatility, (5) terrain capability, (6) operator comfort, and (7) safety. Flexibility, rather than maximizing efficiency for a specific kind of stand, is often a more important goal in developing harvest machines and processes.

Table 130 describes specific changes now in development or contemplated for the felling-bunching, skidding-forwarding, processing, loading, and transport functions. These are stimulated by the following problems which current systems do not adequately address:

1. Operating on steep terrain and on sensitive soils;
2. Operating in stands which contain significant portions of unmerchantable species, or multiple products;
3. Operating in low density stands or stands with many small trees;
4. Operating on small tracts required by regulations or fragmented land ownership;
5. Increasingly expensive road construction and long distance hauling; and
6. Improving utilization of branches, tops, bark and previously unmerchantable material.

Other pressures for change include the need to conserve energy and labor and to protect the long-term productivity of forest lands.

There are major opportunities to reduce costs in ground skidding, cable yarding, and log transportation. These functions are the most capital and energy intensive and the most dangerous. Lighter weight machines and engines, improved tires and suspension systems along with much improved fuel efficiency, will reduce costs significantly. As a result of these changes, longer economical skidding or yarding distances will reduce the need for expensive roads.

Current and Projected Harvest System Characteristics

In order to calculate current and projected harvesting and transport cost per thousand board feet for wood harvested in each U.S. region, the production costs were identified for a range of *current* harvesting systems in each region. These systems are shown in table 131 by the key equipment used. Harvest and transport costs for each system are affected by average tree diameter and volume per acre.

Each harvest system was developed to be close to the "optimum" for the typical diameter/volume/terrain conditions encountered in that region and typical conditions in one region may be extreme conditions in another. Generally, the regional ranking from lowest cost per unit volume to highest is as follows: South, Pacific Northwest-East, Pacific Southwest, Pacific Northwest-West and Rocky Mountains (table 81).

Projected Mix of Harvesting Systems

Substantial shifts in system mix are expected in various regions (table 131). On the flat terrain in the East, and in the North and South, loggers will rely increasingly on mechanized feller-bunching and grapple skidding to central landings for processing and loading. Chainsaw felling is generally being replaced by feller-bunchers in pulpwood operations but will continue to be widely used on saw log and veneer operations to protect valuable butt logs. It is difficult, however, to attract workers to do this hard, dangerous chainsaw work. Grapple skidders are expected to replace most cable skidders by 2040 for safety reasons. Grapple skidders will increase their share of production from 43% to 63% in the South and 5% to 24% in the North. In the South, use of the unique and very labor intensive bobtail truck and farm tractor systems are expected to decline, but will still produce about one-eighth of roundwood output in the South by 2040. These labor intensive systems persist, despite the availability of more efficient equipment, because of a traditional need for off-season farm employment. These systems often produce the least expensive wood, primarily due to the lack of employment alterna-

Table 130.—Technology developments in timber harvesting.

Process	Description	Impact
Felling and bunching		
Lighter weight and/or lower ground pressure machines	For flat terrain, feller-bunchers either smaller, mounted on lighter chassis, or equipped with larger tires, high speed tracks, or air cushions.	Less soil erosion or compaction, maintains productivity, enables harvests on previously "unsuitable" land; fewer roads required.
Walking or self-leveling feller-bunchers or felling-directors	Feller-bunchers able to negotiate slopes over 50%. In larger diameter western stands, more portable machines that direct felling with hydraulic jacks.	Less soil erosion or compaction, maintains productivity, enables harvests on previously "unsuitable" land; fewer roads required.
Multistem carriers attached to feller-bunchers	For smaller diameter stands and plantations, the ability to accumulate several stems before dropping.	Will make plantation management and pole timber thinning economic.
Saw felling heads	In lieu of shears, saw heads eliminate butt splitting.	Improves lumber and veneer recovery from butt log.
Skidding and yarding		
For ground-based skidding and forwarding:		
Lighter weight and/or lower ground pressure machines	Skidders and forwarders, either smaller or mounted on lighter chassis, or equipped with larger tires, high speed tracks, or air cushions.	Less soil erosion or soil compaction, therefore maintaining productivity or enabling harvests on previously "unsuitable" land: fewer roads required.
For aerial cable yarding systems:		
Grapple yarders	Cable yarders that can bunch and grapple by remote control.	Reduces crew size, inefficiency, and danger in hand choker setting
Self releasing chokers or grapples	Load can be released automatically at landing.	Reduces crew size, inefficiency, and danger with hand choker setting.
Synthetic ropes and rigging	Replaces expensive heavy wire cable and massive steel running gear.	Reduces equipment cost, more usable load.
Remote log and tree weight estimation	Enables yarder operator (with or without computer assistance) to judge tree or log weight and thereby plan each load.	Improves system production, safety, and reduces equipment breakage.
Cable tension monitors	Enables yarder to electronically monitor load during retrieval.	Improves system production, safety, and reduces equipment breakage.
More mobile tail block systems	Depending on slope, cable yarding systems require ends of cable system to be moved frequently.	Reduces crew requirements, and increases production.
Cheaper more reliable anchors	Previously, very large stumps were used for cable anchors but these are now seldom available.	Will enable harvests on small timber in steep terrain, extending the area of "suitable" lands.
Smaller systems for smaller timber primarily in the east	Cable yarders for western U.S. conditions are for large logs and long steep slopes. Eastern mountains are less demanding but need cable yarding to avoid soil erosion and residual stand damage caused by partial harvests.	Extends the area of "suitable" land in the east. Reduces need for expensive road construction.

Table 130.—Continued.

Process	Description	Impact
Processing		
Mechanized delimbers	Hardwood sawlogs are expensive and dangerous to delimb. Softwood log form is better and delimbing is less of a problem.	Reduces labor requirements, improves production and safety.
Debarkers	Removing bark on the landing before chipping or hauling.	Reduces hauling cost, increases utilization if clean chips can be produced, leaves more nutrients on site.
Smaller, lighter chippers and/or chunkers	Chips or chunks offer the opportunity to recover vast amounts of wood previously wasted. Chunks are very large chips which require less energy to produce.	Improves utilization, extends timber supply, removes unwanted stocking hindering regeneration.
Merchandisers	Combined chipping/chunking and roundwood processor in the woods that produce and direct species and tree components to their highest value use.	Maximizes return to landowners, extending area of "suitable" lands.
Transportation		
Log weight estimation	Knowing log weights beforehand can increase average load size without overloading.	Reduces overload fines, equipment breakage, improves safety.
Automatic truck weighing	Sensors installed on each truck reporting actual weight.	Reduces overload fines, equipment breakage, improves safety.
Central tire inflation	Compressor and piping on each truck could inflate or deflate tires. Dirt roads last longer when tires have low pressure but highways require high pressure for high speeds.	Extends forest road life.
General developments		
Lightweight machine construction	Development of metal alloys, ceramics, plastic composites for chassis, engine and components will alter machine design, construction and performance.	Lower fuel cost, more power available for useful work, machines can range farther, reducing road requirements, less soil compaction and/or erosion.
Improved fuel economy	New engine designs such as fuel efficient 2-cycle engines, air cooled diesels, gas turbines, and fluidics will decrease fuel consumption and the way power is transmitted for traction or processing.	Lower fuel cost, more power available for useful work.
Improved engine, chassis, suspension, and maintenance	Computer monitoring of machine loading and maintenance needs will increase machine life.	Lower fixed machine costs per unit volume. Lifetime maintenance costs may exceed purchase price.
Ergonomic design (human factor engineering)	Designing machines and their controls to suit the tolerances of humans is a largely untouched but crucial area in harvest equipment design.	Increased production and reduced accidents. Decreased cost for workman's compensation insurance.
Computer aided systems analysis and operation	On-board computer, as well as off-machine systems analysis and operations research technique can make market sensitive real-time decisions and train employees.	Increased productivity, reduced wood losses or grade reduction, more rapid training.

Table 131.—Proportion of timber harvested by various systems by region in 1985, with projections to 2040.

Section and region	1985	Projections 2000	2010	2020	2030	2040
				Percent		
South—flat terrain						
Roundwood						
Cable skidders	35.0	30.0	25.0	20.0	15.0	10.0
Grapple skidders	43.0	47.0	51.0	55.0	59.0	63.0
Bobtail trucks and farm tractors	17.0	16.0	15.0	14.0	13.0	12.0
Whole tree chippers	5.0	7.0	9.0	11.0	13.0	15.0
Total	100.0	100.0	100.0	100.0	100.0	100.0
North[1]—flat terrain						
Roundwood						
Cable skidders	61.0	50.0	40.0	31.0	22.0	14.0
Grapple skidders	26.0	29.0	33.0	36.0	39.0	41.0
Forwarders	5.0	9.0	13.0	17.0	20.0	24.0
Whole tree chippers	9.0	11.0	14.0	16.0	19.0	21.0
Total	100.0	100.0	100.0	100.0	100.0	100.0
North[1] and South—steep terrain						
Cable yarders	10.0	16.0	22.0	28.0	34.0	40.0
Skidders and forwarders	90.0	84.0	78.0	72.0	66.0	60.0
Total	100.0	100.0	100.0	100.0	100.0	100.0
Rocky Mountains[2]						
Tractors—jammers	86.1	83.9	81.7	79.5	77.2	75.0
Cable yarders	13.9	16.1	18.3	20.5	22.8	25.0
Total	100.0	100.0	100.0	100.0	100.0	100.0
Pacific Coast						
Pacific Southwest[3]						
Highlead	6.4	6.1	5.8	5.6	5.3	5.0
Skyline—short	23.2	24.0	24.8	25.4	26.2	27.0
—medium	7.4	8.3	9.2	10.2	11.1	12.0
—long	0.0	0.2	0.4	0.6	0.8	1.0
Tractors	63.0	61.4	59.8	58.2	56.6	55.0
Total	100.0	100.0	100.0	100.0	100.0	100.0
Pacific Northwest						
Pacific Northwest-West						
Highlead	20.0	18.0	16.0	14.0	12.0	10.0
Skyline—short	37.5	38.0	38.5	39.0	39.5	40.0
—medium	7.5	8.0	8.5	9.0	9.5	10.0
—long	2.5	2.6	2.7	2.8	2.9	3.0
Tractors	32.5	33.4	34.3	35.2	36.1	37.0
Total	100.0	100.0	100.0	100.0	100.0	100.0
Pacific Northwest-East						
Highlead	3.0	3.4	3.8	4.2	4.6	5.0
Skyline—short	12.0	12.6	13.2	13.8	14.4	15.0
—medium	6.0	6.4	6.8	7.2	7.6	8.0
—long	0.0	0.4	0.8	1.2	1.6	2.0
Tractors	79.0	77.2	75.4	73.6	71.8	70.0
Total	100.0	100.0	100.0	100.0	100.0	100.0

[1]*Includes North Dakota, Nebraska, and Kansas.*
[2]*Excludes North Dakota, Nebraska, and Kansas.*
[3]*Excludes Hawaii.*

tives. In the North, forwarders are expected to expand from about 26% to 41% by 2040 and whole tree chipping is expected to increase from 9% to 21% by 2040.

The East also possesses considerable "mountainous" terrain. About 55%, 6%, 13%, and 11% of the Northeast, North Central, Southeast, and South Central regions, respectively, are considered mountainous. While not as rugged as the Rockies or Pacific Coast, the proximity of a large concerned population, very erodible soils, and generally less productive sites, heighten the need for cost-effective and environmentally sound harvesting equipment and methods. To date, several small scale cable yarding systems adapted from European and West Coast equipment have been applied with some success. We assume cable systems could increase from 10% of the harvest from mountainous terrain to 40% between 1985 and 2040.

On the Pacific Coast the rugged terrain and extremely large trees frequently require expensive and complex cable yarding systems. Despite their cost, these systems are effective in reducing soil erosion. Highlead systems are expected to decline and to be replaced by more versatile skyline systems. Both use portable guyed steel towers but skyline running gear is more complex. Almost all trees are hand felled in the West because of large diameters and steep slopes. Ground skidding using rubber-tired or crawler tractors on less steep slopes is expected to remain about the same in all Pacific regions. Tractors now account for 33%, 79%, and 63% of production in the Pacific Northwest-West, Pacific Northwest-East, and Pacific Southwest subregions, respectively.

In the Rockies, movable skyline systems are widely used but are expected to be replaced somewhat by smaller cable yarders adapted from the Pacific regions.

Generally, shifts in system mix in all regions are expected to be from less efficient to more efficient systems, and from more labor intensive to less labor intensive systems.

Projecting Harvesting Costs as Stand Characteristics and System Mix Change

Four factors were used to make initial harvest cost projections in each region to 2040: (1) the harvest and transport costs for systems used in each region, (2) the proportion of wood harvested with each system (table 131), (3) the average tree diameter and volume per acre, and (4) the assumed rate of productivity improvement for each harvesting system. The initial harvest cost projections were further modified as noted below.

Tables of harvesting costs (for a range of tree diameters and stand volumes) were computed for each region and decade by weighing harvest cost for individual systems by the proportion of wood harvested by that system (table 131). A single average cost was selected from these tables using projected tree diameter and volume per acre for that region and decade.[45] These projections assume that productivity of individual harvesting systems will not increase between 1985 to 2040. They also assume constant wage rates and energy prices. The initial projected harvest costs change only as a result of changes in stand characteristics and system mix (Bradley 1989). The initial projections were modified in certain regions.[46]

[45]*Tree diameter (DBH) and stand volume per acre were projected to change as follows between 1985 and 2040:*

	DBH	Vol/A
North	+2%	+45%
South	−7%	+31%
RM	−27%	+26%
PNW-W	−49%	0%
PNW-E	−27%	0%
PSW	−49%	0%

[46]*For the Rocky Mountain region, initial logging cost growth rates were raised to equal those of the Pacific Northwest-East. This retains the past position of the Rocky Mountains as the highest cost western U.S. region. Environmental limitations on logging are likely to remain at least as stringent in the Rocky Mountains as elsewhere in the West, thus maintaining higher costs. For the South, logging cost growth rates were raised to maintain the current relative regional cost structure—the revised growth rate for the South, overall, is slightly greater than for the Rocky Mountains and Pacific Northwest-East. Higher cost growth rates in the South could result in part from more rapidly rising labor costs than in other regions (Adams 1989).*

Based on these assumptions and methods, logging costs are projected to increase at a slower rate than that experienced from 1952 to 1985 in all regions except the South. The rate of increase between 1985 and 2040 is greatest in the South—57% (table 81). The slowest growth is 49% in the Pacific Southwest.

Softwood Lumber and Composite Lumber Processing

Conventional softwood lumber is made by breaking down logs, while composite lumber is made by recombining wood flakes and/or veneer into products which perform like lumber in selected applications. Softwood lumber is made from many species for use in construction and remanufacture. It is made in length multiples of 1 or 2 feet as specified by various grading rules. Width commonly varies from 2 to 16 inches nominal (actual width is less). Lumber is categorized by thickness: boards—less than 2 inches nominal; dimension—2 to just less than 5 inches nominal; and timbers—5 inches or more nominal. Lumber for making products is graded under the American Lumber Standard. Lumber for construction may be stress-graded, nonstress-graded, or appearance-graded. Lumber for remanufacture may be factory (shop) grades; industrial clears; molding, ladder, pole timber, or pencil stock; or structural laminations (USDA FS 1987b).

Conventional lumber processing includes yard handling of logs, bucking, debarking, log breakdown by primary and secondary sawing, planing, drying, grading and preparation for shipping. Timber characteristics that influence the recovery of lumber from roundwood and the processing costs include log diameter, length, shape, and defects. Timber characteristics have less influence on the rate of recovery of composite lumber from roundwood. Hardwood lumber processing is discussed in a later section.

Technology Developments

The softwood lumber industry adopts technological improvements to produce lumber in order to (1) reduce costs of wood, (2) reduce processing costs, and (3) maintain and enhance quality for evolving end uses—all while facing a timber resource that is declining in size and quality. Many improvements seek to reduce wood costs and processing costs in response to competition from lumber imports, decline in timber diameter, lower cost for hardwoods compared to softwoods, and the small but growing proportion of plantation timber which has a higher proportion of juvenile wood. Other technological developments seek to minimize processing costs by reducing the need for costly capital, labor, and energy.

Two general trends in sawmill technology are expected. First, more sawmills will be part of integrated wood processing systems rather than independent profit centers. These systems may include logging, wood merchandising, sawmills, plywood mills, particleboard mills, pulpmills, and wood use for energy. These integrated wood processing systems will work to allocate each tree stem to its most profitable use. Second, equipment within a sawmill will continue to change from a collection of independent machines connected by a material transport system to an electronically integrated collection of machines linked by conveyors. For production of traditional lumber products, techniques that increase wood recovery and thus reduce cost include improved scanning to measure log shape; computer control for optimal log breakdown based on the best-opening-face (BOF) concept to provide improved bucking, primary and secondary breakdown, edging and trimming; thinner saw blades, longer wearing teeth and better saw guides to reduce saw kerf and sawing variation; and more closely controlled drying using improved moisture sensing and removal to reduce energy use and degrade (table 132).

Although we do not evaluate their potential impact here, several new lumber type products can further increase wood recovery. These include laminated veneer lumber, composite lumber, composite wood I-beams and hardwood structural lumber made by the Saw-Dry-Rip

Table 132.—Technological developments in softwood lumber, hardwood structural lumber and composite lumber processing.

Product type and development	Description	Impact
Softwood lumber		
Log and board scanners linked with process optimizers	Improved scanning of log and board shape coupled with increasingly sophisticated computer software and log/board positioning equipment provide improved log bucking, primary breakdown, secondary breakdown, edging and trimming	Improves recovery of lumber
Sawline loss reduction	Kerf can be reduced with thinner saws and sawing variation can be reduced with developments of low expansivity alloys for saw blades, improved saw guides and lower wearing narrower saw teeth.	Improves recovery of lumber
Abrasive planing	Abrasive planing, which removes much less wood than knife planing, can be used more as surface irregularities decrease with use of more stable saws.	Improves recovery of lumber
Improved control of drying	Sensing of temperature drop across the load in all zones of a dryer decreases degrade of pieces.	Holds down cost of drying, improves lumber recovery
Tomography for log defect detection	Experiments indicate computer aided tomography using x-rays can recognize internal log defects which could supply computer programs with information to improve grade recovery of lumber.	Improves recovery of lumber
Hardwood lumber—structural		
Saw-dry-rip processing[1] for hardwood structural lumber	The saw-dry-rip-sequence for processing warp prone medium density hardwoods sharply increases the yield of STUD grade structural hardwood lumber.	Production of structural lumber from plentiful medium density hardwoods
Composite lumber		
Laminated veneer[1] lumber	Wide dimension lumber made from laminated sheets of veneer efficiently uses smaller diameter logs to replace long length larger structural lumber (2 by 8, 10, 12) made from larger diameter logs.	High recovery from smaller logs to make deep dimension structural lumber
Parallel strand[1] lumber	Long strands of veneer residue are used to make deep long structural lumber.	Recovery of veneer residue to make structural lumber
Com-ply lumber[1]	Com-ply lumber is formed of a flakeboard center with several laminations of veneer at the edges. Hardwood and softwood may both be used with high recovery from smaller logs to make structural lumber for housing.	High recovery and joint use of smaller diameter softwoods and hardwood to make lumber

[1] *The effects of potential expanded use of these processes is not included in the technology projection model or the timber supply/demand projections.*

(SDR) process. Laminated veneer lumber has gained acceptance where uniform strength, greater depth and long-span support is needed. Composite wood I-beams with laminated flanges (top and bottom edges) and plywood or flake board webs (centers) have also gained acceptance where long-span support is needed. Composite lumber for construction has been produced in the form of Com-ply (lumber with a core made from hardwood and softwood flakes and edges made from veneer) but the prospects for its wide use are not clear. Although there has been little commercial application, structural lumber may be made from medium density hardwoods, such as yellow poplar and cottonwood, using SDR (Maeglin et al. 1981, Maeglin 1985, Allison et al. 1987). The SDR process reduces the tendency of these same species to warp due to growth stresses and it can also be used to reduce warping in lumber made from logs with a high proportion of juvenile wood.

Current and Projected Characteristics of Lumber Processing

A range of sawmill designs that include many of the innovations noted in the previous sections were prepared as part of calculating future lumber recovery factors (LRF) and lumber processing costs (Williston 1987). Mill designs for laminated veneer lumber, composite wood I-beams, composite lumber, or SDR lumber processing were not included. Some designs that were used include considerable improvement over traditional sawmills, including reduction in kerfs and dressing allowance, closer approach to theoretical highest yield (table 133), an increase in log throughput rate and a decrease in labor requirements.

For five regions, mill designs for three mill types at four technology levels were prepared. Mill types were (1) stud mills, (2) random length dimension mills, and (3) board mills. Technology levels were (1) current average mill producing less than 5 million board feet per year, (2) current average mill producing more than 5 million board feet per year, (3) mid-1980s best mill, and (4) future mill.

The chief features of current average mills producing less than 5 million board feet per year were use of a carriage to transport logs with circular saw breakdown, kerf in excess of .250 inch, little or no computer control of breakdown, air drying of lumber and knife planing. The remaining types of mills all produce more than 5 million board feet per year and use kilns for drying lumber.

The current average mills producing more than 5 million board feet per year vary by product produced. The stud mill uses canter log transport and a quad band headrig, kerf less than .200 inch, computer controlled breakdown, but no optimizing edger or trimmer. The random length dimension mill uses full taper canter log transport and a quad band headrig, kerf less than .200 inch, and computer controlled breakdown and edging. The board mill uses carriage log transport with a single band headrig, kerf of about .250 inch, computer assisted log offsets, and an edger optimizer.

Table 133.—Current and projected designs of softwood sawmill systems.

Age of technology[1], size of mill and type of mill	Log transport system/ headrig type	Sawing parameters: Kerf Headsaw	Kerf Resaw	Dressing allowance	Percent[2] of BOF yield attained
			Inches		
Current less than 5 MMBF					
Stud	Carriage/Circular saw	.284	.284	.119	72
Random length dimension	Carriage/Circular saw	.284	.284	.119	72
Board	Carriage/Circular saw	.284	.284	.118	72
Current more than 5 MMBF					
Stud	Canter/Quad band—ex. North	.202	.173	.119	72
	Carriage/Circular saw—North	.205	.179	.119	72
Random length dimension	Full taper canter/Quad band — except North	.202	.173	.119	72
	Carriage/Circular saw—North	.205	.179	.119	72
Board	Carriage/Single band	.252	.183	.118	72
Mid-1980s best					
Stud	Overhead end dog/Quad band	.121	.119	.107	74
Random length dimension	Side dog sharp chain/Quad band	.121	.119	.107	74
Board	Overhead end dog/Quad band	.121	.119	.107	74
Future					
Stud	Magazine/Precision canter	.110	.100	.015	76
Random length dimension	Integral/Precision canter	.110	.100	.015	76
Board	Overhead end dog/Quad band	.110	.100	.015	76

[1]*Mid-1980's best technology and future systems are mills producing more than 5 million board feet per year.*

[2]*Percent of theoretical lumber recovery attained, where theoretical recovery is computed using the Best-Opening-Face computer program with sawing parameters shown in the table.*

Source: Headrig type: Williston 1987. Kerfs and Dressing allowance: Steele et. al. 1987, Steele et al. 1988a. Estimates for mid 1980s best and future mills are from Lunstrum and Danielson 1987.

This double-bandsaw headrig with an end-dogging carriage is one example of innovative technology used in western sawmills.

The mid 1980s best mills also vary by product. All are assumed to have headsaw and resaw kerf just over .125 inch. The stud mill uses overhead end dog log transport and a quad band headrig, computer controlled breakdown, and an optimizing edger. The random length dimension mill uses side clamp sharp chain log transport with a quad band headrig, computer controlled breakdown, and an optimizing edger. The board mill uses overhead end dog log transport with two reducer heads and a quad band headrig, computer assisted log offsets, and an edger optimizer.

The future sawmills are assumed to come into use in the mid 1990s. In the future stud mill, long logs are scanned, bucked and sorted by diameter, length and shape. Input may include plywood cores. Logs are sorted by diameter and irregularities removed to permit high speed magazine feed (30 logs/minute). Logs are cut by precision machinery canters with offset capability which produce smooth 2x4's from the sides and 2x6's from the cant. Stacking is done by an automatic crib-stacker. Lumber is dried under restraint at high temperature and high speed. Dressing removes .015 inch by touch sanding. Grading is done by noncontact scanning at 650 feet per minute followed by sorting and packaging.

In the future random length dimension mill, long logs are scanned and bucked for optimum length and shape. Logs are sorted by diameter, length and grade before storage in the log yard. Log infeed is by diameter class permitting infeed at 8.5 logs/minute. Log transport is by flat chain feed with side and top rollers for positioning. The headrig has log offset and taper sawing capability and contains four reducer heads, a gang saw and built-in edgers. Stacking is automatic. Lumber is dried at high temperature. Dressing removes .015 inch by touch sanding. Grading is done by noncontact scanning followed by sorting and packaging.

In the future board mill, logs are sorted into two grade categories and several diameter classes. Computer aided tomography type scanning is used to sense interior defects. Logs are fed into the mill by class in relatively long runs at 3.5 logs per minute per headrig. Coded grade marks on logs indicate the position of sweep and crook, the location of clear and common faces, and the depth of cut to maximize value recovery. Smaller diameter logs with only one or two opposing clear faces go to a side with overhead end dog transport and a reducer quad band headrig. Larger diameter logs with two or more clear faces go to a side with overhead carriage transport and 90° turning capability and a reducer quad band headrig. Common lumber cants go through an optimizing gang saw. Upper grades pass through an optimizing edger that scans and cuts to optimize value based on appearance grade. A computer controls drying to 12% moisture content. Dressing removes .015 inch by abrasive planing. Boards are then scanned for appearance grade and trimmed and sorted automatically.

Projected Mix of Lumber Processing Systems

Average LRF and processing costs were computed for each region by taking a production-weighted average over all mill types and technology types (table 134). The averages change over time as the proportion of production moves from current technology to the best technology of the mid-1980s to future technology and as average log diameter declines (table 135).[47]

New sawmill capacity is introduced in two ways: remodeling or new construction.[48] Between 1982 and 2040, new or remodeled capacity that is small mill technology[49] is assumed to decline nationwide from 16% to 8%. In 1982 the percentage of mill capacity using this small mill technology varied from 21% in the South to 0.1% in the Pacific Southwest (McKeever 1987b). Between 1982 and 1990, the large mill technology will initially be replaced by current average technology for mills greater than 5 million board feet per year, but will gradually change so that by 1995 large mills will be replaced only by mid-1980s best technology. Between 1995 and 2040, the proportion of new or remodeled capacity that is mid-1980s best technology will gradually decline to zero, while the proportion with the future technology will increase (table 134).

[47]A computer model was used to compute lumber recovery factor (LRF) and processing costs for 3 mill types at each of 4 technology levels for 6 regions. Many mills have the same basic design across regions. Each design has (1) a basic equipment layout; (2) estimated costs for equipment, maintenance, labor, energy, and administration; (3) estimated log throughput rate by log diameter (Williston 1987); and (4) an equation to estimate LRF by log diameter that was prepared using best-opening-face (BOF) computer software (Lewis 1985). Associated with each design and LRF equation are specific sawing characteristics, such as split-taper or full-taper sawing, headsaw kerf, resaw kerf, dressing allowance (table 133), trimming procedures, and proportion of theoretical yield obtained. Sawing parameters for "current average" technologies are from the Sawmill Improvement Program (SIP) (Steele et al. 1987, Steele et al. 1988a) and estimates by Lunstrum and Danielson (1987). Sawing parameters for "mid-1980s best" and "future" mills were estimated by Lunstrum and Danielson (1987). Proportion of theoretical yield attained was estimated by reducing BOF estimated LRF's to match estimated 1985 "real world" recoveries in the Timber Assessment Market Model data set (Haynes 1987). LRF and costs were calculated for each mill type/technology level in each region for the average log diameter processed (table 135). Processing costs exclude wood cost and revenue from sale of mill residue. For our projections to 2040, it is assumed that real wage and energy costs are held constant at 1986 levels. The model's first year is 1982. Log diameters for 1982 are from SIP data (Steele et al. 1988b). The initial proportion of lumber made in mills producing less than 5 MMBF per year is from state and national mill directories (McKeever 1987). The proportion of capacity in stud mills (10%), random length dimension mills (65%) and board mills (25%) is based on data from the USDC Bureau of Census (1982).

[48]A mill is assumed to be remodeled or shut down after 10 years. In 1982, capacity is assumed to be uniformly distributed among 10 1-year age classes. Beginning in 1983, a mill in the 10-year-old age class is assumed to be remodeled or shut down. The mill is assumed to be shut down if there is an externally specified decrease in total capacity. Entirely new capacity is added to fulfill a need for an increase in total capacity.

[49]Current average technology producing less than 5 MMBF.

Projected Recovery and Costs as Log Diameter and Mix of Systems Change

Average softwood lumber recovery in the United States is currently about 49% of the cubic volume processed, and the lumber recovery factor (LRF) is 6.8 board feet lumber tally per cubic foot log scale. Overall recovery is projected to improve by 15% between 1985 and 2040, to 57%. Projections of LRF average 7.8 by 2040 and exceed more than 8.4 in the Pacific Northwest-West (table 88). These projections reflect a decline in diameter of logs processed (table 135). The national averages are weighted by regional production and are influenced by the regional production shift from the West to the South.

Projected increases in lumber recovery vary by region. Between 1985 and 2040, recovery will increase by 19% to 24% in the South and Pacific Northwest-East regions (table 88) where decreases in log diameter are limited. Recovery improvement will be least in the Pacific Northwest-West (8%) and Pacific Southwest (11%) due to a projected 24% decline in average log diameter. The wide range in regional recoveries in 1985 (6.02 to 7.87) will narrow by 2040 (7.18 to 8.47). The Pacific Northwest-West and the Pacific Southwest will retain the highest recovery factors because the South is projected to retain a significant number of small, less efficient mills.

Softwood lumber processing costs are projected to decrease in all regions by 2040 (table 82). Processing costs exclude wood costs and revenue from sale of residue. This departure from the upward cost trend in the 1970s is attributable to continued improvements in sawing technology; less capital, labor and energy per unit; and projected constant wage rates and energy prices. The cost decline between 1985 and 2040 will be the greatest in Pacific Northwest-East (24%), lowest in the Pacific Southwest and Rocky Mountains (16–21%), and 22% in the South and Pacific Northwest-West. Newer mills will be able to keep costs per unit output down, even in regions where diameters decline, by increasing their log throughput rate.

The Impact of Technology Change on Lumber Manufacturing Costs

Lumber manufacturing costs include costs for stumpage, harvesting and hauling, and processing. The technology changes discussed previously hold down the cost

Table 134.—Proportion of various softwood sawmill systems by region in 1985, with projections to 2040.

Section and region	1985	Projections 2000	2010	2020	2030	2040
		Percentage of production				
North[1]						
Old less than 5 MMBF	61	54	49	43	38	33
Old more than 5 MMBF	37	3	0	0	0	0
Mid-1980s best	2	41	39	31	20	7
Future	0	2	12	26	42	61
South						
Old less than 5 MMBF	21	19	17	15	13	11
Old more than 5 MMBF	75	6	0	0	0	0
Mid-1980s best	4	73	64	46	28	9
Future	0	3	20	39	59	80
Rocky Mountains[2]						
Old less than 5 MMBF	12	11	10	9	7	6
Old more than 5 MMBF	84	7	0	0	0	0
Mid-1980s best	4	80	69	50	30	9
Future	0	3	21	42	63	84
Pacific Coast						
Pacific Southwest[3]						
Old less than 5 MMBF	0	0	0	0	0	0
Old more than 5 MMBF	95	8	0	0	0	0
Mid-1980s best	5	89	77	54	32	10
Future	0	3	23	46	68	90
Pacific Northwest						
Old less than 5 MMBF	1	1	1	1	1	0
Old more than 5 MMBF	94	8	0	0	0	0
Mid-1980s best	5	88	76	54	32	10
Future	0	3	23	45	67	90

[1]*Includes North Dakota, Nebraska, and Kansas.*
[2]*Excludes North Dakota, Nebraska, and Kansas.*
[3]*Excludes Hawaii.*

Table 135.—Trend in diameter of softwood logs processed by sawmills, by region, 1985, with projections to 2040.

Section and region	1985	Projections 2000	2010	2020	2030	2040
		Inches				
North[1]	10.1	10.1	10.1	10.1	10.2	10.2
South	10.3	10.3	10.1	10.0	9.9	9.8
Rocky Mountains[2]	10.6	10.2	9.8	9.6	9.4	9.2
Pacific Coast						
Pacific Southwest[3]	13.6	12.4	11.9	11.4	11.0	10.4
Pacific Northwest						
Pacific Northwest-West	12.5	11.4	11.0	10.5	10.1	9.6
Pacific Northwest-East	10.6	10.2	9.8	9.6	9.4	9.2

[1]*Includes North Dakota, Nebraska, and Kansas.*
[2]*Excludes North Dakota, Nebraska, and Kansas.*
[3]*Excludes Hawaii.*
Source: Estimates for 1985 are based on data from the Sawmill Improvement Program, see Steele et al. 1988b.

of making lumber by decreasing the delivered cost of logs per unit of lumber output and by holding down sawmill processing costs.

Projected improvements in lumber recovery will hold down the cost of logs as a component of lumber costs. Even though delivered log costs for the Pacific Northwest-West and South are projected to increase by 10.2% and 13.0%, respectively, per decade through 2040, the cost per unit of lumber output increases only 9.9% and 10.0% per decade, respectively (fig. 78). Technological change is projected to be more effective in holding down log costs as a component of lumber costs in the South due to smaller projected declines in log diameters.

Other improvements in lumber processing, in addition to LRF improvement, will also shield the cost of making lumber from projected increases in log costs. Even though delivered log costs for the Pacific Northwest-West and South increase by 10.2% and 13.0% per decade through 2040, total lumber manufacturing costs increase only 4.9% and 5% per decade on average (fig. 79). Most of the projected increase occurs by 2010 to 2020. Technological change is more effective in holding down overall lumber manufacturing costs in the South. As a result, the South is projected to widen its comparative advantage in lumber manufacturing costs relative to the Pacific Northwest-West over the projection period (fig. 79).

Hardwood Lumber Processing

The principle use of hardwood lumber is for remanufacture into furniture, cabinet work and pallets,

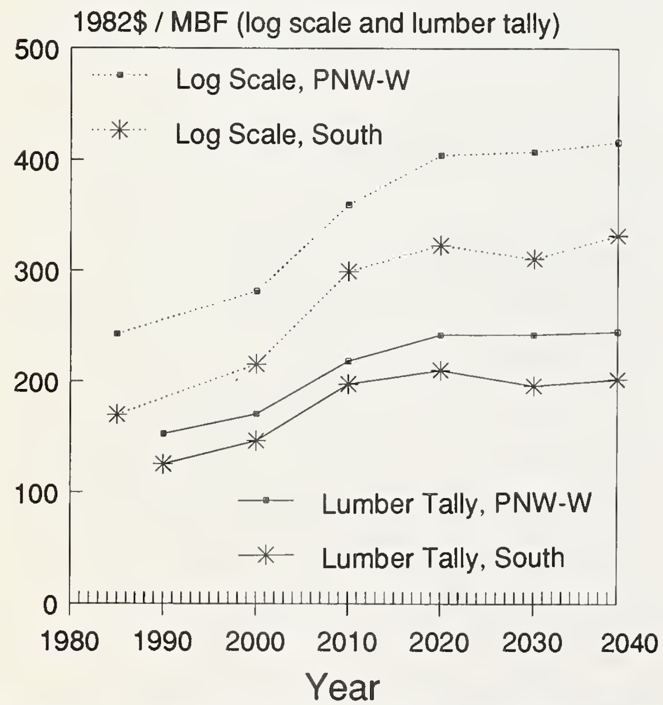
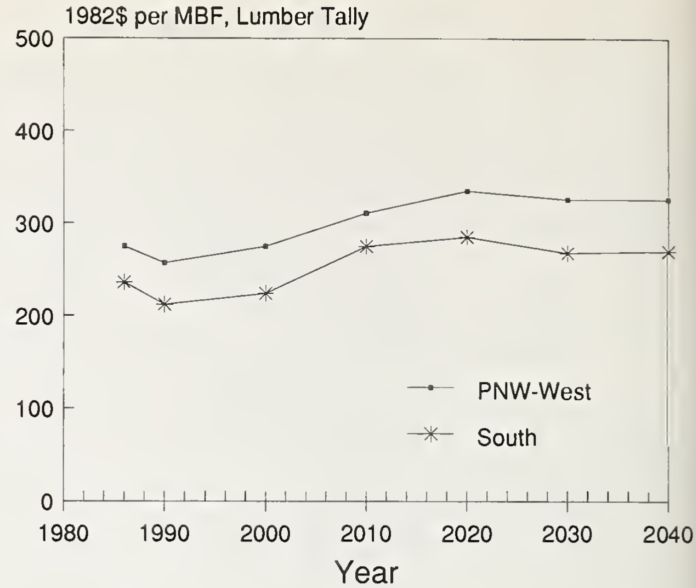


Figure 78.—Delivered log cost for softwood lumber, PNW-West and South.



Costs: stump through manufacturing

Figure 79.—Total softwood lumber-making costs, PNW-West and South.

or directly into flooring, paneling, molding and millwork. It is mainly graded and sold as factory lumber, or processed into dimension parts and finished products. Factory lumber comes in random widths and is graded by the number and size of clear cuttings that may be obtained. It is intended to be cut into smaller pieces after kiln drying (dimension parts) that will be used to make furniture or other fabricated products. Pallet parts are cut from green lumber or cants. Dimension parts are normally kiln dried parts with specific thicknesses, lengths and widths. They may be sold rough or surfaced, and semi-fabricated or fabricated for further use in making products such as furniture. Finished products are sold in finished form. The highest volume example is flooring. Others include lath, siding, ties, planks, car stock, construction boards, timbers, trim, molding, stair treads and risers.

The production of hardwood lumber in general is less automated and less sophisticated than softwood lumber processing. A majority of the mills have wide-kerf circular headrigs instead of narrow-kerf band headrigs and the production capacities are much smaller in hardwood mills. Sophisticated log scanning, computer assisted log processing, and computer controlled edging and trimming are technologies developed for softwood sawmills and are seldom used in the hardwood industry. In general, the technology is too expensive for most options or does not apply to the production of hardwood lumber. Most hardwood logs are processed to produce the highest appearance grade lumber possible. Processing for higher grade lumber normally stops when low grade faces appear on the remaining center cants. Cants are subsequently processed for lower grade lumber or pallet parts at the same mill or a pallet plant.

In general, top grade first-and-second and select (FAS & Sel) lumber is used for moldings, millwork, export, and other uses that require clear or almost clear lumber.

In this cabinet parts rough mill, lumber is ripped into strips (far left) after an operator marks edges to be trimmed with two laser lines, and a computer determines the size of strips to fill mill needs. (Credit: Phil Araman, USDA Forest Service)

Secondary quality lumber, graded number 1 common (1C) and number 2 common (2C), is used primarily for wood furniture, upholstered furniture, cabinets, flooring, and other products that do not require clear lumber. Material below 2C grade is used in railroad ties, mine timbers, pallets, and flooring.

Hardwood lumber drying is more critical than softwood drying for two reasons. First, hardwood lumber must be dried down to 6–8% moisture content for furniture instead of the 15% moisture for most softwood lumber that is kiln dried and used in construction. Second, hardwood lumber must be dried more slowly to avoid drying degrade such as splits, checks, warping, staining, and internal honeycombing. These defects reduce the value and usefulness of the lumber.

After drying, hardwood lumber is converted into cuttings for furniture, cabinets, moldings, flooring, stair treads and risers, and other product parts in processing facilities called rough mills. The lumber is planed, crosscut and ripped, or ripped and crosscut into parts or cuttings. Many of the cuttings are edge glued, planed and then re-ripped to parts. In some systems finger jointing is used to make long parts out of short cuttings. In the future, we may see more rough mill type processing tied directly to sawmill and drying operations. For secondary quality lumber (1C and 2C) we could see production of green dimension cuttings followed by drying. With this system, dry kilns would not have to dry all the waste lumber that is discarded when lumber is cut into dimension parts. This system would increase the capacity of existing kilns to produce dry dimension parts.

Possible Changes in Hardwood Lumber Production

The main pressures to improve or change hardwood lumber processing techniques stem from the need to manufacture enough better grade material for important export and domestic markets. Processors need to improve yields, but they must improve quality and contain costs to maintain markets and reduce the potential competition from substitute wood or nonwood products. Modernization with computer aided manufacturing and computer controlled processing are keys. But, once again this equipment will be used to increase the recovery of higher grade material and not necessarily to cause major increases in overall yields or reductions in wood consumption.

Technology improvements such as computerized log shape scanning and computerized sawing decisions are available and are being adopted by some large mills. These systems provide better sawing consistency, closer tolerances and therefore reduced lumber target sizes, increased lumber yields and increased higher grade lumber output from lower quality logs.

A hardwood computer aided edging system has been developed to properly edge random width hardwood lumber and a more sophisticated system is being investigated that would provide the operator with information on how to obtain the highest grade after edging. Similar systems for hardwood trimming should be available in the future. These systems will be designed to increase grade output.

Improvements will continue to be made in hardwood lumber drying. They will improve grade recovery by reducing drying degrade. Most of the improvements will be a result of more control over the initial drying phase with the use of predriers and by better kiln drying with use of computer controls that allow smooth or continuous curve drying.

A system under development which will incorporate many of the above technologies and more is the Automated Lumber Processing System (ALPS). ALPS will include new techniques for log processing, board defect detection and optimum board cutting in order to maximize the yield of clear wood parts for furniture production. In an ALPS sawmill, logs are scanned internally to locate the position of internal defects. Computers use defect position information to determine and control log breakdown that maximizes grade or value yield of boards. After drying and superficial surfacing, video image analysis locates and classifies defects on each board. Computers use board defect information to determine and control board cutting to yield the maximum number of clear parts for a given cutting bill. Cutting is carried out by computer controlled conventional cutting or high-powered laser cutting. ALPS will increase the recovery of high grade material (McMillin et al. 1984).

Projected Lumber Recovery

The overall impact of changes in technology and other factors will be to improve both grade recovery and overall recovery. The modest assumption of 1% per decade increase in LRF for hardwood lumber processing seems reasonable. Table 136 shows average recovery of hardwood lumber by grade from various size trees for the late 1970s. Larger trees yield a higher proportion of higher grade lumber.[50] For the projections of hardwood lumber consumption in Chapter 7, it was assumed that overall hardwood lumber recovery increased 1% per decade in each tree size category. It was also assumed that the relative proportion of various lumber grades produced from a given size of tree remain constant. This assumption is conservative because improved technology is likely to improve the proportion of higher grade lumber obtained. Other factors that will tend to improve overall recovery and grade recovery are a moderate shift to use of a wider range of hardwood species and increased availability of slightly larger logs, on average, in the future. Slightly larger logs will be the result of increased inventory of hardwoods.

[50]*Yield from trees includes all losses from parts of the tree stem initially considered usable to make lumber plus losses in the sawmill. These overall losses are estimated to be greater for trees of smaller diameter.*

Softwood Plywood Processing

Plywood is a glued wood panel made up of thin layers of wood with the grain of adjacent layers at an angle, usually 90 degrees. Each layer consists of a single thin sheet, called a ply, or two or more plies laminated together with grain direction parallel. The usual constructions have an odd number of layers. The outside plies are called faces or face and back plies, the inner plies are called cores or centers. As compared to solidwood, the chief advantages of plywood are its nearly equal strength properties along its length and width, its greater resistance to splitting, and its size, which permits coverage of greater surfaces.

Two types of structural plywood are produced: sheathing and sanded. The chief distinguishing characteristic between the two is the quality of the face veneer(s). Sanded products require relatively clear veneer whereas sheathing grades tolerate knots and knotholes. Most structural plywood is sheathing grade and this is where oriented strand board and waferboard are competing.

Technology Developments

To improve profitability, softwood plywood mills have to increase wood use efficiency and reduce nonwood costs in several ways. Since sheathing can be made with lower quality veneer, sheathing mills can utilize smaller diameter, less expensive logs. The extent to which smaller diameter logs can be used, however, depends on the ability of the technology to deal with physical differences in logs as size declines. These include (1) a higher proportion of wet sapwood which decreases dryer capacity; (2) an increase in the proportion of the tapered part of the log relative to the cylindrical part, which decreases clipper capacity; (3) the rise in the fraction of the wood contained in the core, which decreases veneer recovery; and (4) the increased wood loss caused by a given error in centering the bolt in the lathe, which decreases overall veneer and full sheet veneer recovery.

Several technological changes have emerged over the last decade that address small log processing problems

Table 136.—Hardwood lumber recovery by size of tree harvested, late 1970s.

Tree diameter	Lumber grade			Total
	Higher grades	No. 1 Common	Lower grades	
inches	*Board feet lumber tally per board foot input*[1]			
11–15	.02	.07	.42	.52
15–19	.10	.25	.42	.76
19+	.20	.31	.37	.88

[1]*Input is standing tree volume harvested as measured by the international quarter-inch log rule. The recovery ratios include loss of volume due to tree defects, hauling, storage and processing prior to entering the sawmill plus losses during sawmilling.*

Source: Recovery data used in the Hardwood Assessment Market Model (HAMM). HAMM recovery figures are based on lumber recovery data by log grade in Hanks et al. (1980) and calculations of logs contained in various size trees, see Binkley and Cardellichio 1985.

(see table 137). In the past, plywood glues were unable to tolerate veneer moisture much above 4%. With modified High Moisture Veneer (HMV) glues now available, that limit has been increased to 12% and higher. Consequently, the wet sapwood of small logs can be accommodated in existing dryers by running the dryers faster. Added benefits are less veneer shrinkage, less breakage from too brittle veneer, and higher moisture in finished panels reducing warpage (Wellons 1988).

Clippers have traditionally been of the guillotine type with maximum running speeds of about 350 ft/min and much slower speeds for roundup (less than full width veneer from the tapered part of the bolt). A new clipper with a rotary cutting motion in place of the up-and-down motion of traditional clippers has become available and has been widely adopted. Clipper speed in excess of 500 ft/min during full sheet clipping can be achieved (Maxey 1977).

To maintain veneer recovery from smaller blocks, the core size and spinout rate have been reduced. This has been accomplished by supplying additional rotational power at the bolt periphery by powered rolls. Core sizes as small as 2 inches are being achieved (Knokey 1986).

In the area of charging, laser scanning is achieving more accurate bolt placement in lathes at speeds rapid enough to maintain throughput with small logs. Charging times approach 2 seconds. Microprocessor-controlled arms place the log into the lathe to achieve the largest possible cylinder, given bolt shape and other characteristics (Moen 1985).

To reduce the traditional labor intensive nature of plywood manufacturing, mills have automated several important facets of the process including green and dry veneer stacking, layup, and press loading. Hours of labor required to produce a thousand square feet of product can be reduced to about 2 from about 3-1/2 through this process of automation.

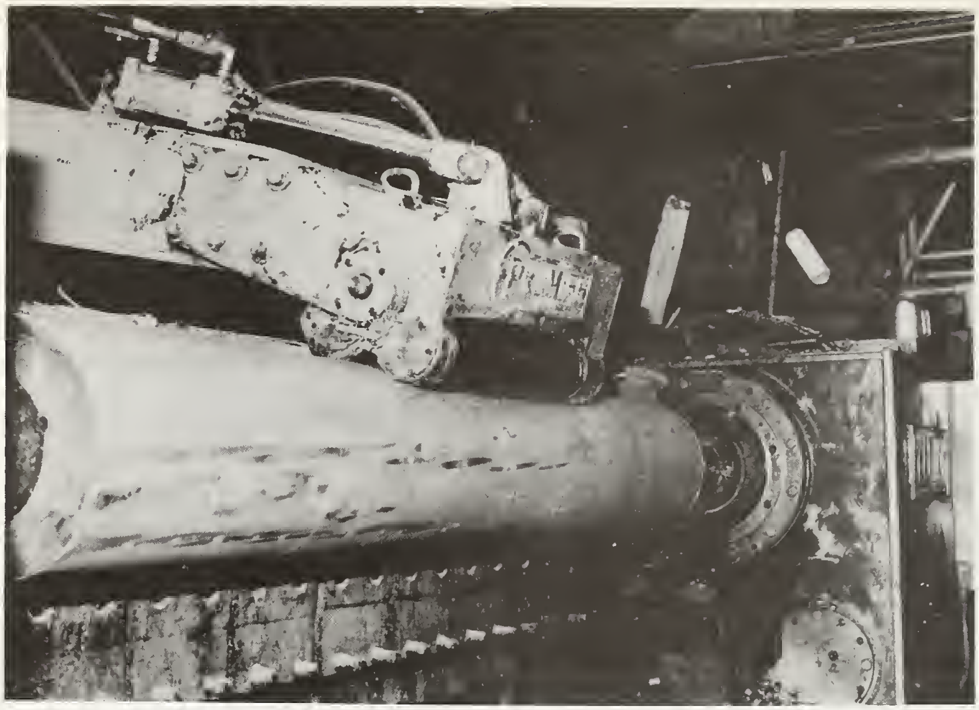
Projected Characteristics of Present and Future Panel Processing Systems

To quantify the effects of these and other technological changes, three mill designs were prepared to represent the level of technologies roughly equivalent to those available in the mid 1970s, the mid 1980s, and the late 1980s (see table 138).

Chief features of the mid-1970s design were (1) dropout cores of 5.25 inches, (2) spinout rate of 8% with average spinout core size of 9.5 inches, (3) charging time

Table 137.—Technological developments in structural panel processing.

Product type and development	Description	Impact
Softwood plywood		
Computerized lathe charging systems	Laser beams reflected off the bolt are analyzed by a computer to determine bolt shape from which the bolt's geometric center is determined	More accurate measurements of bolt's shape and easier maintenance increase veneer recovery
Hydraulic carriage drives	The rate of knife advance is controlled using a hydraulic drive in place of mechanical linkages	Reduced thick-and-thin veneer and increased on-target cutting
Powered nosebars and back-up rolls	Supplementary power to turn bolts provided by powered back-up roll and nosebar	Reduced incidence and size of bolt spinouts, fewer sliver plugups
High-moisture content gluing	Glue formulations with increased tolerance of moisture in veneer	Increased drier output
Radio-frequency redrying of veneer	RF redrying uses microwaves to redistribute moisture inside a stack of veneer eliminating wet spots	Reduced broken veneer and increased capacity of primary driers
Press pressure controls	High initial press pressures are reduced in increments during the press cycle	Permanent compression in panels is reduced allowing thinner target veneer thickness
Nonveneered structural panels		
Isocyanate binders	Isocyanate binders are used to replace phenolic resins to glue panels	Reduced energy requirements, shorter press times increase output on thicker panels
Long log flaker	Flaker produces flakes from random length logs	Reduced generation of fines and saw kerf
Continuous presses	Uninterrupted mat flow through the press	Reduced trim loss



The powered backup roll helps prevent veneer log spin-out by providing torque to the surface of logs. More veneer may be obtained by peeling logs to smaller cores. (Credit: Boise Cascade)

of 3 seconds per bolt, (4) average veneer thickness variation of 6%, (5) maximum clipper speed of 375 feet per minute, (6) conventional moisture target of 4% for veneer, and (7) no automation in veneer stacking, drying, layup, and pressing.

The mid-1980s design featured (1) dropout core size of 3.25 inches, (2) spinout rate of 3% with average spinout core size of 6.8 inches, (3) charging time of 2 seconds per bolt, (4) average veneer thickness variation of 3%, (5) maximum clipper speed of 500 feet per minute, (6) high moisture veneer target of 9%, and (7) automated green and dry veneer stacking, panel layup, and press loading. The late-1980s mill design differed from the mid-1980s mill design with respect to core size, which was 2 inches, and spinout rate, which was set at zero.

The average cost and recovery and optimum bolt diameter range were determined for each design using a mill simulation program.[51] Real energy and wage costs were assumed fixed at 1986 levels. Thus, projected changes in processing costs are due solely to changes in technology.

[51] *The Plywood Mill Analysis Program (PLYMAP) is an economic/engineering model of the plywood manufacturing process. PLYMAP calculates material flows and economic costs based on parameters describing machine capabilities and capacity at each discrete stage of plywood processing. It identifies potential bottlenecks, indicates areas of slack, and calculates overall revenues and costs for a given set of economic and process assumptions. The model has been documented by Spelter (in press). PLYMAP was used to compute recovery factors and processing costs of 3 mill types representing technology levels for the mid 1970s, the mid 1980s, and the late 1980s using parameters shown in table 138 and discussed in the text. A more detailed discussion of technologies in plywood mills is given by Spelter and Sleet (1989).*

Projected Mix of Panel Processing Systems

Average veneer recovery factors and costs were computed for three regions representing almost all softwood plywood manufactured in the United States: Pacific Northwest-West, Pacific Northwest-interior, and South. For each year in the forecast, a capacity mix of old, modern, and advanced technologies was projected in each region (table 139). Each technology type was assumed to process a distribution of log sizes determined by the simulation program to be optimal for that particular set of technologies and consistent with the overall reduction in average log diameter (table 140).

Rapid adoption of new technology is projected in all three regions. By the year 2010, old or mid-1970s equipment was projected to be completely phased out in the South and almost replaced in the West. Because of the higher proportion of old-growth timber in the West, the displacement of older technologies in mills specializing in sanded items was assumed to proceed more slowly.

Projected Recovery and Costs

Softwood plywood product recovery factors have tended to increase with increasing production of commodity sheathing which generates less residue and can use lower grade veneer. Increased use of smaller but less defective second-growth timber has also helped boost recovery. Veneer recovery in plywood mills is estimated to average about 50% of the cubic volume of wood processed. Higher recovery is projected with the mix of capacities shifting to modern and advanced equipment.

Table 138.—Current and projected designs of softwood plywood systems.

Process parameters	Technology type Mid-1970s	Mid-1980s	Late-1980s
Percent of bolts which spinout	8	3	0
Spinout core size (inches)	9.5	6.8	N/A
Target core size (inches)	5.0	3.3	2.0
Ratio of actual-to-nominal veneer thickness	1.024	1.000	1.008
Ratio of thickness variability to actual veneer thickness	.055	.032	.040
Clipper speed (fpm)	375	500	500
Target veneer moisture (percent dry basis)	4.5	9.0	9.0

Table 139.—Proportion of various softwood plywood systems by region in 1985, with projections to 2040.

Section and region	1985	Projections 2000	2010	2020	2030	2040
South						
Mid-1970s	40	5	0	0	0	0
Mid-1980s	60	70	65	63	62	60
Late-1980s	0	25	35	37	38	40
Pacific Coast						
Pacific Northwest						
Pacific Northwest-West						
Mid-1970s	70	30	20	17	16	15
Mid-1980s	30	55	52	51	50	50
Late-1980s	0	15	28	32	34	35
Pacific Northwest-East						
Mid-1970s	40	20	15	12	10	10
Mid–1980s	60	68	65	60	55	55
Late-1980s	0	12	20	28	35	35

Table 140.—Trend in diameter of softwood veneer logs processed by plywood mills, by plywood mill system and region in 1985, with projections to 2040.

Section and region	1985	Projections 2000	2010	2020	2030	2040
			Inches			
South						
Mid-1970s	12.0	12.5	12.7	12.6	12.5	12.4
Mid-1980s	11.0	11.0	11.0	11.0	11.0	11.0
Late-1980s	9.0	9.0	9.0	9.0	9.0	9.0
Pacific Coast						
Pacific Northwest						
Pacific Northwest-West						
Mid-1970s	15.5	14.8	14.5	14.3	14.1	14.0
Mid-1980s	14.5	13.0	12.5	12.1	11.7	11.5
Late-1980s	12.0	11.8	11.5	11.0	10.6	10.2
Pacific Northwest-East						
Mid-1970s	15.5	14.5	14.0	13.5	13.2	13.0
Mid-1980s	14.0	12.5	12.0	11.7	11.6	11.5
Late-1980s	10.0	10.0	10.0	10.0	10.0	10.0

This occurs despite the drop in average bolt diameters that would tend to depress recovery. Overall recovery is expected to increase by 6% in the Pacific Northwest-West and 20% in the South between 1985 and 2040 (table 89); average U.S. recovery would rise by 15% to 58% by 2040.

Processing costs are also projected to decline by about 5–7% in real terms between 1985 and 2040 (table 83). This development continues historical trends (interrupted briefly by rising energy costs in the 1970s) toward lower real manufacturing costs in plywood and is a direct outgrowth of labor and material saving technologies installed in modernized facilities.

The Impact of Technology Change on Plywood Manufacturing Costs

Plywood manufacturing costs include costs for stumpage, harvesting and hauling, and processing. The technology changes discussed previously hold down the cost of making plywood by decreasing the delivered cost of logs per unit of plywood output and by holding down plywood mill processing costs.

Projected improvements in plywood recovery will hold down the cost of logs as a component of plywood costs. Even though delivered log costs for the Pacific Northwest-West and South are projected to increase by 10.2% and 13.0% per decade through 2040 respectively, the cost per unit of plywood output increases only 9.8% and 10.5% per decade, respectively (fig. 80). Technological change is projected to be more effective in holding down log costs as a component of plywood costs in the South due to smaller projected declines in log diameters.

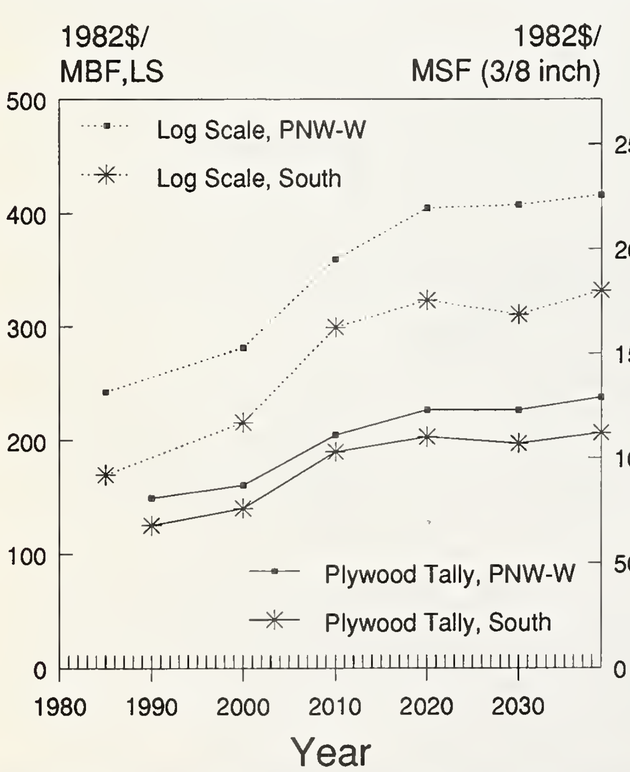


Figure 80.—Delivered log cost for softwood plywood, PNW-West and South.

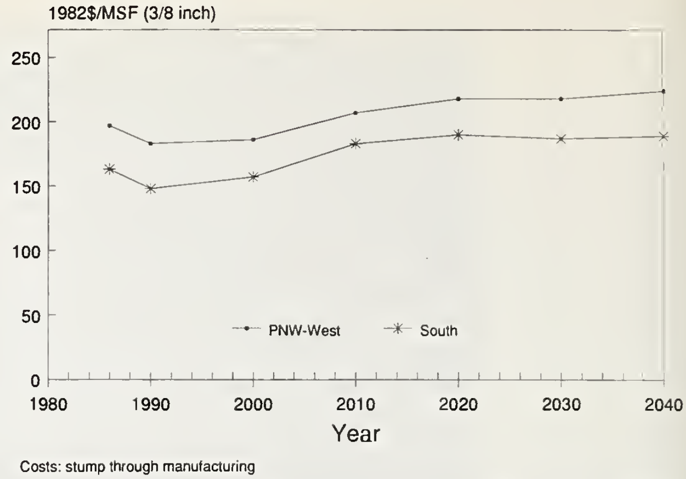


Figure 81.—Total softwood plywood-making costs, PNW-West and South.

Projected improvements in plywood processing costs will further shield the cost of making plywood from projected increases in log costs. Even though delivered log costs for the Pacific Northwest-West and South increase by 10.2% and 13.0% per decade through 2040, total manufacturing costs increase only 2.4% and 2.7% per decade on average (fig. 81). Most of the projected increase occurs by 2010 to 2020. Technological change in both regions is projected to maintain a nearly constant level of comparative advantage for the South in plywood manufacturing costs relative to the Pacific Northwest-West over the projection period (fig. 81).

Nonveneered Structural Panel Processing

Nonveneered panels consist of wood wafers or strands smaller than veneer sheets but larger than wood fiber. Unlike conventional particleboards, the raw material for structural products normally comes direct from roundwood sources rather than mill byproducts; adhesives used are exterior rather than interior type; particles are usually aligned in several discrete layers rather than laid down at random.

Technology Developments

Technology developments in processing oriented strand board and waferboard are likely to focus on two areas: increasing their range of applications and decreasing wood loss during the flaking, forming, and trimming processes.

Oriented strand board and waferboard have been used as sheathing in walls and roofs, and for floor underlayment, and technology has more recently been developed for applications such as concrete forms and siding. Suitable performance is being achieved by using phenolic paper overlays to stabilize the surface and provide a

Examples of structural composite products, from top left: wood joist with laminated veneer lumber (LVL) flange and plywood web, wood joist with LVL flange and wood particle web, waferboard and subfloor/underlayment, Parallam (reg. trademark of McMillan Bodel Inc.), conventional plywood, COM-PLY (reg. trademark of the American Plywood Association), LVL, and Waveboard (reg. trademark of the Alberta Research Council). (Credit: Forest Products Research Society)

suitable basis for paint or concrete forming. To improve panel stability, the trend has been to displace phenolic adhesives, either totally or in part, with isocyantate adhesives. While more costly than phenolics on a pound for pound basis, isocyanate adhesives are more profitable for a given level of panel stability than phenolic adhesives because they allow shorter press times and more moisture in the furnish.

Better flaker designs are likely to be adopted in the future to reduce the generation of fines (pieces of wood too small to be used) and improve forming techniques to increase wood utilization. Disc flakers are normally used in mills today. These machines normally require logs to be reduced to 4-foot bolts for processing. The flakers generate from 8–10% small particles (fines) that are unsuitable for use in panels along with about 4% kerf losses caused by the primary and secondary slasher saws. To reduce these losses, whole log flaking utilizing ring and disk waferizers, with losses due to fines also in the 8–10% range but lower slasher kerf losses of about 2%, seems likely to be adopted (Pallmann GMBH 1987).

In current practice, fines are burned for fuel, but with improved mat formers, some of the fines could be used in the core layer of panels without reducing panel strength. This can be accomplished by electrostatically orienting particles. Panel strength increases as uniformity of particle alignment improves (Fyie et al. 1980). Electrostatic orienters achieve higher orientation ratios than mechanical orienters, thus achieving panel strength with smaller particles that are as good as mechanically oriented panels with standard size furnish. The effectiveness of electrostatic orientation, however, decreases with large particle sizes, thus electrostatic orientation will likely complement mechanical formers rather than displace them (Buecking et al. 1980).

Another means to reduce wood losses is to employ continuous presses now gaining acceptance in particleboard and medium density fiberboard facilities. Continuous mats would eliminate end trimming resulting in wood savings of 1–2%. But the larger size and rougher surface of oriented strand board and waferboard furnishes wear out the steel bands used in these presses and for that reason their adoption by industry appears unlikely (Soine 1988).

Projected Recovery and Costs

Nonveneered structural panel wood recoveries are estimated to average between 55% and 60% (based on losses of 4% for trimming log ends and log rejects, 8–12% for fines, 35–38% for panel densification, and 3% for panel trim). This rate of recovery is projected to increase about 2% between 1986 and 2040 due to improvements in bolt preparation and flaking and more complete utilization of fines (table 90).

Oriented strand board and waferboard manufacturing costs have decreased during the past 5 years because of savings made possible by improved glue blenders. Resin dosages of liquid phenolic resins have declined from over 5% to less than 4%. Powdered resin dosages have also been reduced from 3% to 2%. Further potential for savings in this area is limited, so the projections of processing costs for waferboard show more modest declines than those for plywood. The adoption of modern technology by remaining mills is expected to account for the bulk of the projected 4% reduction in processing costs between 1986 and 2040 (table 84).

Pulp, Paper, Paperboard and Related Products

Paper and board products are made primarily from new or recycled wood fiber. New wood fiber is in the form of woodpulp which is made from pulpwood. Recycled wood fiber is derived from wastepaper which consists of old newspapers, old corrugated containers, mixed grades, pulp substitutes, and high grade deinking. Different paper and board products use different mixes of woodpulps, wastepaper, and other fiber. This mix, or fiber furnish, reflects the requirements for a particular product grade, the level of technology, and the availability of fibers.

Paper and board products are classified into paper grades and paperboard grades. The major paper grades include tissue (sanitary products, napkins, toweling), printing and writing (bond paper, computer paper, copying paper, and paper for books and magazines), packaging and industrial (wrapping papers, bags, and sacks), and newsprint. The major paperboard grades include unbleached kraft (linerboard for corrugated boxes), semichemical (corrugating medium for boxes), solid bleached (folding boxes and food containers), and recycled paperboard (a variety of products including gypsum wallboard facing).

Although specific manufacturing processes and fiber requirements differ among the product grades, paper and board processing generally involves wood handling (debarking, chipping, and chip screening), pulping and bleaching (conversion of chips into pulp using chemical or mechanical processes, bleaching when needed), stock preparation (repulping, deinking, and removal of other contaminants from wastepaper furnish, fiber refining, mixing pulp with additives and recycled fiber), and conversion to paper and board (sheet formations, pressing, drying).

Technological Developments

Technological developments in the U.S. paper and board industry focus on the ability to improve production efficiency and product quality while mitigating or eliminating negative impacts on the environment. Some of the technical challenges facing the industry include the need to reduce energy costs, reduce capital equipment costs, improve strength and quality of recycled fiber, increase fiber recovery, develop processes that can use more hardwood fiber, develop processes that are more environmentally benign, and provide better quality paper products for present and future uses.

An experimental spinning disk separator takes a stream of recycled paper slurry and spins sticky contaminates to an outer ring while dropping useable pulp fiber to an inner ring. (Credit: USDA Forest Products Laboratory)

Many current and likely future technological developments address the above challenges. Table 141 provides a list of such developments in paper and board processing, describing the likely impact of each development on wood requirements. These developments are viewed as very likely to take effect over the next 50 years. They were incorporated into the projections of paper and board, woodpulp, and pulpwood production shown in Chapter 7 (Ince et al., in prep.).

Table 142 lists those technological developments that were considered, but not included in the projections. They were not included because they were viewed by industry, university, and government researchers as less likely to be commercially significant during the next 50 years.

Paper and Board Manufacturing Processes

As mentioned above, each paper and board product grade uses specific production processes. These processes can be defined in terms of the percentages of fiber used, the nonfiber manufacturing costs, and the date of commercial availability. Technological developments result in new, more cost-effective processes which use increasing amounts of wastepaper and mechanical pulps and have lower nonfiber manufacturing costs.

Table 141.—Technological developments in pulp and paper processing included in the projections.

Type of development	Description	Impact
Meeting needs for improved stacking strength in corrugated boxes	Edgewise compressive strength eventually becomes the principal performance criterion	Compressive strength is improved with higher density linerboard, increased use of higher-yield pulps and more hardwood; improved quality control in kraft linerboard
Meeting increasing demands for quality and uniformity in printing and writing papers with improved papermaking technology	Increased use of higher quality fillers, drainage and retention additives, coating pigments, and hardwood fiber; more machine finishing and alkaline papermaking	Less total wood fiber use per ton of product; lower basis weight with more uniform quality; more hardwood
Meeting demand for printability and quality in linerboard with improved forming and finishing technology	Development of multi-ply forming; improved stock preparation systems; use of hardwood fiber for printability on the surface, or sandwiching hardwood or recycled fiber in the core for economy	Higher proportions of hardwood fiber and recycled fiber in unbleached kraft paperboard; separate pulping and refining for hardwoods and softwoods
Gradual replacement of traditional groundwood pulp by modern mechanical pulps in newsprint and other groundwood papers	Thermomechanical (TMP), Chemithermomechanical (CTMP), and pressurized groundwood (PGW) replace some older groundwood and refiner processes, with improvement in pulp quality	Wider market potential for higher yield mechanical pulp; greater ability to substitute for lower yield chemical pulp
Improvement in pulp bleaching systems to reduce capital costs and operating costs, and to meet environmental objectives	Adoption of short-sequence bleaching systems, chlorine dioxide in bleaching, and lower yield in bleached kraft pulping; development of peroxide and other bleaching technologies for TMP and CTMP; use of higher yield bleached mechanical pulps	Greater use of bleached mechanical pulps will reduce wood input requirements, although lower yield kraft pulping will increase wood requirements
Modernization of equipment and processes in older mills to improve efficiency and reduce costs	More tree-length wood handling and chip thickness screening; improvements in stock preparation, paper machine systems, and kraft chemical recovery; energy savings through use of variable-speed drives, high-efficiency motors and upgraded turbine generators; use of more wood or bark for fuel	Lower wood requirements due to gains in wood utilization efficiency, especially in older bleached kraft and sulfite mills; offset somewhat by more use of wood for fuel
Better recycled fiber recovery, improved contaminant removal technology for wastepaper furnish, and increased use of recycled fiber; technological responses to increased supply of recyclable paper	Improved centrifugal cleaners, slotted screens, deinking systems, and high-consistency refining; technology for removal of contaminants such as "stickies"; chemical treatment to restore some bonding strength to recycled fibers	Modest growth in recycled paperboard production, but substantial growth in use of recycled fiber in traditionally virgin fiber grades, such as kraft linerboard, semichemical corrugating medium, newsprint, and tissue
Displacement of chemical pulp fractions by modern high-yield mechanical pulp, in newsprint and tissue, and to some extent in printing and writing paper, reducing capital requirements and wood costs	TMP and CTMP with higher percentages of hardwood fiber will replace some chemical pulp fractions in newsprint and tissue, providing better opacity and bulk; substitution in printing and writing limited by color reversion and brightness	Higher yield and cost savings; increased use of hardwoods with CTMP
Continued adoption of improved pressing technology in papermaking, reducing sheet drying costs, increasing throughput, and improving product quality	Wide-nip and high-impulse press sections will continue to be installed in linerboard mills, and will be installed in mills producing other grades	Increased ability to use hardwood and recycled fiber in kraft linerboard; higher production rates; energy and capital cost savings
Commercial adoption of impulse drying, press drying, or related improvements in pressing and drying technology	Interfiber bonding and substantial strength improvements with higher yield pulps, especially with hardwoods, result from drying under pressure or simultaneous pressing and drying	Substantial savings in capital, energy, and wood requirements; increased use of higher yield pulp and more hardwood in grades like kraft linerboard
Further development of nonwoven products and improvements in sanitary products based on fluff pulp	Innovation in sanitary products and new durable nonwoven products; use of new specialty market pulps; some displacement of woodpulp by "superabsorbent" additives	More efficient use of wood fiber per unit in sanitary and nonwoven products; more use of bleached CTMP
Development of laminated paper and packaging products	Development of laminated or coextruded packaging structures based on paper or paperboard with plastic or metal foil surfaces	Expanded product market potential, but lower wood use for current paper and board packaging
Continued displacement of some fiber products by plastics and other substitutes	Continued innovation and substitution of plastics in packaging, especially food packaging, bag and grocery sacks, and shipping containers; use of synthetic polymers to reinforce paper and paperboard	Decline in the long-term rate of growth in demand for packaging grades relative to GNP and population growth

Table 141.—Continued.

Type of development	Description	Impact
Substitution of paper by electronic means of communication and information storage	Gradual long-term displacement of print media and written communication by electronic and computer technology; short-term complementary effects on demand for printing and writing paper	Decline in the long-term rate of growth in demand for newsprint and printing and writing grades relative to GNP and population growth
Regulation related to recycling	Decreasing availability of sanitary landfill capacity and escalating waste disposal costs are prompting legislative initiatives on recycling	Increased supply of recycled fiber from wastepaper
Increased demands for product uniformity and quality control; better control of inventory in packaging and shipping	Improvements in instrumentation and on-line testing for product quality control, mill test labs, and computer controls in production;	With the assurance of better quality control and uniformity, lower basis weights will be acceptable in some markets; more consumer demand will be satisfied per ton of product output

Table 142.—Potential technological developments in pulp and paper processing not included in the projections.

Type of development	Description	Impact
Expanded use of new chemical treatments to improve properties of paperboard products	Chemical impregnation to increase strength and moisture resistance; chemical saturation for flame resistance	Improved product performance can be achieved for specialty applications
Expanded use of anthraquinone (AQ) in kraft, sulfite, and soda pulping	AQ additives provide marginal enhancement of chemical pulping processes; neutral sulfite AQ process is an alternative to bleached kraft for high tensile strength products	Marginally higher pulp yield is achieved, but concept is limited by cost of AQ chemical, plus differences in capital and energy inputs
Biological fiber treatment, and "biopulping"	Pretreatment with biological lignases or fungi prior to mechanical pulping; treatments could include biobleaching	Improved efficiency in mechanical pulping processes with application of biotechnology, but development is in early stages
Advances in biological effluent treatment systems	Use of microbial agents for decolorization, removal of waste, and improvement in effluent treatment systems	Improved efficiency in effluent control and waste treatment; potential impact on optimal pulp yield or pulping process
Commercial development of nonsulfur chemimechanical pulping process (NSCMP)	Potential application in corrugating medium and linerboard mills; a relatively high yield process suitable for small or medium size mills using hardwoods or mixed species	Elimination of inorganic sulfur emissions; less wood input with higher pulp yield
Organisolv pulping	Development of pulping processes based on organic solvents instead of water; includes alcohol pulping as a substitute for kraft, and ester mechanical pulping with chemical recovery	Economic advantages derive from higher yield and lower capital costs; likely to require additional development
Fiber-based structural products	Development of molded fiber structural components and products; includes potential products reinforced with high-strength polymers or carbon fibers;	New product market potential for use of wood fiber in high performance products, but mass-commodity markets likely to be met by lower cost solid-wood products
Production of new food substances for animals or humans using wood or pulp-mill by-products	Traditional examples include vanillin, torula yeast, animal feed molasses, shiitake mushrooms, wood chip animal fodder and ruminant feed	Product development likely to be limited except in a national emergency
New chemicals from wood	Various chemical feedstocks can be produced from wood, in addition to the conventional silvichemicals, naval stores, lignosulfonates, and other pulp mill by-products; direct acid hydrolysis, "wood-to-oil" processes, and fermentation offer alternatives	Technologies will remain available, but will not likely be developed so long as adequate supplies of petroleum, coal, and other resources are available at low cost
Substitution of wood fiber by kenaf or other natural fibers	Kenaf, bagasse, straw, cotton, and other natural fibers are used for specialty products, or in regions of the world with scarce wood resources	Limited development potential in the United States because of abundant wood resources

Table 143 describes the processes used to make selected paper and board grades. The table describes those processes which are currently available as well as those future processes that are expected to become available in the next 50 years. For example, in making newsprint, there are four processes which are currently used. Newsprint processes one and two use mostly mechanical pulp with smaller fractions of chemical pulps. Newsprint process three uses only wastepaper, and has a lower nonfiber manufacturing cost than processes one and two. Newsprint process four uses equal amounts of mechanical pulp and wastepaper. Another example is unbleached kraft, for which two current processes and two future processes are identified. Unbleached kraft processes one and two use principally chemical pulp with only a small portion of wastepaper. Unbleached kraft process three, a future process, uses higher yield kraft pulp and more hardwood. Another future process, unbleached kraft process four, shifts a substantial portion of the furnish to high yield mechanical pulps, while further increasing the amount of wastepaper used. Nonfiber manufacturing costs are the highest for process one and the lowest for process four.

The projections of paper and board, woodpulp, and pulpwood in Chapter 7 are based, in part, on projections by product grade and process. Figures 82 and 83 show the production of unbleached kraft and newsprint by process. For unbleached kraft, the projections show a shift from processes one and two to processes three and four. Newsprint process three, which uses only wastepaper, is projected to become the dominant process for manufacturing newsprint in the United States, although the Canadians are expected to continue to make newsprint largely from raw wood fiber.

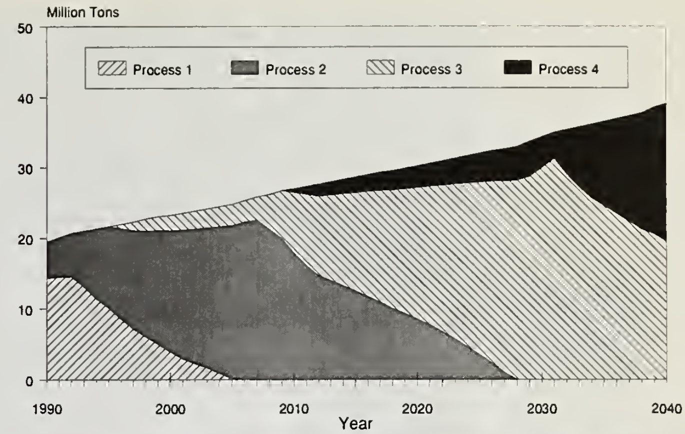


Figure 82.—Unbleached kraft production in the United States by process.

Table 143.—Fiber consumption and date of availability of paper and board manufacturing processes, by product grade.

Product grade	**Chemical pulp**	**Mechanical pulp**	**Wastepaper**	**Nonfiber costs per ton of product**	**Date available[1]**
	Fiber consumption				
		Percent		*1986 dollars*	*Year*
Newsprint					
Process One	25	75		360[2]	—
Process Two	9	91		386[3]	—
Process Three			100	351[2]	—
Process Four		50	50	399[4]	—
Unbleached Kraft					
Process One	93		7	177[3]	—
Process Two	85		15	158[3]	—
Process Three	85	15		140[3]	1,995
Process Four	50	30	20	133[3]	2,010
Semichemical					
Process One	60		40	201	—
Process Two	90		10	214	—
Process Three		100		215	2,000
Solid Bleached					
Process One	100			460	—
Process Two	37	63		370	1,995
Recycled					
Process One			100	230[3]	—

[1]*No year is specified for processes that are currently available.*
[2]*North and South.*
[3]*South.*
[4]*Rocky Mountains and Pacific Coast.*

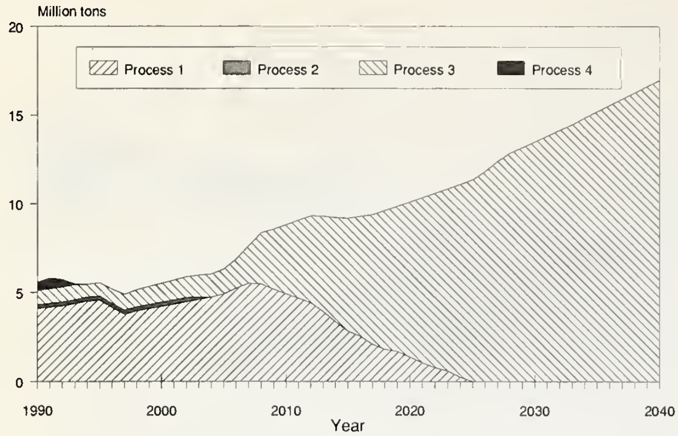


Figure 83.—Newsprint production in the United States by process.

Wood Product Use in Construction

Construction, and repair and alteration of houses, apartments and nonresidential structures use most of the structural lumber and structural panels that are produced (tables 95 and 98). There are many opportunities to improve construction practices to reduce the volume of wood used while maintaining the quantity and quality of construction (Row and Hagenstein 1988). There are also opportunities to expand wood use, such as use of wood in place of concrete in making residential housing foundations.

Possible Changes in Technology

There are many ways to save wood in construction because most wood structures are built stronger than needed (NAHB Res. Foundation 1971). Although this has long been recognized, builders continue to rely on conservative practices that waste material. For example, 90% of exterior wall framing is spaced at 16-inch intervals (McKeever 1988) even though 24-inch spacing gives adequate strength for one-story homes and the top floor walls of multistory structures. Similarly, 91% of interior walls space framing at 16-inch intervals. Even in roofs, where structurally efficient wood trusses are widely used, 28% of roof framing is placed at 16-inch intervals.

Overdesign is partly a holdover of practices imposed by older technologies. Sixteen inch spacing probably stems from the time when walls were plastered over wooden lath. Tradesmen found it difficult to plaster on lath when studs were spaced more than 16 inches apart. In modern times, most walls are finished with plasterboard that easily spans 24 inches. Approximately 400 board feet of lumber could be saved in walls and partitions of a typical single-family home by converting to 24-inch spacing.

Where walls intersect to form corners, it is necessary to provide supports for finish wall sheeting. This has traditionally been done by using an additional stud at intersections. Three-stud corners could be replaced by metal brackets that are available to support wallboard. In a typical home, the elimination of 3-stud corners could save about 100 board feet.

Overdesign extends to floors where bridging between joists and overlapping of joists on the center girder are common. But bridging adds nothing to the strength of a floor, and joints that are butted on the center girder instead of overlapped can be adequately held together by metal plates and plywood subflooring. Additional material could be saved by using 1-inch boards for header joists (at the end of the floor joists) instead of 2-inch stock. Shorter joists may be used with an "in-line" joist system where one joist is cantilevered (extended) over the center girder and held to a second shorter "in-line" joist by a structural splice. Stress is reduced in the overhanging (extended) joist. Structurally sound floors have also been built using only 1-inch wide stock, but this reduces the nailing surface (Hanke 1986). A more practical approach is to continue to use 2-inch stock, but with narrower dimensions such as 2x8s instead of 2x10s. The amount of lumber saved by using smaller joists, thinner headers, and butted joints is about 700 board feet in an average size home; but the nationwide impact of such a change would be about half that savings per home since about half of new homes are built on a concrete slab and use no lumber for flooring.

Adoption of "optimum value engineering" practices such as those listed above could save 10–15% of the dimension lumber required in a conventional house. Another way to economize on wood use in a building is to develop more efficient building materials. The metal plated wood roof truss is one example. Roof trusses transfer loads to exterior load bearing walls, eliminating outward thrust and the need for interior load bearing walls. Wood roof trusses are widely used in all construction sectors in increasingly diverse shapes and configurations. A high percentage of residential structures already use trusses; thus, increased savings due to expanded use in housing is limited.

A more recent wood saving product is the prefabricated wood I-joist. I-joist design recognizes that the most critical parts of a member are its top and bottom edges. Accordingly, most of the material is contained in the two flanges (the edges). The flanges are connected by a web of plywood or structural flake board. I-joists are usually used in floors where they replace traditional 2x10 and 2x12 joists, but they can be used for longer spans up to 40 feet. Because they are a fabricated product, they can be made in continuous lengths. They are also less likely to shrink and swell over time and thereby reduce the likelihood of squeaky floors. They are lighter and stronger than lumber, and precut holes in the web easily accommodate piping and duct work. Web stiffeners are required at points where they support load bearing walls and lateral support is critical in many applications.

Another engineered product that saves wood is laminated veneer lumber (LVL). LVL is a solid structural product made from 1/10 or 1/8-inch thick veneers, laid together in parallel grain pattern, coated with waterproof adhesives which are cured by heat and pressure, with lengths ranging up to 80 feet. It is somewhat stronger

Engineered wood structural members are used frequently in nonresidential structures. (Credit: USDA Forest Products Laboratory)

and stiffer than lumber. LVL has been used for flanges of I-joists, headers and beams, concrete forms, scaffold planks and partition framework. It has found uses in prefabricated housing where its higher strength is better able to resist forces while house sections are moved.

Structural members are also being made from reconstituted strands of wood. A product is being made by laminating long strands of wood with exterior adhesives and heat pressing into shapes similar to dimension lumber. Its properties and uses are similar to those for LVL.

Stressed skin panels, consisting typically of two outer layers of plywood or oriented strand board with foam insulation in the core, can reduce wood use in timber frame residential construction and construction of industrial and commercial buildings. In timber frame construction and many industrial/commercial buildings, the loads are carried by a few key members. The intervening bays require only a nonload bearing wall. This means that the structural requirements on the wall are less than for walls in light frame construction. A conventional built-up system using 2x4s and foam sheathing results in overdesigned wall sections and inferior insulation. In contrast, stressed skin panels require less lumber and provide superior insulation performance. These panels may be used in roofs as well as walls in industrial/commercial buildings.

Decay of wood in structures due to moisture is a serious problem and an increasing concern since insulation in walls has increased which may lead to greater condensation. Correcting this problem will hold down need for wood use in repair. Under winter conditions, humidity from the building enters into the framing cavities and condenses. This reduces the R value of the insulation, and promotes fungus growth, which leads to decay. Proper installation of polyethylene vapor retarders avoids the problem, but proper installation is difficult in practice because of the many breaks in the sheet to accommodate electrical outlets and the like. An alternative system, called the Airtight Drywall Approach (ADA), uses gaskets between the framing and the interior drywall only (Lstiburek 1985). The vapor retarder is the painted drywall. The system is based on the idea that infiltration through gaps in the barrier, rather than the permeability of the barrier, is the chief cause of excessive vapor transmission. By closing off infiltration routes with gaskets, infiltration is decreased, and drywall is less likely to be inadvertently punctured during construction than a plastic barrier. Studies have shown that if air vapor movement from the inside of the structure is controlled, moisture build-up in insulated walls is not severe enough to cause structural decay.

The rate of adoption of the wood saving techniques mentioned above will depend in part on the in-place costs of wood products and the resultant pressure to reduce wood cost and wood use.

Substitution Between Wood and Nonwood Materials

Wood use may decrease or increase in certain types of construction as its competitive position changes with respect to steel and concrete. In evaluating suitability for various types of construction, wood products are compared to steel and concrete in structural capability, fire resistance (in large structures), insulation, and cost.

The main structural property of concrete is its compressive strength. In addition, reinforced concrete possesses good tensile strength. But these favorable properties are in excess of what is typically required in residential and smaller commercial structures. At over $100/cubic yard, this material is expensive for the required performance levels in such structures. Moreover, other positive features of concrete, such as its fire insulating capabilities and low sound transmission, become crucial factors only in large structures. The superior strength of concrete becomes economic only when it is fully utilized, e.g., in larger structures. Thus, no major displacement of wood by concrete is expected in most construction markets.

One area where concrete is used in light frame construction is for basement walls and footings because it is impervious to decay by soil organisms. Improper curing, however, may lead to basement walls that leak and opportunities to use treated wood products for foundations. A chemically treated but otherwise conventional stud and plywood wall may be placed over a coarse gravel footing. The key element is a drainage path through the gravel to a gravel bed under the floor where the water collects and is removed by a sump pump or is diverted by pipe to daylight. By not allowing moisture pressure to build up, leakage is eliminated, and the chemical treatment makes the structure durable and lasting. Preserved wood foundations generally cost less than poured concrete and are slightly more economic than concrete block due to speed of installation (Spelter 1985a). But quality control requirements (use of galvanized steel nails, proper chemical treatment, proper installation technique, etc.) are strict and the system has not been as widely adopted as initially thought, although many homes in colder climates have been built with chemically treated wood foundations.

Like concrete, steel has superior strength properties compared to wood, and can cost less than wood in some cases. But the rate that heat is conducted through a 2x4 steel stud is about two and a half times that conducted through a wooden stud. Sound transmission through steel is also greater. These drawbacks cannot be overcome without incurring expenses that negate what initial economic advantage may exist. Nevertheless, steel construction is more likely than concrete to displace wood, particularly in larger residential and mid-sized commercial structures. The degree of displacement will depend on relative changes in in-place wood and steel costs.

Projected Wood End-Use Rates in Construction

Projected wood use rates in this analysis take into account the potential effects of technology developments mentioned above and the expected changing competitive position of wood materials compared to steel and concrete. The rate of change in use rates is driven by the economic pressure of changing in-place wood prices and changing in-place prices for steel and concrete. Higher prices for wood will increase adoption of wood saving practices and decrease the competitiveness of wood versus steel and concrete in selected applications. Under the economic scenario portrayed in the base projections in Chapter 7, use of softwood lumber per square foot of floor area in residential construction declines by 24% between 1986 and 2040 (table 144). Total structural panel usage is more stable, however, because one consequence of more efficient lumber use is a need for thicker structural panels in walls, roofs and floors.

Wood needed per household for repair and alteration is projected to remain relatively constant for softwood lumber and plywood, but is expected to increase for oriented strand board and waferboard. Wood use per dollar of nonresidential construction is projected to remain stable for softwood lumber, and rises slowly for structural panels as declines in use of softwood plywood are offset by increases for oriented strand board and waferboard (table 145).

Table 144.—Single-family and multifamily average floor area and wood product use per square foot of floor, 1986, with projections to 2040.

Year	Average floor area	Softwood lumber	Structural[1] panels
	Square feet	*Bd. ft./ sq. ft.*	*Sq. ft. 3/8-inch basis per sq. ft.*
		Single-family housing	
1986	1825	6.3	3.4
2000	1950	5.9	3.2
2010	1975	5.5	3.3
2020	1990	5.2	3.3
2030	2000	5.0	3.2
2040	2010	4.8	3.2
		Multifamily housing	
1986	956	4.2	2.6
2000	1065	4.0	2.5
2010	1080	3.9	2.5
2020	1090	3.7	2.5
2030	1100	3.6	2.5
2040	1100	3.6	2.5

[1]*Softwood plywood and oriented strand board/waferboard.*

Table 145.—Wood product use factor indexes for housing alteration and repair, nonresidential construction, manufacturing and shipping, 1986, with projections to 2040.

Year	Softwood lumber	Hardwood lumber	Structural panels
		(1986 = 100)	
		Housing alteration and repair[1]	
1986	100	—	100
2000	100	—	111
2010	105	—	113
2020	105	—	117
2030	105	—	120
2040	100	—	124
		Nonresidential construction[2]	
1986	100	—	100
2000	100	—	127
2010	100	—	103
2020	100	—	108
2030	100	—	112
2040	100	—	115
		Manufacturing[3]	
1986	100	100[4]	100
2000	80	74	95
2010	74	57	89
2020	69	42	85
2030	67	39	80
2040	65	18	76
		Shipping[3]	
1986	100	100	100
2000	61	83	82
2010	45	79	66
2020	35	68	62
2030	27	57	63
2040	24	46	66

[1]*An index of board feet (or squar feet) per household per year.*
[2]*An index of board feet (or squar feet) per constant dollar of construction.*
[3]*An index of board feet (or square feet) per unit of the Federal Reserve Board index of manufacturing output.*
[4]*An index of board feet per unit of furniture production.*

Wood Product Use in Manufacturing and Shipping

Manufacturing and shipping consume more lumber and panel products than for any use except new residential construction. Manufacturing, as defined here, includes production of furniture, other wood products made for sale,[52] and wood products used in various production processes. Shipping includes pallets and skids, wooden containers, and dunnage, blocking, and bracing. In 1986, an estimated 72% of all hardwood lumber consumed was for manufacturing and shipping (7.3 billion board feet). Lesser volumes of softwood lumber (4.3 billion board feet), and structural panels (1.6 billion square feet, 3/8-inch basis) were also consumed. Nonstructural panel consumption for manufacturing and shipping was 44% of total consumption in 1986 (8.0 billion square feet 3/8-inch basis) (table 21). Nonstructural panels include hardwood plywood, hardboard, insulating board, particleboard, and medium density fiberboard.

[52]*Includes sporting goods, musical instruments, boat-building and repair, toys and games, luggage and trunks, handles, wood pencils, mortician's goods, shoe and boot findings, wooden matches, commercial refrigeration, signs and displays, patterns and jigs, truck bodies and trailers, general machinery, agricultural implements, electrical equipment, and textile machinery supplies.*

Improvements in manufacturing and shipping technologies have the potential to decrease or increase wood consumption. Technology changes may decrease wood use by enabling producers to use less wood in manufacturing process, in finished products, and in packaging and shipping of the finished products. Other technology changes may increase wood use by permitting substitution of wood parts for nonwood parts, by requiring more wood per unit output, or by opening new markets for wood products. Technology changes may also extend timber supply by allowing products to be made from trees, logs and lumber of previously unused species, sizes or grades.

Furniture and pallets are the largest users of wood in manufacturing and shipping. In 1986 furniture production used 43% of the lumber used in manufacturing, and pallets used 93% of the lumber used in shipping (tables 11 and 12). These products have traditionally been large users of hardwood lumber. Half of all lumber used in furniture, and more than three-fourths of all lumber used for pallets is hardwood (McKeever and Martens 1983, McKeever et al. 1986, McCurdy et al. 1988).

The production of furniture, and, to an increasing extent, the production of pallets, tends to be highly mechanized. Adoption of new technologies by furniture and pallet manufacturers can hold down timber demand by reducing the amount of wood used per unit of output. Selected technologies likely to affect furniture and pallet production are discussed below.

Possible Changes in Furniture Production

There are several technology developments which may reduce the wood needed to make a given furniture part, or reduce the proportion of high grade lumber needed to make a given set of parts. Technologies being developed could increase the efficiency of the breakdown of hardwood lumber and, to a lesser extent softwood lumber, to make furniture parts. These technologies are the Automated Lumber Processing System (ALPS) (McMillin et al. 1984), and YIELD-O-MATIC. ALPS and YIELD-O-MATIC are in the basic development stage, and are not expected to be commercially available for more than 10 years. Both systems will increase both lumber recovery value and volume. Growth and improvements in existing technologies such as edge, end and finger jointing; computer assisted cross and rip sawing; and better finishing of less desirable species are now increasing both lumber recovery value and volume. Other technologies such as computer numerical control of woodworking operations in furniture plants will lower costs by speeding production, improving accuracy, and using labor more efficiently.

Technology improvements in structural and nonstructural panel processing will increase the substitution of panels for lumber, and the substitution of nonstructural panels for structural panels. As a result, demand will increase for hardwood veneer and panels using paper overlays. These two types of substitution will reduce the demand for medium-to-high grade hardwood lumber, and will hold down timber demand generally as a greater proportion of product volume uses more efficient panel making techniques to convert logs to products.

Other factors affecting the use of lumber and wood products for furniture include changing consumer preferences for wood versus nonwood furniture, particularly for higher value furniture, the relative cost of producing furniture from wood verses other materials such as steel, and the competition from foreign producers. We expect increased use of nonwood materials in low-to-middle quality furniture, and relatively constant use of wood in high value furniture. Foreign trade in unassembled wood furniture and parts is expected to increase.

Projected Wood Use Rates in Furniture Manufacturing

The overall impact of technology changes and other factors on wood use in furniture manufacturing are summarized in table 145. Overall, hardwood lumber use per unit of furniture production is expected to fall over the next 50 years even though use may increase for high value furniture. The decline will be caused by several factors, including technology changes that increase the efficiency of lumber conversion to furniture parts, substitution of panels for lumber, substitution of nonwood materials for wood in low-to-middle quality furniture, and increasing imports of unassembled wood furniture. Softwood lumber and structural panel use are also expected to decline, but not as much as hardwood lumber. This is because the relative lower cost of these products makes substitution of other nonwood products less profitable. Nonstructural panel use is expected to increase.

Possible Changes in Pallet Production and Use

The pallet industry is the single largest consumer of lower grade hardwood lumber. One-third to one-half of all hardwood lumber is used for pallets. Pallets have traditionally been a means for sawmills to use the lower grade lumber they produce. They produce one or two types of pallets using little or no automated equipment. Today up to half of all pallets are produced using nailing machines and a limited number of producers have large, modern facilities with automated sawing, lay-up, and nailing, and a large product line. There is great potential for raw material savings through increased use of these new sawing and pallet construction techniques.

The greatest potential for saving wood in pallets is from increased use of new computerized pallet design systems. Pallets have traditionally been designed to support the heaviest possible load. This results in excessive lumber use. Computerized pallet design systems permit producers to quickly change pallet design based on the type of load. More efficient lumber use will result as the pallets are better matched to their loads.

Wood use in pallets may also be affected by a shift from reusable to expendable pallets. Expendable pallets will use less wood per pallet, but due to a shorter life, more will be produced. Reusable pallets require more wood but last longer, especially with repairs. Another shift that could save large amounts of wood would be the salvage and repair of reusable pallets. Salvage and repair is expected to increase with increasing costs of pallet production and disposal of damaged pallets. Mechanical pallet dismantlers will make pallet repair operations more profitable.

Lumber consumption in pallets may also decrease as more composite materials are used in pallets. Pallet decks made from structural panels provide a flatter, more uniform surface than lumber decks. Pallets made from molded particleboard can be custom made to meet the specific transportation needs of products.

Growth in pallet production is also expected to be held down with increasing competition from substitute materials-handling products, such as plastic slip sheets, and from increasing saturation of industries that can use palletized shipping.

Projected Wood Use Rates for Shipping

The overall impact of technology change and other factors on wood use for shipping are shown in table 145. Hardwood lumber use in shipping per unit of manufacturing output is expected to decrease over the next 50 years. The decrease will be caused by several factors, including technology changes that increase the efficiency of lumber use in pallets, substitution of panels for lumber, a trend towards greater re-use of damaged pallets, and increased use of pallets made from nonwood materials. Use of oriented strand board and waferboard in shipping per unit of manufacturing output is expected to increase as it becomes an acceptable substitute for lumber decking. Softwood lumber and plywood use are also expected to decline with the rapidly declining use of wooden containers in favor of paper and plastic, and the virtual elimination of wood use for dunnage, blocking, and bracing during transportation. A small increase is expected in the use of nonstructural panels.

Wood Use for Energy

Wood, together with bark, is most widely converted into energy by direct combustion in many types of burners. Black liquor, a woodpulp byproduct, is also used to produce energy at pulp plants. Some wood or black liquor is used to produce electricity in cogeneration plants. Technology is also available, although not always economical, to (1) convert wood to gas by thermochemical gasification and burn it in boilers, driers, and kilns or internal combustion engines; (2) convert wood to synthesis gas for manufacture of liquid fuels such as methanol, or chemical feedstocks; (3) convert wood to gas, liquids and solids (such as charcoal) by pyrolysis; and (4) convert wood to other liquid fuels such as ethanol by hydrolysis and fermentation.

Recent and future technology improvements in converting wood to energy will improve wood energy's competitive position relative to alternate fuels and increase wood energy use. Technology improvements will also improve the efficiency of wood conversion to energy and tend to hold down wood demand for energy.

With decreasing fossil fuel supplies and environmental and economic problems in the use of other alternatives such as nuclear energy, there is an overall tendency for increased use of wood for energy. Wood use for energy has both environmental benefits and costs. Unlike much coal and some petroleum, wood has little or no sulfur and appears less likely to produce oxides of nitrogen during combustion. Therefore wood burning emissions are less likely to contribute to the production of acid rain. This is in contrast to fossil fuels which increase atmospheric carbon dioxide content and may cause damage because of the greenhouse effect (Zerbe and Skog 1988). However, caution must be used to prevent excessive removal of biomass in forest harvests to avoid nutrient depletion or increased potential for soil erosion. Wood burning may have other environmental costs. Combustion of wood in inefficient combustors without proper controls adds smoke and particulate emission to the air. This problem has resulted in development of residential wood stove performance regulations by the U.S. Environmental Protection Agency which limit particulate emissions. There has also been concern about proper combustion of wood contaminated with other materials such as paint, adhesives, and/or preservatives.

Improved wood conversion technology may make wood for energy more competitive, even with oil prices increasing more slowly than anticipated. But, a major factor in using more wood for energy is high cost of forest harvesting. It is prudent to use wood for energy that is less valuable and less suited for use in other consumer products. However, the lower value wood is often from smaller trees that are more expensive to harvest. Harvesting is also more expensive for lower density stands and stands that have a higher proportion of hardwoods rather than softwoods.

While harvesting of small trees for fuel may be expensive, increased use of logging residue may be an inexpensive way to aid in forest management. In public and private forests under management for timber production and other purposes, there are significant management costs from cleanup after logging operations. Often brush from logging operations is broadcast-burned to prepare land for new tree growth. This is costly and subjects the atmosphere to more particulate loading. On some national forests in California, broadcast burning is avoided through cleanup credits for harvesting excess wood for energy. In some areas of California, dense brush in forests at urban-forest interface areas is being successfully harvested for energy, thereby significantly decreasing the fire hazard to houses at the forest perimeter.

Possible Changes in Technology

Use of wood for energy may be divided into three roughly equal categories of consumption. These are residential wood burning, black liquor burning, and industrial wood waste/roundwood burning. Lesser, but growing, amounts of wood are consumed in power generation and commercial and institutional applications.

For residential use of wood for energy the traditional approach has been roundwood consumption in fireplaces or simple stoves. Fireplaces are inherently inefficient and are more esthetic than utilitarian. However fireplaces are being used more efficiently with newer technology developments in the control of makeup air and hot air distribution, and in the use of better designed insert units (stoves) for fireplace spaces. Stoves are also being designed to use roundwood more efficiently with better control of air for combustion.

A newer development in residential wood burning is the combining of improved fuels with improved combustion units to attain more efficient and more automatic operation. Fuels may be made more efficient, cleaner burning, and easier to handle by control of size and moisture content. Examples are dried chips and pellets. A new product is chunkwood which comes in larger size particles, and may be more efficient to produce, handle, and store. More sophisticated stoves and furnaces have been designed to take advantage of improved fuels such as pellets.

In industrial applications, older boiler technologies such as the Dutch oven and traveling grate are still operating satisfactorily, but new technologies including the fluidized bed and gasification are providing advantages in combustion and emission control. Promising developments for industry in the future are a gravel bed combustor; new technology for gas, liquid, and char fuels; and burning wood in combination with coal.

Development of a pressurized gravel bed combustor may allow wood to be used to power gas turbine engines, primarily for generation of electricity. Advanced industrial and utility power systems often use gas or liquid-fueled gas turbine engines. They burn fuels directly in a turbine, without going through an intermediate heat exchanger to heat air for use in the turbine. This is an efficient means of generating electricity. Using coal or wood combustion gases to directly power a gas turbine has yet to be accomplished commercially, primarily because the ash can cause erosion, deposition, and corrosion of the turbine blades. The size, distribution, concentration, and composition of the ash, as well as the turbine design, determine the lifetime of the turbine blades. New direct combustion turbines using pressurized gravel bed combustors to alleviate these problems are under development (Ragland and Baker 1987). Successful completion of this work could make wood power generation in the range from 10 MW to 50 MW more competitive.

Improvements in converting wood to gas, liquid and char fuels are possible. If wood is to become a viable, more general replacement for oil as oil becomes more expensive, wood needs to be used in ways other than as a boiler fuel and residential space heating fuel. Wood may be converted to liquid and gaseous fuels and to improved forms of solid fuel such as charcoal. Technology is available to make ethanol from wood at a cost comparable to making ethanol from corn, but this technology is only economical with a large subsidy in today's market. The current large federal subsidy which sets the pattern for state subsidies is scheduled for elimination by the end of 1992, and a more competitive liquid fuel is needed to compete in later years. Provision of gaseous fuel from wood can be achieved with known technology, but the cost of gas derived from wood is much higher than the cost of natural gas (Zerbe 1988).

Gasification and pyrolysis research may lead to more economical liquid fuels from wood such as methanol, pyrolysis oils, or conventional gasoline. For the near term, development of a viable methanol from wood process is realistic to expect. Other potential products are gas for operation of internal combustion engines, turbines, and lime kilns, and pyrolysis oils for diesel fuel.

Wood may be increasingly burned along with coal in industrial boilers. Federal regulations stipulate that for coal boilers with capacities of 100 million Btu/hr or more, the particulate emission limit is 0.05 lb/million Btu heat input if coal is burned alone; but if coal is cofired with wood, the limit is raised to 0.1 lb/million Btu heat. Emission limits for sulfur dioxide and oxides of nitrogen from combustion of coal and wood are based on total heat input, no matter what the fraction of wood used. These regulations provide an incentive to burn wood in combination with coal in large boilers, particularly in the case of high sulfur coals (Dykes 1988).

Projected Efficiency in Conversion of Wood to Energy

The preceding discussion suggests many ways that the demand for and efficiency of residential and industrial wood burning may change. The projections of wood energy use given in table 107 resulted in part from the influence of the changes discussed here. The projections in Chapter 7 assumed that the efficiency of industrial/commercial wood burning will increase at the same rate as for fossil fuels between 1985 and 2040. For residential wood burning between 1985 and 2000, the efficiency of wood and fossil fuel burning was assumed to increase, but the increase in fuel oil efficiency will be somewhat faster than for wood or natural gas. After 2000, all fuels were assumed to increase in efficiency at the same rate (tables 93 and 94).

RESEARCH AND CHANGES IN WOOD UTILIZATION TECHNOLOGY

The first two sections of this chapter discussed historic trends and prospective future trends in wood utilization technology. This section discusses the linkage between research, technological change in industry, and various economic benefits, especially changes in timber consumption and prices. The questions we address are: (1) What are the key influences on research, development and adoption of new technologies and resulting technology change? (2) How effective has past wood utilization research and resulting technology change been in creating various benefits? and (3) How effective might selected current areas of Forest Service research be in changing technology and altering timber consumption and prices?

Key Influences on Research, Development, and Adoption of New Technology

Several influences are particularly important for the forest products industry in determining the course of research and development, and the pace of adoption of new technology. These include (1) innovations imported from other industries, (2) the effect of raw material shortages, (3) the effect of economic performance of innovations, (4) problems in developing and using innovations for a heterogeneous raw material, and (5) problems in developing and using innovations for heterogeneous final products.[53]

Innovations Imported from Other Industries

Prospects for technological change in forest products are heavily influenced not only by commitment of resources to research and development within public and private institutions focused on the industry but also by developments that are remote from forest products. A study for 1974 found that lumber and wood products firms were the expected main user of $67 million (1974 dollars) of R&D performed in other industries and $64 million of R&D performed inside the industry (Scherer 1982).[54] The highest dollar value of other industry research used was in industries making machinery, motor vehicles and equipment, paints and other chemical products, and fabricated metal products (75% of $64 million). For the pulp and paper sector, the figures were $120 million and $86 million, respectively. The dollar value of other industry research used most heavily was in industries making machinery, paints and other chemical products, synthetics/resins/fibers/rubber, and computer and office equipment (55% of 120 million).

One example of use of outside technology in forest products industries has been the considerable use of sophisticated electronic components, including computers and lasers, for quality control of processing and products. The extent to which new outside technologies will be applied to forest products will depend upon the

[53]Material for this section is selected from a study report by Nathan Rosenberg (1988) for the USDA Forest Service, Forest Products Laboratory.

[54]Excludes innovations developed by government and university laboratories.

rate at which those technologies experience reductions in their own costs of production as well as improvements in their performance and versatility. In this respect, the future of the forest products industry is influenced by forces largely beyond its own control. Improved monitoring and evaluation of developments in other domestic industries and foreign industries could speed development and transfer of technology to U.S. forest products industries.

The Effect of Raw Material Shortages

Technology change in forest products industries although influenced by outside technology developments is also strongly influenced by the structure of raw material costs within the industry, and more broadly by the structure of costs for all manufacturing inputs and the prices of products competing with forest industry products. Here, because of our interest in timber resources, we focus on the response to raw material scarcity. The industry has an advantage in being able to predict with some confidence the trend in availability of logs of various sizes in a region 20 years ahead. But forecasting a response, including a technology response, to a particular timber trend may be difficult.

Public and private research are responsive to expectations concerning future availability of various types of timber and will develop research programs to counter the scarcity. Increasing scarcity of an input, and the associated rise in its price, calls into play a wide range of more immediate economic and social adjustments—simple conservation measures, changes in design of products, and substitution of products using more abundant materials. Technology response may include technological changes that reduce costs by reducing labor and capital requirements, or substitute more abundant for scarcer inputs (e.g., capital for material), or reduce the quantity or quality of wood input per unit of output. For example, increasing scarcity of saw logs in recent decades has encouraged use of a technology that uses smaller logs and lower quality timber in general. Also, the sharp increase in veneer log prices in the early 1970s undoubtedly spurred the expansion of waferboard/oriented strand board production which uses lower cost wood input. Expected long range and short range trends in raw material scarcity and associated trends in labor and capital scarcity, while being key influences on technology change, induce a wide range of adjustments which require a detailed analysis to sort out.

The Effect of Economic Performance of Innovations

Decisions to develop and to adopt new technologies are ultimately based upon economic performance and not purely technological considerations. Seemingly superior technologies may be adopted slowly because, when all costs are taken into account, they are not decisively cost-reducing in their impact. Most distinctly new technologies do not constitute just a slight modification in a single dimension of an existing technology. Rather, they represent clusters of new characteristics, some of which are positive and some of which are negative. Development and commercialization involves a sorting out process, in which negative features are reduced while positive ones are enhanced. One example is promising new mechanical pulping technologies, which hold out the prospect of higher yield, but are burdened with the requirement of higher energy costs (Ince 1987). The speed of adoption of innovations will turn heavily upon the nature of the positive and negative features and their relative ease of malleability. In many cases this situation gives rise to a long and costly period of development activity. When commercial introduction of an innovation is contemplated, costly new equipment is often required. Therefore, the introduction is likely to be associated with replacement of depreciated equipment or establishment of new mills. In either case, required special market conditions for inputs, or access to favorable financing may long delay introduction.

In the forest products industry there is a particular institutional feature that may significantly influence the timing of the adoption decision. Substantial research is currently done in the public sector, by the USDA Forest Products Laboratory, regional Forest Service research stations, and state universities. But commercial success usually requires more research, development, and demonstration than can be attained by a public agency. That is, fine tuning product design and characteristics to user needs, as well as further process and machinery improvements may be needed. Therefore, the final push in making improvements and adoption has to come from the private sector and must await the stimuli of changing prices or costs that ordinarily influence private firm decisions. These stimuli may be particularly important to large corporations that may be more resistant to change (Blair 1972).

After initial commercial adoption, a technology's technical and cost performance continues to change. The first application of a new technology is typically crude in comparison to characteristics eventually attained. Although this feature is shared with other industries, it may assume greater importance in forest products where improvement from one generation to the next may be slower because of difficulties in acquiring information about harvesting, processing, and using wood of widely varying properties.

Problems in Using Innovations for a Heterogeneous Raw Material

The forest products industry, if not unique, is at least at the extreme end of a spectrum of possibilities with respect to the variety of inputs that it employs in its different productive processes. Wood is an organic material with a remarkable degree of natural diversity and versatility which reflects a range of conditions: species of tree, age, location, growing space, climate, moisture, position in the tree, etc. Such heterogeneity complicates the process by which useful knowledge is accumulated and diffused within the industry. Research findings in aluminum, iron and steel, pharmaceuticals, or electronics have the potential for some immediate wider degree of generality, but the situation is very different for forest products. The behavior of wood is highly variable not only from one species to another, but even from one location in a log to another. Many of the difficulties of the industry in developing and applying innovations result from the fact that technological problems are often too subtle and too multivariate for scientific methodology to offer general guidance. It is not that the necessary information cannot be obtained, but that each relatively small "bit" of information typically has to be acquired at a slow pace and at a high cost. Furthermore, scientific information, once obtained, cannot be readily used in other contexts involving other species, subspecies, or locations. It is this inherent difficulty in the information acquisition process, and not the mature stage of the industry, that accounts for the difficulties in bringing scientific methodologies more effectively to bear upon the industry's technical problems. A major thrust of research and technological change in the industry has been to overcome these effects of input heterogeneity.

Problems in Using Innovations for Heterogeneous Products and Product Use Conditions

The heterogeneity of wood input leads directly to heterogeneity in characteristics of wood products. In addition, when placed in use, wood products face a wide range of demanding use conditions. In wood-based construction, for example, every final product, even after grading, is to some degree unique, and its required performance is unique because of the specific environment where it is used. A consequence of having heterogeneous outputs, plus long life of products in construction, is that it takes an unusually long time to sort out the contributions of separate variables on product performance. One major thrust of research and technological change in the industry is to make products of relatively uniform performance characteristics from heterogeneous inputs. Many innovations have involved taking a diversity of low quality timber and converting it into more reliably performing products with lumber-type, or plywood-type characteristics. Examples are laminated veneer lumber, parallel strand lumber, waferboard and oriented strand board. Problems of acquiring information about performance is similar for the pulp and paper sector. It may take years to clarify something as elementary as the energy requirements associated with a new pulping technology, partly because of heterogeneity among wood inputs and partly because of the varied performance requirements of the pulp.

The Impact of Past Research

Having discussed several important influences on the course of research, and development and adoption of innovations, we turn to more specific discussion of the actual effectiveness of research, development, and technology transfer efforts. In general, successful research and technology transfer efforts lead to technology change that has been shown to be a major component of economic growth and development. New technologies can create new industries, replace old products with new ones, and, in many ways, improve processes which provide goods and services. The role of public and private research in generating technical change has been examined extensively during the past several decades, and the link between investment in research and productivity growth has been repeatedly demonstrated in empirical studies (Mansfield 1972, Evenson et al. 1979, Griliches 1987).

Similarly, forest products research and resulting technology change have been major forces influencing timber resource utilization. Changes in species availability and growing stock have been accommodated by changes in forest products technology, thus averting severe dislocations and scarcity. "As preferred species, sizes, and qualities of wood have become depleted due to increased demand, processing technologies have been adjusted to work with more abundant species and materials previously thought to be unusable" (U.S. Congress OTA 1983, p. 130).

The sweeping changes in wood utilization technology in recent decades suggest that the economic impacts of forest products research have been substantial. Until recently, however, there has been no empirical evidence to support this notion. Table 146 summarizes the results of recent economic evaluations of wood utilization research, categorized as either aggregate or case study evaluations. Aggregate studies examine the relationship between investment in research and productivity growth in an entire industry or sector of the economy. Innovation case studies focus on the impacts of specific new technologies produced by a research effort.

Aggregate Evaluations

Haygreen et al. (1986) evaluated the impacts of seven major timber utilization technologies. They compared actual research expenditures to projected benefits (net savings of timber value) due to technology adoption. Even with a very conservative assessment of benefits and liberal estimate of costs, the calculated rate of a return on the investment in forest products research is 14–36%.

Seldon (1987) used an econometric modeling approach to estimate returns[55] of research conducted to produce softwood plywood in the South. He explained the high internal rates of return—in excess of 300%—mainly by the fact that public softwood research was applied research that was quickly adopted by softwood plywood producers.

Seldon and Hyde (1989) applied Seldon's (1987) econometric modeling approach to the U.S. softwood

[55] *Returns included estimated savings to consumers in the form of lower product prices and savings to producers in the form of lower production costs.*

Table 146.—Economic evaluations of wood utilization research.

Study	Research evaluated	Time period	Measures of economic impact: Marg. IRR(%)[1]	Avg. IRR(%)	B/C Ratio
Aggregate evaluations					
Haygreen et al. (1986)	Timber Utilization	1972–2000		14–36	
Seldon (1987)	Softwood plywood	1950–80	+300		
Seldon & Hyde (1989)	Softwood lumber	1950–80	5–30	13–47	
Brunner & Strauss (1987)	Wood preserving	1950–80			15/1–66/1
Bengston (1985)	Lumber & wood products	1942–73		34–40	
Innovation case studies					
Bengston (1984)	Structural particleboard	1950–2000	27–35	19–22	
Mansfield et al. (1977)	Paper innovation	1960–73		82	

[1]*IRR = internal rate of return.*

lumber industry for the period 1958–80. Average internal rates of return of public research in this area ranged from 13% to 47% over this period, depending on several assumptions. Marginal IRR ranged from 5% to 30%.

Brunner and Strauss (1987) evaluated the economic benefits of public research and development in the U.S. wood preserving industry. Technical change in this industry involved innovations in chemical preservatives, new treatment methods, and new methods for conditioning wood prior to treatment. Using the evaluation method developed by Seldon (1987), Brunner and Strauss found significant social benefits[56] stemming from this public research. Over the period 1950 to 1980, the net present value of research benefits amounted to between $7.5 and $17.7 billion (1982 dollars) depending on several assumptions, and benefit-cost ratios ranged from 15 to 66.

Bengston (1985) estimated the rate of return to investments in U.S. lumber and wood products research from 1942 to 1973 to be 40%.[57] Recognizing that technical change in the lumber and wood products industry depends in part on innovations developed in other industries, the costs of interindustry technology flows were included in the analysis. After adjusting for the flow of technology changes from other industries, the rate of return was calculated at 34%.

Innovation Case Studies

Bengston (1984) estimated the return[58] on investment in public and private research which led to the manufacture of oriented strand board/waferboard. Oriented strand board/waferboard is a reconstituted wood panel with properties suitable for structural and exterior applications. This major innovation has a significant impact on timber utilization in North America because it uses relatively abundant soft or low density hardwoods rather than scarce softwood species. Using an economic surplus model, estimated rates of return from investment in oriented strand board/waferboard research range from 19% to 22%. Estimated marginal rates of return ranged from 27% to 35%, suggesting that even higher investments in this type of research would have produced even more attractive returns.

Mansfield and others (1977) evaluated an innovation in paper manufacture—a new paper product that cut costs for users—in an evaluation of 17 industrial innovations. They estimated the social and private returns[59] from research and development that generated these innovations. The social rate of return to research leading to the paper innovation was estimated to be 82%. The private rate of return was found to be 42%, indicating that the benefits from this innovation were shared between consumers and the innovating firm.

Conclusions

These studies confirm that many types of utilization research have significant economic returns. Some studies suggest the returns are higher than for other public forestry investments such as public nonindustrial private forest incentives or public forest timber management investments (Boyd and Hyde 1989). Utilization research has been a highly attractive investment compared to public investments generally—the social rate of return to utilization research is substantially above the return obtainable from most other public investments, which typically range from 5% to 15%. This is some evidence of an underinvestment in utilization research. An optimal level of investment is one where the returns to all investments are equal at the margin, i.e., the returns to added research investments are equal to returns on other investments (given equal levels of risk). Higher levels of investment in utilization research would be justified if, after adjusting for different risk, return on additional investment is above the average return for other public investments.

[56]*See note 55.*

[57]*Returns included estimated savings to producers in the form of lower production costs.*

[58]*Returns included estimated savings to consumers in the form of lower product prices.*

[59]*Returns included estimated savings to consumers in the form of lower product prices and selected returns to inventors.*

The Impact of Selected Areas of Current Forest Service Research

The previous section indicates how past utilization research leads to benefits in the form of lower costs to consumers for products, and/or lower production costs for producers. In this section, to more closely evaluate the potential effect of research on the adequacy of future timber supplies, we evaluate how selected current U.S. Forest Service research may, in association with other research, development, and technology transfer efforts, change future timber consumption and prices. Because of our focus on the timber market consequences of research we do not evaluate many other important potential benefits of utilization research, such as improved worker or consumer safety, or environmental protection.

To conduct this evaluation, seven areas of Forest Service research were identified which, if successful, would influence prices and consumption in timber markets. These areas ranged from basic research on certain pulping processes, to applied research on timber harvesting, to technology transfer efforts to improve lumber and plywood/veneer production. The research areas are as follows:

1. Harvesting,
2. Lumber and plywood/veneer processing,
3. Design and performance of wood structures,
4. Development of improved adhesives from renewable resources,
5. Expanded use of timber bridges,
6. Development of new or improved composite products using wood, and
7. Pulp, paper, and paperboard processing.

Scientists at the USDA Forest Service, Forest Products Laboratory (FPL) and other regional forest research stations identified how successful completion of research-development-adoption efforts would alter timber processing or demand for timber products. For many research areas, we assumed complementary research and development would be done by universities and/or industry. For each research area (other than pulp, paper, and paperboard) scientists described how research would alter such technical factors as product recovery factors, processing costs, or rate of wood use in various end-products, as well as the timing of such changes. These expected technology changes were translated into sets of changes (one set for each research area) to the base case assumptions used to make timber market projections to 2040 with the Timber Assessment Market Model (TAMM) and the Hardwood Assessment Market Model (see Chapter 7). We use 'TAMM' to refer to both models. The sets of changes were used to make separate simulation runs to project timber market conditions that reflect successful completion of each research area. Finally, we compared TAMM projections of timber and wood product consumption and prices between the base case and the altered cases. For research area 7—pulp, paper and paperboard—we used the FPL Pulpwood Model. Scientists estimated technical characteristics (pulp yield and cost) of new ways to make various grades of paper, and the timing of their commercial introduction. These new processes were inserted in the FPL Pulpwood Model to alter projections of pulpwood and paper/paperboard production and prices (Howard et al. 1988). Altered projections of pulpwood and selected paper/paperboard price and production were compared to the base case. Altered projections of pulpwood consumption were then inserted in the TAMM model and the resultant saw timber and solid product projections were compared to the TAMM base case.

The first section below explains the research being conducted in each area and the resultant anticipated technology changes as implemented in TAMM or the FPL Pulpwood Model. The section on findings explains the potential impact of the research areas in terms of differences in timber and wood products prices, differences in harvest/consumption levels, and differences in total annual product value (price times volume) between the base case and altered projections.

Harvesting

We evaluated two kinds of Forest Service harvesting research in terms of their potential impact on softwood saw timber/veneer log harvesting: (1) research to transfer analyses and ideas about which types of existing equipment are best to use in various situations, and (2) research to improve equipment and systems efficiency with new types of hardware or new designs. To implement the effect of the first research activity, we increased the pace of change in the mix of harvesting systems used (see harvesting section above and Bradley 1989). We assumed the base case system mix for the year 2001 would be achieved by 2000. To implement the effect of the second research activity, Forest Service harvesting researchers estimated how cost efficiency could be improved in various equipment systems by 2040 with continued research by the Forest Service, universities, and industry. We assumed the Forest Service would produce about one-third of the efficiency gains (in rough proportion to research expenditures). The combined effect of the two research activities, after accounting for projected changes in stand density and stem diameter, is estimated to reduce harvesting cost 5–7% by 2040 in various U.S. regions.

Lumber and Plywood/Veneer

We evaluated three Forest Service activities that will improve lumber and plywood/veneer processing: the IMPROVE program, research to use Best-Opening-Face (BOF) concepts for hardwood lumber production, and research to develop the Automated Lumber Processing System (ALPS) for hardwood lumber. IMPROVE is a technology transfer program to develop and distribute a series of personal computer programs for sawmill, veneer, and plywood industries for improving product output and profitability from existing operations. Applying BOF concepts to hardwood lumber will increase overall lumber recovery and grade recovery from hardwood logs. Research on ALPS is intended to: (1) develop tomography and computer software for internal defect detection and breakdown of logs, (2) develop computer vision and computer control for cutting lumber into furniture parts, and (3) develop lasers to cut lumber into furniture parts.

We estimate the IMPROVE program would speed up improvement in softwood lumber and plywood recovery, and reductions in processing costs. The program would also help increase hardwood lumber recovery, as described later in this report. As a result of such acceleration, we assume improvements formerly estimated to occur by 2001 would occur by 2000. By 2000, softwood lumber and plywood recoveries would improve an extra 0.3% and 0.5%, respectively, and processing costs would decrease an extra 0.5% and 0.1%, respectively.

With successful completion and adoption of BOF research to make hardwood lumber, as well as efforts in the IMPROVE program, we estimate that overall hardwood lumber recovery would increase at a rate of 1.6% per decade between 1985 and 2000, and 1.5% per decade between 2000 and 2040. In the base case, hardwood lumber recovery would increase 1.0% per decade.

ALPS would increase recovery of higher hardwood lumber grades by using tomography to scan for internal defects and computers to aide in breakdown. With use of this technology, we estimate 10% of the lumber formerly graded as less-than-1-common would move to 1-common, and 10% of the lumber formerly graded as 1-common would move to higher grades. We assume this technology would be used for 25% of lumber production by 2040. ALPS would also decrease the amount of lumber needed to produce a given quantity of furniture parts by using computer vision and computer controlled conventional or laser cutting. We assume computer vision would initially reduce lumber use per unit of furniture parts by 10% in 1995, expanding to 15% by 2040. By 2040, we assume 50% of furniture parts production would use the technology.

Design and Performance of Wood Structures

The Forest Service is engaged in 10 research activities that will improve the design and performance of wood structures. These include:

1. Development of more reliable engineered wood structural components such as wooden I-beams,
2. Improved design criteria for efficient and reliable structural connectors,
3. Accurate determination of effects of use conditions on structural components,
4. Improved resistance of wood products and assemblies to fire,
5. Improved techniques for rehabilitating wood structures,
6. Development of advanced design procedures to improve competitiveness of designs using wood relative to designs that use steel or concrete,
7. Improved adhesive-connected structural components,
8. Accurate assessment of structural lumber properties (aids in using advanced design concepts),
9. Flexible and precise nondestructive evaluation techniques to aid grading of lumber, and
10. Development of stress class/species independent grading to enhance use of diverse species.

We judged that success in these research activities would increase lumber and panel use for nonresidential structures, and decrease lumber use and increase panel use per square foot of residential construction. For nonresidential structures, we assume that by 2010 and thereafter the research will increase lumber, plywood, and oriented strand board/waferboard use by 15% over levels in the base case by increasing the number of buildings where wood is used. This increase accounts for the fact that advanced design procedures will reduce the wood used per square foot of floor area. For single- and multifamily homes, we assume this research will accelerate technology changes projected to occur at a slower pace in the base case. For single-family homes, lumber use will decrease 15% because of more efficient design (by 2010 rather than 2040), and structural panel thickness will increase (to provide needed strength with wider stud spacing) in floors, wall sheathing and siding by an average of 7.5% to 12% by 2010. For multifamily homes, lumber use in floors will decrease slightly and average floor panel thickness will increase. Lumber use in roofs and walls is already quite efficient. The aggregate effect of research on design and performance of wood structures will be to increase both lumber and structural panel consumption above levels in the base case projections.

Adhesives From Renewable Resources

Adhesives developed from renewable resources, particularly tree components, may be important because they may be cheaper than petroleum-based phenolics if oil prices increase substantially. The availability of adhesives from renewable resources may hold down the cost of structural panels, especially oriented strand board. If adhesives from renewable resources are not available, and if oil prices roughly double to $50 per barrel (1982 dollars) by 2020, we estimate increases in phenolic adhesive prices would increase plywood prices by 5–16% and oriented strand board prices by 46% by 2020. Availability of economical adhesives from renewable resources would hold down such panel price increases.

Expanded Use of Timber Bridges

The Forest Service has undertaken a program to promote use of timber to replace thousands of smaller bridges in the United States each year. Roughly one-quarter million bridges are in need of eventual repair or replacement. Currently, less than 1,000 timber bridges are built each year. With improved economical designs, we estimate that the annual construction of timber bridges could be increased to 7,500 bridges by 1995 and continue at that level through 2040. An average bridge would use 1,300 cubic feet of wood, for a total of 9.75 million cubic feet per year. We estimate that between 1995 and 2040, the West would produce an extra 60 million board feet per year of softwood lumber/timber for bridges, and the East produce an extra 30 million board feet of both hardwood and softwood lumber/timber. This extra production would be 0.19% and 0.33% of 1986 softwood and hardwood lumber production, respectively.

New or Improved Composite Products

Forest Service research on composite wood products includes development of steam injection pressing to form panels, chemical treatments to improve dimensional stability and water resistance of composite panels, and composites of wood and nonwood materials (e.g., plastics) for many applications.

We assume that chemicals will be injected by steam injection pressing in oriented strand board-type products to make them dimensionally stable and suitable for exterior use in construction. Specifically, treated oriented strand board will be used more widely for concrete forms in construction and for wood foundations, siding, and exterior millwork for single-family housing. We assume that by 2040 (1) treated oriented strand board will largely substitute for plywood in foundations and concrete forms, (2) treated oriented strand board will substitute for some plywood in single-family housing and will slightly expand the market, and (3) treated oriented strand board will substitute for about half the lumber millwork in exterior applications. These changes amount to a relatively small shift from plywood and lumber to oriented strand board-type products compared to the base case.

Research on composites of wood and nonwood materials could yield products that pair wood with nonwood biomass, metal, plastics, glass, or synthetic fibers. Much current research is devoted to wood-plastic composites. These composites could substitute for existing wood products such as packaging (containers, cartons, pallets) and decrease wood use, or they could substitute for nonwood products such as auto and truck components and increase wood use. We assume wood-plastic composites will have the widest use, and will, overall, tend to increase wood use. We use wood-plastic composites in auto or truck components as a proxy to indicate the overall net increase in wood use. Wood use in such composites would be 3.6 million cubic feet by 2040, assuming 15% wood use in 30% of such auto or truck components. This increased consumption is small compared to 1987 wood consumption of 18.7 billion cubic feet.

Pulp, Paper and Paperboard

We evaluated five areas of Forest Service pulp, paper, and paperboard research: improved mechanical pulping of hardwoods to make linerboard, and printing and writing paper; peroxymonosulfate pulping for cheaper, less polluting pulping of hardwoods; techniques to increase or improve wastepaper recycling; production of newsprint from 100% hardwoods; and development of Spaceboard I (a replacement for corrugated boxboard). Anticipated developments in these areas were used to make 18 changes in the way 8 grades of paper and paperboard are made in the FPL Pulpwood Model (Howard et al. 1988).

Research on mechanical pulping for hardwoods in linerboard could lead to use of pulp with yields of 85% to 95% compared to levels of 50% to 55% for conventional unbleached kraft pulp. The research may provide a means to make linerboard from 100% hardwoods with 80% yield by the year 2015—specifically, chemithermomechanical pulping (CTMP) with press drying to form paperboard. Mechanical pulping could also increase the use of hardwoods in making printing and writing papers. Research on mechanical pulping is oriented toward reducing energy consumption, increasing paper strength, and, for printing and writing grades, maintaining optical properties as needed, reducing color reversion, and achieving high brightness.

By 2010, research on peroxymonosulfate pulping may facilitate the increased use of hardwood in newsprint, unbleached kraft paperboard, solid bleached paperboard, printing and writing papers, packaging and industrial papers, and tissue. Peroxymonosulfate pulping may be able to produce a relatively high-yield pulp from 100% hardwoods that has improved bonding strength and higher brightness relative to other hardwood pulps. Peroxymonosulfate pulp could be used in combination with other pulps to make many grades of paper.

By 2010 to 2015 research on wastepaper recycling may facilitate additional increases in use, or altered use, of recycled paper for newsprint, unbleached kraft paperboard, solid bleached paperboard, recycled paperboard, printing and writing paper, packaging and industrial paper, and tissue. To increase recycling, research is being done in the following areas: development of a disk separation process to separate contaminants from recycled fiber, improvement of means to remove contact and noncontact ink from printing and writing papers, and development of chemical and biological treatments to restore bonding strength to recycled paper fibers.

Research on CTMP and biomechanical pulping (BMP) with press drying may be successfully combined to make newsprint from 100% hardwoods. Mills using CTMP/press drying, or BMP/press drying may be possible beginning in 2015 and 2025, respectively. Combining CTMP with press drying may achieve higher sheet strength previously attainable only with softwoods. Bleaching may be needed when using certain hardwood species. Combining BMP with press drying has the possibility of increasing strength and also retaining optical properties for more hardwood species (low and medium density species).

Research may provide a new product, FPL Spaceboard I, that would replace some corrugated fiberboard to make boxes (Setterholm 1985). Spaceboard is a sandwich of two or more pulp-molded structures. The structures have a flat surface on one side and a structural waffle-like rib pattern on the other. The structures are glued together, rib to rib, to form a structural board. Spaceboard could be made with several kinds of fiber. We assume that manufacturing plants for Spaceboard I, located near large cities, will be built by 2000 and will use 100% recycled corrugated containers as raw material. We estimate Spaceboard I may replace 25% of corrugated container board by 2040.

General Findings

As we have described, the objectives of wood utilization research are diverse. They serve a wide variety of interest groups, including forest landowners, loggers, product producers, and consumers. To conduct a welfare analysis that would identify a complete range of welfare gains and losses for all forest sector interests is beyond the scope of this study. (For an example of such an analysis see Adams et al. 1977.) Nevertheless, the limited set of measures used in our study clearly show that the interest groups who gain and lose vary from one research area to another. The approach used here is similar to one used by Skog and Haynes (1987) to evaluate past wood utilization research.

To measure market impact, we used the change in timber and wood product prices, harvest/consumption volume, and harvest/consumption deflated dollar value (1982 dollars). These measures clearly indicate gains or losses for some groups. For example, stumpage price increases or harvest volume increases that lead to increased value of harvest are a gain to landowners, whereas price increases for final products are a loss for consumers. But these measures do not clearly indicate gains or losses for producers. For example, a decrease in lumber price caused by reduced cost of timber may lead to a profit gain for producers, but a decrease in lumber price caused by reduced demand for lumber may lead to a profit loss.

For all research areas, change in price, harvest/consumption, and value were estimated for softwood and hardwood saw timber, softwood and hardwood lumber, softwood plywood, and oriented strand board/waferboard. These estimates were produced using TAMM model projections.[60] For pulp, paper, and paperboard research, change in price of softwood pulpwood, and change in production of softwood and hardwood pulpwood and selected grades of paper and paperboard were estimated. These estimates were made using the FPL Pulpwood model.

In terms of the magnitude of impact, the research areas fall into three groups. Research on harvesting, lumber and plywood/veneer, timber bridges, and composite products cause less than 5% change in price, harvest/consumption, and value through 2040. Research on design and performance of wood structures and development of adhesives from renewable resources may change the price or consumption of some products by 5–20% by 2040. Research on pulp, paper, and paperboard may decrease softwood pulpwood consumption by 36% by 2040. A key difference between the first two categories and pulp and paper research is that the full effect of research in the first two categories is expected well before 2010, whereas the effect of pulp and paper research will not begin until 2010–2020. The six research areas (except for pulp, paper, and paperboard) are expected in the long run to lead to higher softwood saw timber prices; and with the exception of adhesives and pulp, paper, and paperboard research, to higher softwood saw timber harvest.

The percentage of change in softwood saw timber prices caused by the alternate research areas is generally greater than the change in harvest volume. This is because stumpage supply is not very responsive to price changes and solid-wood product demand is not very responsive to product price changes. As a result, the increase in softwood saw timber value caused by research in categories 1 and 2 is caused primarily by increases in stumpage price and not increases in harvest volume.

The potential decreases in pulpwood harvest volume resulting from pulp, paper, and paperboard research are much larger than any potential increase in saw timber harvest resulting from any of the research areas. The potential 36% decrease in pulpwood harvest by 2040 is equal in volume to 30% of the projected softwood saw timber harvest in 2040.

The potential decreases in harvest value—both for pulpwood and saw timber—resulting from pulp, paper, and paperboard research are much greater than any potential increase in saw timber harvest value caused by other research areas. The potential annual value decrease in pulpwood alone would exceed $1.4 billion by 2020, and $3 billion by 2040. The associated annual value decrease for softwood saw timber could be $0.2 billion by 2020, and $3.2 billion by 2040.

Findings for Specific Research Areas

Harvesting research, by holding down softwood saw timber harvesting costs, would increase lumber consumption and softwood saw timber production by a few tenths of a percent over the projection period, and increase softwood saw timber price by up to 4.2%. The annual value of softwood saw timber harvest increases by up to 4.6% ($413 million in 2030). Lower harvest cost reduces lumber prices and overall value for softwood lumber consumption by up to 0.9% by 2040. The price and consumption of plywood and oriented strand board/waferboard vary above and below the base case as variation in relative prices causes substitution between panels and lumber.

Lumber and plywood/veneer research and technology transfer raise softwood lumber and plywood conversion efficiency and lower manufacturing costs through the year 2000. Efficiency improvements result in a near-term

[60] *To try to avoid observing the effects of technology differences on short-term business cycles generated in TAMM, we compared average price and consumption levels between the base case and altered cases. Averages were taken for 9-year periods around 2000, 2010, 2020, and 2030.*

reduction in softwood saw timber price and harvest, and a slight increase in lumber production. In the long run, lower manufacturing costs increase saw timber harvest, price, and value. The annual value of saw timber harvest increases by up to 2.3% (in 2030). Higher timber costs lead to higher lumber prices, lower production levels, and lower lumber value (by 0.4% in 2040), a counterintuitive result. Research on hardwood lumber leads to higher hardwood lumber conversion efficiency and less lumber use per unit of furniture production. This results in lower hardwood saw timber and lumber consumption, prices, and value. The value of hardwood saw timber and lumber decrease by 2.0% and 2.7%, respectively, by 2040. The price, consumption, and value of plywood and oriented strand board/waferboard vary above and below the base case as variation in relative prices causes substitution between panels and lumber.

Research on design and performance of wood structures increases consumption, prices, and value for softwood saw timber, lumber, and plywood, as would be expected. The value of softwood saw timber, lumber, plywood, and oriented strand board increases by 7.0%, 3.1%, 6.2% and 5.0%, respectively, relative to base case projections by 2040. Hardwood saw timber and lumber prices remain relatively unchanged because hardwood lumber demand is not altered (table 147).

Research to produce adhesives from renewable resources would keep down the price of adhesives as petroleum-based products increase in price. This would keep oriented strand board/waferboard prices as much as 20% lower, and plywood prices as much as 3.9% lower. These estimated price effects are greater than could actually be achieved because we assumed in our analysis that the new adhesives could keep glue prices constant at current levels. Because of the price inelasticity of demand for panels, a much lower oriented strand board/waferboard price (held down by cheaper glues) would result in only 2% higher production. Plywood production with cheaper adhesives will be lower than in the base case. This is because oriented strand board/waferboard will be in a relatively stronger competitive position with cheaper glue than in the base case. With lower glue costs, the annual value of panels consumption is $831 million less by 2040. Much of this will be saving of glue costs. The combined annual value of softwood plywood and oriented strand board is lower by 4.6% and 22.8%, respectively, by 2040. With lower glue costs there is higher timber demand for panels, saw timber and lumber prices are higher, their harvest/consumption is lower, and their change in value is mixed over time (table 147).

The expanded use of timber bridges increases saw timber harvest by roughly 0.2% and 2.5% for softwoods and

Table 147.—Potential impact of research on engineered structures and adhesives, on price, production level, and value of various types of timber and wood products in the future.

Market characteristic and product	Design and performance of structures					Adhesives from renewable resources				
	2000	2010	2020	2030	2040	2000	2010	2020	2030	2040
	Percent difference from base case projection[1]									
Price[2]										
SW sawtimber	3.1	5.6	6.0	7.4	6.8	0.2	0.9	*	1.5	1.2
HW sawtimber	*	–0.1	*	0.1	0.1	*	0.1	0.2	0.4	0.6
SW lumber	0.9	1.1	1.3	1.9	1.4	0.2	0.5	–0.2	–0.3	0.1
HW lumber	*	*	*	0.1	0.1	*	0.1	0.2	0.3	0.4
SW plywood	1.0	2.1	3.5	0.9	6.0	–1.8	–3.4	–3.5	–3.8	–3.9
OSB/waferboard	0.2	–0.8	0.5	–0.2	–0.1	–10.0	–15.0	–20.0	–19.0	–19.0
Harvest/consumption[3]										
SW sawtimber	0.3	0.5	0.1	0.3	0.1	*	–0.1	–0.2	–0.4	–0.6
HW sawtimber	*	*	*	–0.1	*	*	*	–0.1	–0.1	–0.2
SW lumber	0.7	1.4	1.5	1.6	1.7	–0.1	–0.2	–0.1	*	0.1
HW lumber	*	*	*	*	*	*	–0.1	–0.1	–0.1	–0.2
SW plywood	0.7	1.0	0.9	1.0	0.2	–0.6	–1.2	–1.4	–0.9	–0.5
OSB/waferboard	2.3	4.5	4.7	4.8	5.0	1.3	2.0	1.6	1.1	0.8
	Value difference in millions of 1982 dollars[1]									
Value										
SW sawtimber	183	461	539	701	664	–13	–54	13	–100	–59
HW sawtimber	–1	–6	0	0	6	0	–3	–8	–18	–29
SW lumber	278	520	654	817	740	–27	–68	64	73	–32
HW lumber	0	3	2	4	3	0	0	7	13	21
SW plywood	67	137	204	93	331	–94	–211	–238	–249	–246
OSB/waferboard	37	71	110	104	127	–134	–304	–473	–513	–585

**Value is between –0.05 and 0.05.*
[1]A positive value indicates the altered case is greater than the base case.
[2]Sawtimber prices are for stumpage. Other prices are for delivered products.
[3]Sawtimber volume is for U.S. harvest. Other volumes are for amounts consumed in the United States. Net imports from Canada may change and are included.

hardwoods, respectively. Softwood and hardwood saw timber prices will increase by 1–2%. This will lead to an annual saw timber value increase of about $300 million in 2040. The value of softwood and hardwood saw timber harvest will increase by 0.9% and 2.7%, respectively, by 2040. The increased demand for hardwood lumber for bridges in the East will lead to higher consumption and prices. However, the increased demand for softwood lumber in the West and East, while leading to greater consumption, will unexpectedly lead to a mix of increases and decreases in softwood lumber price over time. The greater demand for softwood lumber will create a greater demand for softwood plywood as a substitute and result in higher plywood prices and annual plywood consumption value.

Research on composite products could lead to a decrease in softwood plywood use (1.6% by 2040), and an increase in oriented strand board/waferboard use (2.4% by 2040) and softwood lumber use. These shifts result in an increase in softwood saw timber price and harvest of slightly less than 1% by 2040. They also result in varying changes in softwood plywood and oriented strand board/waferboard price above and below base projections. As a result of the consumption and price trends altered by research, annual saw timber value is generally higher, up to $80 million higher in 2030; softwood lumber value is generally lower, up to $126 million lower in 2030; oriented strand board/waferboard value is generally higher, up to $64 million higher in 2030; and softwood plywood value varies above and below base case value projections.

Table 148.—Potential impact of selected pulp, paper and paperboard research on price, production level, and value of softwood pulpwood, hardwood pulpwood, and selected grades of paper and paperboard in the future.

Market characteristic and product	Pulp, paper, and paperboard				
	2000	2010	2020	2030	2040
	Percent difference from base case projection[1]				
Price[2]					
SW pulpwood	1.3	−0.6	−13.1	−7.2	−8.7
Harvest/production					
SW pulpwood	−0.3	−1.0	−13.7	−20.1	−32.7
HW pulpwood	−0.5	0.4	−0.8	−1.9	−0.8
	Value difference in millions of 1982 dollars[1]				
Value[3]					
SW pulpwood	39	−74	−1,304	−1,530	−2,459
HW pulpwood	−11	14	−30	−74	−353

[1]*A positive value indicates the altered case is greater than the base case.*
[2]*Price change is from the price-endogenous portion of the FPL Pulpwood Model, which takes into account technology changes only in making semichemical paperboard, solid bleached paperboard, and recycled paperboard. Harvest change is from combined estimates from the price-endogenous and exogenous portions of the FPL Pulpwood Model and takes into account technology changes in all eight paper and paperboard grades.*
[3]*Softwood (SW) pulpwood value change includes price change noted in table. Hardwood value change assumes no change in hardwood prices between the base case and altered case.*

Table 149.—Potential impact of research on pulp, paper and paperboard on price, production level, and value of various types of timber and wood products in the future.

Market characteristic and product	Pulp, paper, and paperboard				
	2000	2010	2020	2030	2040
	Percent difference from base case projection[1]				
Price[2]					
SW sawtimber	−6.1	2.5	−5.6	−29.0	−43.0
HW sawtimber	([4])	−.1	−.1	−.2	−2.0
SW lumber	−1.2	([4])	−4.1	−14.1	−37.9
HW lumber	([4])	−.1	([4])	−.1	−.3
SW plywood	−2.3	.8	−.1	−10.7	−10.4
OSB/waferboard	.3	([4])	.4	−2.0	−5.2
Harvest/consumption[3]					
SW sawtimber	.5	.7	3.0	11.7	16.8
HW sawtimber	([4])	([4])	([4])	([4])	−.1
SW lumber	.5	.5	1.0	3.0	4.7
HW lumber	([4])	.1	([4])	.1	.1
SW Plywood	.7	.2	.2	1.7	1.8
OSB/Waferboard	−.4	−.2	([4])	−.1	−.1
	Value difference in millions of 1982 dollars[1]				
Value					
SW sawtimber	−307	240	−241	−1873	−3189
HW sawtimber	2	−3	−2	−8	−170
SW lumber	−133	108	−729	−2690	−8243
HW lumber	1	−1	−2	−5	−18
SW plywood	−62	44	4	−460	−474
OSB/waferboard	−1	−5	−10	−47	−135

[1]*A positive value indicates the altered case is greater than the base case.*
[2]*Sawtimber prices are for stumpage. Other prices are for delivered products.*
[3]*Sawtimber volume is for U.S. harvest. Other volumes are for amounts consumed in the United States. Net imports from Canada may change and are included.*
[4]*Value is between −0.05 and 0.05.*
Sources: Forest Service harvesting research projects and scientists—Northern flat terrain: Michael Thompson, NCFES, Houghton, Michigan; Southern flat terrain: Donald Sirois and Bryce Stokes, SFES, Auburn, Alabama; Eastern mountainous terrain: Penn Peters, NEFES, Morgantown, West Virginia; Rocky Mountain: Michael Gonsior, IFRES, Bozeman, Montana; and Pacific Coast: Charles Mann and Robert McGaughey, PNWFRES, Seattle, Washington.

Pulp, paper, and paperboard research leads to substantially different effects than the other categories of research. First, the effects are expected much further in the future (after 2010); second, both pulpwood and sawtimber harvest and prices will be substantially affected; and third, the potential changes in price, harvest/consumption, and value will be much greater. Projections of pulpwood consumption using the FPL Pulpwood Model indicate that greater efficiency in pulpwood use; a continuing shift from softwoods to hardwoods; and greater recycling will lead to a 14% reduction in softwood pulpwood use and a 1% reduction in hardwood pulpwood use by 2020 (table 148). These reductions would reach 33% and 8%, respectively, by 2040. The hardwood reductions are smaller because of a shift to greater relative use of hardwoods. The 33% reduction in softwood pulpwood use is equal in volume to 27% of the projected base case softwood sawtimber harvest in 2040. The softwood pulpwood price would decrease roughly 9% by 2040. Hardwood pulpwood price would also decline given the decrease in harvest, but a specific estimate is not possible with the current structure of the FPL Pulpwood Model. If we assume no change in hardwood prices from the base case, the combined decline in annual pulpwood harvest value would be $1.2 and $2.8 billion in 2020 and 2040, respectively. For 2040, this value decrease is 39% and 8% for softwood and hardwood pulpwood, respectively.

Declines in pulpwood harvest would increase the supply of sawtimber, and lead to increased solid-wood product consumption (table 149). The largest change is for sawtimber stumpage; price decreases 5.6% and 43.0% by 2020 and 2040, respectively; and harvest increases by 3.0% and 16.8%, respectively, by 2020 and 2040. The annual value of softwood sawtimber harvest would decline $.2 and $3.2 billion by 2020 and 2040, respectively.

The FPL Pulpwood Model estimates that the price and consumption of the five grades of paper in the endogenous portion of the model would change less than 0.05% relative to the base case. This lack of change, despite substantial pulpwood cost savings, is due to the relatively small cost contribution of pulpwood to overall paper/paperboard costs, and the fact that demand for paper and paperboard is relatively unresponsive to changes in price. Annual consumption value changes are less than 0.05%. In dollar terms, the total annual value decrease for the five grades of paper and board would be $868 million in 2020 and $112 million in 2040.

Conclusions

Research on pulp, paper, and paperboard processing has by far the greatest long-term potential for altering timber and wood product prices, harvest/consumption, and value; although the research-induced changes would not occur until after 2010. Softwood pulpwood consumption may decrease by one-third, and softwood sawtimber consumption may increase by one-sixth by 2040 relative to the base case if research is successful. The value of pulpwood harvest may decrease by $1.4 and $3.0 billion by 2020 and 2040, respectively. In addition, the value of softwood sawtimber harvest may decrease by $0.2 and $3.2 billion by 2020 and 2040, respectively, because of declines in stumpage prices.

The full effects of solid-wood products research would occur well before 2010. The solid-wood product research areas evaluated would, in the long run, all increase softwood sawtimber price. Their effect on product prices and on harvest/consumption levels would vary. Research on design and performance of wood structures has the potential for increasing sawtimber and wood product value the most—by $0.6 billion in 2000 and 1.9 billion in 2040 relative to the base case.

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APPENDIX A. GLOSSARY OF FOREST INVENTORY TERMS USED IN THE ASSESSMENT

Annual mortality.—The volume of sound wood in trees that died from natural causes during a specified year.

Annual removals.—The net volume of trees removed from the inventory during a specified year by harvesting, cultural operations such as timber stand improvement, land clearings, or changes in land use.

Bottomland hardwood.—Bottomland forests in which 50% or more of the stand is tupelo, blackgum, sweetgum, oak and southern cypress, singly or in combination, and southern pine makes up less than 25%. Common associates include cottonwood, willow, oak, elm, hackberry, and maple. This type is found on the alluvial flood plains of the Mississippi and other southern rivers.

Coarse materials.—Wood residues suitable for chipping, such as slabs, edgings, and trimmings.

Commercial species.—Tree species suitable for industrial wood products.

Cord.—A stack of wood containing 128 cubic feet within its outside surface. The standard dimensions are 4 by 4 by 8 feet.

Cropland.—Land used for the production of adapted crops for harvest, including row crops, small grain crops, hay crops, nursery crops, orchard crops, and other specialty crops. The land may be used continuously for these crops, or they may be grown in rotation with grasses and legumes.

Cull tree.—A live tree, 5.0-inches dbh or larger, that is unmerchantable for sawlogs now or prospectively because of rot, roughness, or species. (See definitions for rotten and rough tree.)

Diameter class.—A classification of trees based on diameter outside bark measured at breast height (4-1/2 feet above ground). Dbh is the common abbreviation for "diameter at breast height." When using 2-inch diameter classes, the 6-inch class, for example, includes trees 5.0 through 6.9 inches dbh.

Douglas-fir subregion.—The area in the states of Oregon and Washington that is west of the crest of the Cascade Range.

Economic opportunities to increase net annual growth on:

Timberland.—All opportunities on timberland to increase net annual timber growth or value that would yield 4% or more (in constant dollars net of inflation or deflation) on the investments required to implement the opportunities.

Cropland and pasture.—All opportunities on cropland and pasture that would yield higher rates of return to the owner if planted to pine.

Farmer-owned lands.—Lands owned by a person who operates a farm, either doing the work himself or directly supervising the work.

Fiber products.—Products derived from wood and bark residues, such as pulp, composition board products, and wood chips for export.

Fine materials.—Wood residues not suitable for chipping, such as planer shavings and sawdust.

Forest industries.—A diverse group of manufacturers that harvest, process, and use timber products in their final products. Activities include the harvesting of the timber resource; conversion of logs to primary timber products, such as lumber, plywood, and woodpulp; and the conversion of primary timber products to secondary or final products, such as pallets, furniture, and paper products. Forest industries include all or part of four industry groups classified under the Standard Industrial Classification (SIC) System—Major group 24—Lumber and wood products, Major group 25—Furniture and fixtures, Major group 26—Paper and allied products, and Industry 2861—Gum and wood chemicals. These classifications are used by the Bureau of the Census in the preparation of the Censuses of Manufacturers.

Timber Processing Industries.—"Forest industries" which produce or use substantial amounts of timber. Based on the types of raw materials consumed, the "forest industries" can be divided into industries using primarily solid-wood, those using primarily wood fiber, and those using raw materials other than wood. Industries consuming only small amounts of wood are excluded from the timber processing industries. The five timber processing industries follow SIC product definitions and are: (a) logging and lumber; (b) plywood, veneer, and other wood products; (c) wood furniture and fixtures; (d) pulp, paper, and board; and (e) converted paper and paperboard.

Primary Timber Processing Industries.—Industries producing timber products which will be further processed into finished products, largely by other industries. Manufacturers are grouped into one of seven categories based on the types of products produced: (a) timber harvesting, (b) lumber manufacturing, (c) structural panels manufacturing, (d) nonstructural panels manufacturing, (e) woodpulp manufacturing, (f) paper and paperboard manufacturing, and (g) other primary timber products manufacturing. Unlike the "forest industries" or "timber processing industries," primary timber processing industries are defined by the type of product produced; categories do not necessarily follow SIC major groups or industries.

Forest land.—Land at least 10% stocked by forest trees of any size, including land that formerly had such tree cover and that will be naturally or artificially regenerated. Forest land includes transition zones, such as areas between heavily forested and nonforested lands that are at least 10% stocked with forest trees, and forest areas adjacent to urban and built-up lands. Also included are pinyon-juniper and chaparral areas in the West, and afforested areas. The minimum area for classification of forest land is 1 acre. Roadside, streamside, and shelterbelt strips of timber must have a minimum crown width of 120 feet to qualify as forest land. Unimproved roads and trails, streams, and clearings in forest areas are classified as forest if less than 120 feet in width.

Forest type.—A classification of forest land based upon the species presently forming a plurality of the live-tree stocking.

Fuelwood.—Wood used by conversion to some form of energy, primarily residential use.

Growing stock.—A classification of timber inventory that includes live trees of commercial species meeting specified standards of quality or vigor. Cull trees are excluded. When associated with volume, includes only trees 5.0-inches dbh and larger.

Hardwood.—A dicotyledonous tree, usually broad-leaved and deciduous.

Highly erodible cropland.—All cropland in Land Capability Classes (classifications used by the Soil Conservation Service to rate the suitability of soils for agricultural production) 3e, 4e, 6e, and 7e.

Industrial wood.—All commercial roundwood products except fuelwood.

International 1/4-inch rule.—A log rule, or formula, for estimating the board-foot volume of logs. The mathematical formula is:

(0.22D2–0.17D)(0.904762)

for 4-foot sections, where D = diameter inside bark at the small end of the section.

Land area.—(a) Bureau of Census: The area of dry land and land temporarily or partly covered by water, such as marshes, swamps, and river food plains; streams, sloughs, estuaries, and canals less than 1/8 statute mile wide; and lakes, reservoirs, and ponds less than 40 acres in area. (b) Forest Inventory and Analysis: same as (a) except that the minimum width of streams, etc., is 120 feet, and the minimum size of lakes, etc., is 1 acre. This latter definition is the one used in this publication.

Live cull.—A classification that includes live, cull trees. When associated with volume, it is the net volume in live, cull trees that are 5.0 inches dbh and larger.

Logging residues.—Downed and dead wood volume left on the ground after trees have been cut on timberland.

Major eastern forest type groups:

White-red-jack pine.—Forests in which eastern white pine, red pine, or jack pine, singly or in combination comprise a plurality of the stocking. (Common associates include hemlock, aspen, birch, and maple.)

Spruce-fir.—Forests in which spruce or true firs, singly or in combination comprise a plurality of the stocking. (Common associates include white cedar, tamarack, maple, birch, and hemlock.)

Longleaf-slash pine.—Forests in which longleaf or slash pine, singly or in combination comprise a plurality of the stocking. (Common associates include other southern pines, oak, and gum.)

Loblolly-shortleaf pine.—Forests in which loblolly pine, shortleaf pine, or southern yellow pines, except longleaf or slash pine, singly or in combination comprise a plurality of the stocking. (Common associates include oak, hickory, and gum.)

Oak-pine.—Forests in which hardwoods (usually upland oaks) comprise a plurality of the stocking, but in which pine or eastern redcedar comprises 25–50% of the stocking. (Common associates include gum, hickory, and yellow-poplar.)

Oak-hickory.—Forests in which upland oaks, or hickory, singly or in combination comprise a plurality of the stocking except where pines comprise 25–50%, in which case the stand would be classified as oak-pine. (Common associates include yellow-poplar, elm, maple, and black walnut.)

Oak-gum-cypress.—Bottomland forests in which tupelo, blackgum, sweetgum, oaks, or southern cypress, singly or in combination comprise a plurality of the stocking except where pines comprise 25–50%, in which case the stand would be classified as oak-pine. (Common associates include cottonwood, willow, ash, elm, hackberry, and maple.)

Elm-ash-cottonwood.—Forests in which elm, ash, or cottonwood, singly or in combination comprise a plurality of the stocking. (Common associates include willow, sycamore, beech, and maple.)

Maple-beech-birch.—Forests in which maple, beech, or yellow birch, singly or in combination comprise a plurality of the stocking. (Common associates include hemlock, elm, basswood, and white pine.)

Aspen-birch.—Forests in which aspen, balsam poplar, paper birch, or gray birch, singly or in combination comprise a plurality of the stocking. (Common associates include maple and balsam fir.)

Major western forest type groups:

Douglas-fir.—Forests in which Douglas-fir comprises a plurality of the stocking. (Common associates include western hemlock, western redcedar, the true firs, redwood, ponderosa pine, and larch.)

Hemlock-Sitka spruce.—Forests in which western hemlock and/or Sitka spruce comprise a plurality of the stocking. (Common associates include Douglas-fir, silver fir, and western redcedar.)

Redwood.—Forests in which redwood comprises a plurality of the stocking. (Common associates include Douglas-fir, grand fir, and tanoak.)

Ponderosa pine.—Forests in which ponderosa pine comprises a plurality of the stocking. (Common associates include Jeffrey pine, sugar pine, limber pine, Arizona pine, Apache pine, Chihuahua pine, Douglas-fir, incense cedar, and white fir.)

Western white pine.—Forests in which western white pine comprises a plurality of the stocking. (Common associates include western redcedar, larch, white fir, Douglas-fir, lodgepole pine, and Engelmann spruce.)

Lodgepole pine.—Forests in which lodgepole pine comprises a plurality of the stocking. (Common associates include alpine fir, western white pine, Engelmann spruce, aspen, and larch.)

Larch.—Forests in which western larch comprises a plurality of the stocking. (Common associates include Douglas-fir, grand fir, western redcedar, and western white pine.)

Fir-spruce.—Forests in which true firs (*Abies* spp.), Engelmann spruce, or Colorado blue spruce, singly or in combination comprise a plurality of the stocking. (Common associates include mountain hemlock and lodgepole pine.)

Western hardwoods.—Forests in which aspen, red alder, or other western hardwoods, singly or in combination comprise a plurality of the stocking.

Chaparral.—Forests of heavily branched dwarfed trees or shrubs, usually evergreen, the crown canopy of which at maturity covers more than 50% of the ground and whose primary value is watershed protection. The more common chaparral constituents are species of Oak, mountain mahogany, silk tassel, ceanothus, manzanita, and chemise. It also includes urban forest land, which due to its location is unavailable for sustained timber harvesting.

Management intensities.—Growth and yield catagories developed for the Aggregate Timberland Assessment System to represent the development of stands under various improved management practices. Five alternative management intensities were developed for pine plantations in the Southcentral and Southeastern regions, and for the Douglas-fir and western hemlock types in the Douglas-fir subregion. These are:

Douglas-fir subregion

1. Yields represent the current average growth rate for all stands.
2. Plantation establishment of 400 trees per acre.
3. Plantation establishment and practice precommercial thinning.
4. Plantation established with genetically improved seedlings, practice precommerical thinning, and fertilize 10 years prior to harvest.
5. Plantation established with genetically improved seedlings, practice precommerical thinning, commercial thin and fertilize 10-years prior to final harvest.

South

1. Regular planting stock without thinning.
2. Regular planting stock with commercial thinning.
3. Genetically improved planting stock without thinning.
4. Genetically improved planting stock with thinning.
5. Genetically improved planting stock without thinning but with the most intensive site preparation and management practices.

Marginal cropland and pasture.—Cropland and pasture that would yield higher rates of return to the owner if planted to pine.

Mixed pine-hardwood.—Forests in which 50% or more of the stand is hardwood, usually upland oaks, and southern pines make up 25–49%. Common associates include upland oak-shortleaf pine in the foothills and plateaus; mixed hardwood-loblolly pine on moist sites; and scrub oak-longleaf pine in the sand hills of the Carolinas, Georgia, and Florida.

Natural pine.—Forests in which 50% or more of the naturally established stand is loblolly pine, slash pine, shortleaf pine, longleaf pine, or other southern pines singly or in combination. Common associates include oak, hickory, and gum.

Net annual growth.—The net increase in the volume of trees during a specified year. Components include the increment in net volume of trees at the beginning of the specific year surviving to its end, plus the net volume of trees reaching the minimum size class during the year, minus the volume of trees that died during the year, and minus the net volume of trees that became cull trees during the year.

Net volume in board feet.—The gross board-foot volume of the sawlog portion of live sawtimber trees less deductions for rot or other defects affecting use for lumber.

Net volume in cubic feet.—The gross volume in cubic feet less deductions for rot, roughness, and poor form. Volume is computed for the central stem from a 1-foot stump to a minimum 4.0-inch top diameter outside bark, or to the point where the central stem breaks into limbs.

Noncommercial species.—Tree species of typically small size, poor form, or inferior quality, which normally do not develop into trees suitable for industrial wood products.

Nonforest land.—Land that has never supported forests and lands formerly forested where use of timber management is precluded by development for other uses. (Note: Includes area used for crops, improved pasture, residential areas, city parks, improved roads of any width and adjoining clearings, powerline clearings of any width, and 1- to 40-acre areas of water classified by the Bureau of the Census as land. If intermingled in forest areas, unimproved roads and nonforest strips must be more than 120 feet wide, and clearings, etc., more than 1 acre in size, to qualify as nonforest land.)

Nonstocked areas.—Timberland less than 10% stocked with growing stock trees.

Other forest land.—Forest land other than timberland and reserved timberland. It includes unproductive forest land, which is incapable of producing annually 20 cubic feet per acre of industrial wood under natural conditions because of adverse site conditions such as sterile soils, dry climate, poor drainage, high elevation, steepness, or rockiness. It also includes urban forest land, which due to its location is unavailable for sustained timber harvesting.

Other land.—Nonforest land less the area in streams, sloughs, estuaries, and canals between 120 and 660 feet and lakes, reservoirs, and ponds between 1 and 40 acres in area (i.e., nonforest land less non-Census water area).

Other products.—A miscellaneous category of roundwood products that includes such items as cooperage, pilings, poles, posts, shakes, shingles, board mills, charcoal, and export logs.

Other red oaks.—A group of species in the genus Oak that includes scarlet, northern pin, southern red, bear, shingle, laurel, blackjack, water, pin, willow, and black.

Other removals.—Unutilized wood volume from cut or otherwise killed growing stock, from nongrowing stock sources on timberland (e.g., precommercial thinnings), or from timberland clearing. Does not include volume removed from inventory through reclassification of timberland to reserved timberland.

Other sources.—Sources of roundwood products that are nongrowing stock. These include salvable dead trees, rough and rotten trees, trees of noncommercial species, trees less than 5.0 inches dbh, tops, and roundwood harvested from nonforest land (e.g., fence rows).

Other white oaks.—A group of species in the genus Oak that includes overcup, chestnut, and post.

Ownership.—The property owned by one ownership unit, including all parcels of land in the United States.

Ownership unit.—A classification of ownership encompassing all types of legal entities having an ownership interest in land, regardless of the number of people involved. A unit may be an individual; a combination of persons; a legal entity such as a corporation, partnership, club, or trust; or a public agency. An ownership unit has control of a parcel or group of parcels of land.

Pine plantations.—Forests in which 50% or more of the stand is loblolly pine, slash pine, shortleaf pine, longleaf pine or other southern pines, which have been established by planting or direct seeding.

Plant byproducts.—Wood material (such as slabs, edgings, trimmings, miscuts, sawdust shavings, veneer cores and clippings, and pulp screenings) from primary manufacturing plants used for pulp and other products.

Ponderosa pine subregion.—The area in the states of Oregon and Washington that is east of the crest of the Cascade Range.

Primary wood-using mill.—A mill that converts roundwood products into other wood products. Common examples are sawmills that convert sawlogs into lumber and pulpmills that convert pulpwood into woodpulp.

Private Ownerships:

Farmer.—An ownership class of private lands owned by a person who operates a farm, either doing the work or directly supervising the work.

Other.—Land owned by private individuals except farmers.

Productivity class.—A classification of forest land in terms of potential annual cubic-foot volume growth per acre at culmination of mean annual increment in fully stocked natural stands.

Public Ownerships:

Federal.—An ownership class of public lands owned by the U.S. Government.

National forest.—An ownership class of federal lands, designated by Executive Order or statute as national forests or purchase units, and other lands under the administration of the Forest Service including experimental areas and Bankhead-Jones Title III lands.

Bureau of Land Management (BLM).—An ownership class of federal lands administered by the Bureau of Land Management, U.S. Department of the Interior.

County and municipal.—An ownership class of public lands owned by counties or local public agencies, or lands leased by these governmental units for more than 50 years.

Indian.—An ownership class that includes tribal lands held in fee by the federal government, but administered for Indian tribal groups and Indian trust allotments.

Other Federal.—An ownership class of federal lands other than those administered by the Forest Service or the Bureau of Land Management.

Other public.—An ownership class that includes all public lands except national forest.

State.—An ownership classification of public lands owned by states or lands leased by states for more than 50 years.

Pulpwood.—Roundwood, whole-tree chips, or wood residues that are used for the production of woodpulp.

Reserved timberland.—Forest land that would otherwise be classified as timberland except that it is withdrawn from timber utilization by statute or administrative regulation.

Residues.—Bark and woody materials that are generated in primary wood-using mills when roundwood products are converted to other products. Examples are slabs, edgings, trimmings, miscuts, sawdust, shavings, veneer cores and clippings, and pulp screenings. Includes bark residues and wood residues (both coarse and fine materials) but excludes logging residues.

Rotten tree.—A live tree of commercial species that does not contain a sawlog now or prospectively, primarily because of rot (i.e., when rot accounts for more than 50% of the total cull volume).

Rough tree.—(a) A live tree of commercial species that does not contain a sawlog now or prospectively, primarily because of roughness (i.e., when sound cull due to such factors as poor form, splits, or cracks accounts for more than 50% of the total cull volume); or (b) a live tree of noncommercial species.

Roundwood.—Logs, bolts, or other round sections cut from growing stock and nongrowing stock sources such as trees smaller than 5 inches dbh; stumps, tops, and limbs of growing stock trees; rough and rotten trees; dead trees; and trees that grow on land other than timberland.

Roundwood equivalent.—The volume of logs or other round products required to produce given quantities of lumber, plywood, woodpulp, paper, or other similar products.

Roundwood supplies.—The volume of roundwood harvested or available for harvest in the future. Includes roundwood from growing stock and nongrowing stock sources.

Salvable dead tree.—A standing or down dead tree that is considered currently or potentially merchantable by regional standards.

Sawlog.—A log meeting minimum standards of diameter, length, and defect, including logs at least 8 feet long, sound and straight, and with a minimum diameter inside bark of 6 inches for softwoods and 8 inches for hardwoods, or meeting other combinations of size and defect specified by regional standards. A log usually used in the manufacture of lumber.

Sawlog portion.—That part of the bole of a sawtimber tree between a 1-foot stump and the sawlog top.

Sawlog top.—The point on the bole of a sawtimber tree above which a sawlog cannot be produced. The minimum sawlog top is 7.0-inches diameter outside bark (dob) for softwoods and 9.0-inches dob for hardwoods.

Sawtimber.—Stands at least 10% occupied with growing stock trees, with half or more of total stocking in sawtimber or poletimber trees, and with sawtimber stocking at least equal to poletimber stocking.

Sawtimber trees.—Live trees of commercial species containing at least one 12-foot sawlog or two noncontiguous 8-foot logs, and meeting regional specifications for freedom from defect. Softwood trees must be at least 9.0 inches dbh, and hardwood trees must be at least 11.0 inches dbh.

Select red oaks.—A group of species in the genus Oak that includes southern red, northern red, and shumard.

Select white oaks.—A group of species in the genus Oak that includes white, swamp white, bur, swamp chestnut, and chinkapin.

Site productivity.—A measure of the inherent capability of land to grow timber based on fully stocked natural stands.

- **High sites.**—Land capable of growing 85 cubic feet of wood per acre per year in fully stocked natural stands.
- **Medium sites.**—Land capable of growing 50 to 85 cubic feet of wood per acre per year in fully stocked natural stands.
- **Low sites.**—Land capable of growing 20 to 49 cubic feet of wood per acre per year in fully stocked natural stands.

Softwood.—A coniferous tree, usually evergreen, having needles or scalelike leaves.

Sound dead.—The net volume in salvable dead trees.

Stocking.—The degree of occupancy of land by trees, measured by basal area and/or number of trees by size and spacing, compared to a stocking standard; i.e., the basal area and/or number of trees required to fully utilize the growth potential of the land.

Stumpage.—Standing timber (trees) in the forest.

Stumpage price.—The price paid for standing timber (trees) in the forest.

Timber removals.—The net volume of growing stock trees removed from the inventory by harvesting; cultural operations, such as timber stand improvement; land clearing; or changes in land use.

Timber supplies.—The volume of roundwood harvested or available for harvest in the future. Includes roundwood from growing stock and nongrowing stock sources.

Timberland.—Forest land that is producing or is capable of producing crops of industrial wood and not withdrawn from timber utilization by statute or administrative regulation. (Note: Areas qualifying as timberland have the capability of producing in excess of 20 cubic feet per acre per year of industrial wood in natural stands. Currently inaccessible and inoperable areas are included.)

Tops.—The wood of a tree above the merchantable height (or above the point on the stem 4.0-inches dob). It includes the usable material in the uppermost stem and branches.

Unreserved forest land.—Forest land (timberland and woodland) that is not withdrawn from use by statute or administrative regulation.

Veneer log.—A roundwood product from which veneer is sliced or sawn and that usually meets certain standards of minimum diameter and length and maximum defect.

Urban and other areas.—Areas within the legal boundaries of cities and towns; suburban areas developed for residential, industrial, or recreational purposes; school yards; cemeteries; roads, railroads; airports; beaches, power lines, and other rights-of-way; or other nonforest land not included in any other specified land use class.

Veneer logs.—The logs used in the manufacture of veneer.

Weight.—The weight of wood and bark, oven-dry basis (approximately 12% moisture content).

APPENDIX B. CONVERSION FACTORS FOR FORESTRY AND THE TIMBER PRODUCTS INDUSTRY

This appendix presents conversion factors for the standing forest resource, roundwood products, and primary wood products processed within the United States. Forest resources include all standing timber, and the subcategories of growing stock and nongrowing stock timber. Roundwood products are defined as sawlogs, pulpwood, veneer logs and bolts, fuelwood, and other miscellaneous products. The primary wood products included in these conversion factors include lumber, structural panels (softwood plywood and oriented strand board/waferboard), and nonstructural panels (hardwood plywood, hardboard, particleboard and medium density fiberboard, and insulation board).

The units of measure used in forestry and the timber products industry are many and varied. For a given unit of measure, the volume of solid-wood varies with species, form, size, and the quality of the pieces being measured. Conversion factors vary accordingly, and a detailed discussion of all possibilities is beyond the scope of this appendix. Thus, the conversion factors presented here are averages for the products and locations they represent. They are based, in part, on data collected as a part of the periodic surveys of forest resources of each state, conducted by the USDA Forest Service and cooperating public and private organizations. Research conducted throughout the timber products industry also contributes to these conversion factors. Thus, many of these factors represent the mix of species, sizes, and quality in the inventory and in the roundwood product output in 1986, as shown in Forest Statistics of the United States (Waddell et al. 1989).

Conversion factors are presented in both standard United States and cubic units. The following tabulation of metric conversions is provided to assist in converting to the metric system.

Metric Conversion Factors

1 metric ton = 1.102311 short tons

1 cubic meter = 35.3145 cubic feet

Table B-1.—Net volume of timber on timberland in the United States, by species group, class of timber, region and subregion, 1987.

Region and subregion	Softwoods				Hardwoods			
			Nongrowing stock				Nongrowing stock	
	All timber	Growing stock	Live cull	Sound dead	All timber	Growing stock	Live cull	Sound dead
	Percent							
North								
Northeast	100.00	91.29	6.54	2.17	100.00	91.44	7.68	0.89
North Central	100.00	94.18	5.20	0.62	100.00	84.37	15.11	0.52
Total	100.00	92.73	5.87	1.40	100.00	87.91	11.39	0.70
South								
Southeast	100.00	98.65	0.99	0.36	100.00	87.66	12.18	0.16
South Central	100.00	95.85	3.30	0.85	100.00	80.61	19.03	0.36
Total	100.00	97.25	2.15	0.60	100.00	84.13	15.61	0.26
Rockies								
Great Plains	100.00	90.52	3.47	6.01	100.00	67.73	31.26	1.06
Rocky Mountains	100.00	94.33	2.02	3.65	100.00	72.42	12.40	15.17
Total	100.00	92.42	2.75	4.83	100.00	70.08	21.83	8.12
Pacific Coast								
Pacific Southwest	100.00	95.84	2.90	1.25	100.00	88.08	11.18	0.75
Pacific Northwest[1]	100.00	96.67	0.87	2.46	100.00	93.34	6.56	0.09
Alaska	100.00	94.90	3.31	1.79	100.00	92.65	7.16	0.18
Total	100.00	95.81	2.36	1.84	100.00	91.36	8.30	0.34
United States	100.00	94.55	3.28	2.17	100.00	83.37	14.28	2.36

Note: Variation in the ratios of inventory in growing stock and nongrowing stock trees between regions and subregions is due to differences in the amounts of defective or unmerchantable material in the stands.

Data may not add to totals because of rounding.

[1]Data for the Pacific Northwest-West and Pacific Northwest-East subregions are not available.

Source: Waddell et al. 1989.

Table B-2.—Growing stock/sawtimber inventory ratios in the United States, by softwoods and hardwoods, region and subregion, 1987.

Region and subregion	Cubic feet growing stock per board foot sawtimber	Board feet sawtimber per cubic foot growing stock	Percent of growing stock in sawtimber	Cubic feet per 1,000 board feet sawtimber
	Softwoods			
North				
Northeast	0.3901	2.563	64.72	252.5
North Central	0.3538	2.827	54.75	193.7
Total	0.3720	2.695	59.73	223.1
South				
Southeast	0.3004	3.329	69.78	209.6
South Central	0.2511	3.982	76.82	192.9
Total	0.2758	3.656	73.30	201.3
Rockies				
Great Plains	0.2808	3.561	77.00	216.2
Rocky Mountains	0.2543	3.932	78.70	200.2
Total	0.2676	3.746	77.85	208.2
Pacific Coast				
Pacific Southwest	0.1601	6.244	95.02	152.2
Pacific Northwest	0.1725	5.798	88.56	152.7
Pacific Northwest-West	0.1714	5.835	93.06	159.5
Pacific Northwest-East	0.1736	5.762	84.07	145.9
Alaska	0.2201	4.543	92.20	202.9
Total	0.1842	5.529	91.93	169.3
United States	0.2749	3.953	75.91	198.4
	Hardwoods			
North				
Northeast	0.4529	2.208	54.19	245.4
North Central	0.3825	2.614	53.59	205.0
Total	0.4177	2.411	53.89	225.2
South				
Southeast	0.3454	2.896	65.26	225.4
South Central	0.3661	2.731	59.59	218.2
Total	0.3557	2.813	62.43	221.8
Rockies				
Great Plains	0.3000	3.333	65.86	197.6
Rocky Mountains	0.5059	1.977	36.74	185.8
Total	0.4029	2.655	51.30	191.7
Pacific Coast				
Pacific Southwest	0.3231	3.095	71.95	232.5
Pacific Northwest	0.3081	3.247	63.69	196.1
Pacific Northwest-West	0.3032	3.299	65.42	198.3
Pacific Northwest-East	0.3130	3.195	61.95	193.9
Alaska	0.5377	1.860	43.74	235.2
Total	0.3896	2.734	59.79	221.3
United States	0.3915	2.653	56.85	215.0

Note: The relationships between growing stock and sawtimber are indicative of tree size and quality. Cubic feet of growing stock per board foot of sawtimber decreases as the proportion of growing stock in sawtimber-size trees increases. This proportion is smaller for hardwoods than for softwoods, both because of tree size and because the lower limit for hardwood sawtimber is 11 inches in diameter at breast height compared to 9 inches for softwoods. Sawtimber is measured in thousand board feet, International 1/4-inch log rule.

Source: Waddell et al. 1989.

Table B-3.—Source of roundwood timber products in the United States, by softwoods and hardwoods, product, region and subregion, 1986.

Region, subregion, and product	Softwoods			Hardwoods		
	All sources	Growing stock	Other sources	All sources	Growing stock	Other sources
	Percent					
North						
Northeast	100.0	70.7	29.3	100.0	43.2	56.8
Sawlogs	100.0	80.1	19.9	100.0	88.5	11.5
Pulpwood	100.0	78.9	21.1	100.0	82.1	17.9
Veneer logs	100.0	82.6	17.4	100.0	92.1	7.9
Fuelwood	100.0	13.3	86.7	100.0	13.3	86.7
Other products	100.0	66.4	33.6	100.0	87.8	12.2
North Central	100.0	78.5	21.5	100.0	53.7	46.3
Sawlogs	100.0	97.6	2.4	100.0	89.8	10.2
Pulpwood	100.0	89.1	10.9	100.0	83.1	16.9
Veneer logs	100.0	100.0	0.0	100.0	93.9	6.1
Fuelwood	100.0	21.3	78.7	100.0	13.5	86.5
Other products	100.0	83.1	16.9	100.0	85.3	14.7
Total	100.0	74.6	25.4	100.0	48.4	51.6
Sawlogs	100.0	88.8	11.2	100.0	89.2	10.8
Pulpwood	100.0	84.0	16.0	100.0	82.6	17.4
Veneer logs	100.0	91.3	8.7	100.0	93.0	7.0
Fuelwood	100.0	17.3	82.7	100.0	13.4	86.6
Other products	100.0	74.7	25.3	100.0	86.6	13.4
South						
Southeast	100.0	95.6	4.4	100.0	77.0	23.0
Sawlogs	100.0	98.9	1.1	100.0	93.8	6.2
Pulpwood	100.0	93.0	7.0	100.0	81.1	18.9
Veneer logs	100.0	99.4	0.6	100.0	97.0	3.0
Fuelwood	100.0	63.1	36.9	100.0	52.8	47.2
Other products	100.0	97.5	2.5	100.0	88.4	11.6
South Central	100.0	96.4	3.6	100.0	78.9	21.1
Sawlogs	100.0	98.5	1.5	100.0	96.6	3.4
Pulpwood	100.0	93.9	6.1	100.0	87.9	12.1
Veneer logs	100.0	98.0	2.0	100.0	97.9	2.1
Fuelwood	100.0	43.0	57.0	100.0	30.6	69.4
Other products	100.0	96.4	3.6	100.0	90.7	9.3
Total	100.0	96.0	4.0	100.0	78.0	22.0
Sawlogs	100.0	98.7	1.3	100.0	95.2	4.8
Pulpwood	100.0	93.4	6.6	100.0	84.5	15.5
Veneer logs	100.0	98.7	1.3	100.0	97.5	2.5
Fuelwood	100.0	53.0	47.0	100.0	41.7	58.3
Other products	100.0	97.0	3.0	100.0	89.6	10.4
Rockies						
Great Plains	100.0	90.3	9.7	100.0	17.5	82.5
Sawlogs	100.0	99.0	1.0	100.0	89.8	10.2
Pulpwood	100.0	100.0	0.0	NA	NA	NA
Veneer logs	NA	NA	NA	100.0	95.3	4.7
Fuelwood	100.0	13.7	86.3	100.0	6.0	94.0
Other products	100.0	95.4	4.6	100.0	31.7	68.3
Rocky Mountains	100.0	88.1	11.9	100.0	27.0	73.0
Sawlogs	100.0	98.5	1.5	100.0	97.1	2.9
Pulpwood	100.0	73.3	26.7	100.0	100.0	0.0
Veneer logs	100.0	100.0	0.0	NA	NA	NA
Fuelwood	100.0	6.6	93.4	100.0	7.8	92.2
Other products	100.0	93.8	6.2	100.0	99.9	0.1
Total	100.0	89.2	10.8	100.0	22.2	77.8
Sawlogs	100.0	98.7	1.3	100.0	93.4	6.6
Pulpwood	100.0	86.6	13.4	100.0	100.0	0.0
Veneer logs	100.0	100.0	0.0	100.0	95.3	4.7
Fuelwood	100.0	10.2	89.8	100.0	6.9	93.1
Other products	100.0	94.6	5.4	100.0	65.8	34.2

Table B-3.—Continued

Region, subregion, and product	Softwoods			Hardwoods		
	All sources	Growing stock	Other sources	All sources	Growing stock	Other sources
Pacific Coast						
Pacific Southwest	100.0	88.1	11.9	100.0	18.0	82.0
Sawlogs	100.0	93.6	6.4	100.0	93.6	6.4
Pulpwood	100.0	23.7	76.3	100.0	23.7	76.3
Veneer logs	100.0	98.9	1.1	NA	NA	NA
Fuelwood	100.0	47.4	52.6	100.0	16.4	83.6
Other products	100.0	100.0	0.0	NA	NA	NA
Pacific Northwest	100.0	84.9	15.1	100.0	76.0	24.0
Sawlogs	100.0	96.0	4.0	100.0	96.3	3.7
Pulpwood	100.0	6.8	93.2	100.0	15.3	84.7
Veneer logs	100.0	90.6	9.4	100.0	82.2	17.8
Fuelwood	100.0	45.1	54.9	100.0	74.9	25.1
Other products	100.0	54.1	45.9	NA	NA	NA
Pacific Northwest-West	100.0	78.3	21.7	100.0	70.6	29.4
Sawlogs	100.0	93.3	6.7	100.0	92.6	7.4
Pulpwood	100.0	13.6	86.4	100.0	15.3	84.7
Veneer logs	100.0	82.8	17.2	100.0	82.2	17.8
Fuelwood	100.0	63.8	36.2	100.0	68.6	31.4
Other products	100.0	98.8	1.2	NA	NA	NA
Pacific Northwest-East	100.0	91.6	8.4	NA	NA	NA
Sawlogs	100.0	98.6	1.4	NA	NA	NA
Pulpwood	100.0	0.0	100.0	NA	NA	NA
Veneer logs	100.0	98.4	1.6	NA	NA	NA
Fuelwood	100.0	26.5	73.5	NA	NA	NA
Other products	100.0	9.5	90.5	NA	NA	NA
Alaska	100.0	94.0	6.0	100.0	81.5	18.5
Sawlogs	100.0	96.9	3.1	100.0	100.0	0.0
Pulpwood	100.0	86.7	13.3	NA	NA	NA
Veneer logs	NA	NA	NA	NA	NA	NA
Fuelwood	100.0	83.0	17.0	100.0	81.2	18.8
Other products	100.0	97.8	2.2	100.0	100.0	0.0
Total	100.0	89.0	11.0	100.0	58.5	41.5
Sawlogs	100.0	95.5	4.5	100.0	96.6	3.4
Pulpwood	100.0	39.1	60.9	100.0	19.5	80.5
Veneer logs	100.0	94.8	5.2	100.0	82.2	17.8
Fuelwood	100.0	58.5	41.5	100.0	57.5	42.5
Other products	100.0	84.0	16.0	NA	NA	NA
United States	100.0	87.2	12.8	100.0	53.0	47.0
Sawlogs	100.0	95.4	4.6	100.0	94.5	5.5
Pulpwood	100.0	75.8	24.2	100.0	71.7	28.3
Veneer logs	100.0	96.2	3.8	100.0	90.9	9.1
Fuelwood	100.0	34.8	65.2	100.0	30.1	69.9
Other products	100.0	87.6	12.4	100.0	92.0	8.0

NA = Not available.
Data may not add to totals because of rounding.
Source: Waddell et al. 1989.

Table B-4.—Removals from growing stock and other sources in the United States, by softwoods and hardwoods, type of removal, region and subregion, 1986.

Region and subregion	Growing stock: Total removals	Growing stock: Roundwood products	Growing stock: Logging residues	Growing stock: Other removals	Other sources: Total removals	Other sources: Roundwood products	Other sources: Logging residues	Other sources: Other removals
Softwoods								
	Percent							
North								
Northeast	100.0	92.1	4.7	3.2	100.0	50.9	45.5	3.6
North Central	100.0	85.4	3.1	11.5	100.0	69.7	14.9	15.4
Total	100.0	88.7	3.9	7.4	100.0	60.3	30.2	9.5
South								
Southeast	100.0	85.2	6.8	8.1	100.0	55.3	30.4	14.3
South Central	100.0	92.1	5.9	2.0	100.0	23.6	70.1	6.3
Total	100.0	88.6	6.3	5.0	100.0	39.5	50.3	10.3
Rockies								
Great Plains	100.0	92.5	7.0	0.5	100.0	97.2	0.5	2.4
Rocky Mountains	100.0	89.0	11.0	0.0	100.0	100.0	0.0	0.0
Total	100.0	90.8	9.0	0.3	100.0	98.6	0.2	1.2
Pacific Coast								
Pacific Southwest	100.0	90.7	9.3	0.0	100.0	35.2	64.3	0.4
Pacific Northwest	100.0	85.3	14.7	0.0	100.0	48.6	49.5	1.9
Pacific Northwest-West	100.0	88.2	11.8	0.0	100.0	55.6	43.4	1.0
Pacific Northwest-East	100.0	82.4	17.5	0.0	100.0	41.6	55.6	2.8
Alaska	100.0	78.8	21.1	0.1	100.0	29.8	70.2	0.0
Total	100.0	84.9	15.0	0.0	100.0	37.9	61.3	0.8
United States	100.0	88.3	8.6	3.2	100.0	57.3	37.6	5.1
Hardwoods								
North								
Northeast	100.0	83.6	9.8	6.6	100.0	81.2	14.3	4.5
North Central	100.0	74.5	7.8	17.7	100.0	79.4	7.3	13.4
Total	100.0	79.0	8.8	12.1	100.0	80.3	10.8	9.0
South								
Southeast	100.0	69.4	14.5	16.1	100.0	43.5	31.8	24.7
South Central	100.0	76.5	12.7	10.7	100.0	27.5	51.5	21.0
Total	100.0	73.0	13.6	13.4	100.0	35.5	41.7	22.9
Rockies								
Great Plains	100.0	70.1	8.0	21.9	100.0	94.8	1.3	3.8
Rocky Mountains	100.0	70.1	29.9	NA	100.0	100.0	NA	NA
Total	100.0	70.1	19.0	10.9	100.0	97.4	0.7	1.9
Pacific Coast								
Pacific Southwest	100.0	100.0	NA	NA	100.0	100.0	NA	NA
Pacific Northwest	100.0	90.9	8.3	0.8	100.0	70.5	24.8	4.8
Pacific Northwest-West	100.0	90.9	8.3	0.8	100.0	70.5	24.8	4.8
Pacific Northwest-East	NA	NA	NA	NA	NA	NA	NA	NA
Alaska	100.0	96.2	2.2	1.6	100.0	93.3	6.7	0.0
Total	100.0	95.7	3.5	0.8	100.0	87.9	10.5	1.6
United States	100.0	79.5	11.2	9.3	100.0	74.0	17.3	8.6

Note: Other removals include timber removed from inventories by land clearing, cultural operations, and changes in land use.
Data may not add to totals because of rounding.
Source: Waddell et al. 1989.

Table B-5.—Growing stock removals per roundwood product output in the United States, by softwoods and hardwoods, product, region and subregion, 1986.

Region and subregion	All products	Sawlogs	Pulpwood	Veneer logs	Fuelwood	Other products
	Softwoods					
	Cubic feet per cubic foot					
North						
Northeast	0.768	0.870	0.857	0.898	0.145	0.721
North Central	0.884	1.100	1.004	1.127	0.240	0.936
Total	0.841	1.001	0.947	1.029	0.195	0.842
South						
Southeast	1.123	1.161	1.092	1.167	0.740	1.145
South Central	1.047	1.070	1.019	1.063	0.467	1.046
Total	1.083	1.114	1.054	1.113	0.598	1.094
Rockies						
Great Plains	0.977	1.071	1.082	0.000	0.148	1.031
Rocky Mountains	0.989	1.106	0.823	1.123	0.074	1.054
Total	0.983	1.088	0.955	1.102	0.112	1.042
Pacific Coast						
Pacific Southwest	0.972	1.032	0.262	1.090	0.523	1.103
Pacific Northwest	0.996	1.125	0.080	1.062	0.529	0.634
Pacific Northwest-West	0.888	1.058	0.154	0.939	0.723	1.120
Pacific Northwest-East	1.111	1.196	0.000	1.194	0.322	0.115
Alaska	1.193	1.229	1.100	0.000	1.053	1.241
Total	1.048	1.124	0.460	1.116	0.689	0.989
United States	0.988	1.081	0.859	1.090	0.394	0.992
	Hardwoods					
North						
Northeast	0.517	1.059	0.982	1.101	0.159	1.051
North Central	0.679	1.136	1.052	1.188	0.171	1.080
Total	0.613	1.128	1.045	1.177	0.170	1.096
South						
Southeast	1.109	1.350	1.168	1.397	0.761	1.273
South Central	1.031	1.261	1.148	1.280	0.399	1.185
Total	1.068	1.304	1.157	1.335	0.571	1.227
Rockies						
Great Plains	0.250	1.281	0.000	1.360	0.086	0.451
Rocky Mountains	0.385	1.385	1.427	0.000	0.111	1.426
Total	0.317	1.333	1.426	1.360	0.098	0.939
Pacific Coast						
Pacific Southwest	0.180	0.936	0.237	0.000	0.164	0.000
Pacific Northwest	0.836	1.059	0.168	0.904	0.824	0.000
Pacific Northwest-West	0.777	1.018	0.168	0.904	0.755	0.000
Pacific Northwest-East	NA	NA	NA	NA	NA	NA
Alaska	0.847	1.039	0.000	0.000	0.844	1.039
Total	0.611	1.009	0.204	0.859	0.601	0.000
United States	0.667	1.189	0.902	1.144	0.379	1.158

Note: Because of volume losses in the form of logging residues and other removals, the volume of softwood timber taken from growing stock inventories can exceed product output. Lower ratios for hardwoods indicate a greater reliance on other sources of roundwood. The low factors shown for fuelwood reflect the high percentage of this product that is obtained from nongrowing stock sources.

Source: Derived from tables B-3 and B-4.

Table B-6.—Timber product yields and raw material requirements in the United States, by product, 1986.

Product	Standard unit	Solid volume per standard unit of product	Raw material required per standard unit of product	Ratio of raw material volume to volume of product	Solid volume of product as a percent of raw material volume
		Cubic feet per standard unit	*Cubic feet, roundwood equivalent, per standard unit*	*Cubic feet, roundwood equivalent, per cubic feet of product*	*Percent*
Lumber					
Softwood	Thousand board feet	60.00	155.1	2.76	36.2
Hardwood	Thousand board feet	83.33	189.9	2.00	49.9
Structural panels					
Softwood plywood	Thousand square feet, 3/8-inch basis	31.25	71.1	2.25	44.5
Waferboard and oriented strand board	Thousand square feet, 3/8-inch basis	31.25	62.3	1.99	50.2
Nonstructural panels					
Hardboard	Thousand square feet, 3/8-inch basis	31.25	45.9	1.47	NA
Insulation board	Thousand square feet, 3/8-inch basis	31.25	14.3	0.46	NA
Particleboard	Thousand square feet, 3/8-inch basis	31.25	45.6	1.46	NA
Hardwood plywood[1]	Thousand square feet, 3/8-inch basis	31.25	64.2	2.06	48.6

NA = Not applicable.

Note: The low product yields indicated by the ratios of raw material volume to product volume are not an accurate measure of total wood utilization. Nearly all of the byproducts of lumber and panel production (slabs, edgings, sawdust, veneer cores, and clippings) are used for pulpwood, particleboard, or hog fuel. Secondary processing of these byproducts are not accounted for in these conversion factors.

The difference between the cubic volumes of softwood and hardwood lumber is due to differences in the characteristics and dimensions of the products as they are commonly sold by the producing mills. Based on nominal dimensions, 1,000 board feet of lumber of any species would contain 83.33 cubic feet. The actual volume of wood per thousand board feet of lumber is affected by many factors. The sawing accuracy and quality control of the sawmill, target dimensions (width and thickness) which differ for softwoods and hardwoods and also vary by region, and the condition of the lumber when measured (rough-green, rough-dry, or surfaced-dry) all affect cubic volume and yield. Volumetric shrinkage is less for softwoods than for hardwoods, and softwoods are more often sawn to closer tolerances than hardwoods. Hardwoods are commonly sawn oversize to allow for greater shrinkage and sawing variation. Softwood lumber is most commonly sold by producing mills as surfaced-dry, while hardwood lumber is commonly sold as rough-dry.

Conversion factors for particleboard, hardboard, and insulation board indicate a loss of raw material in the production of particleboard and hardboard, and a gain in the production of insulation board. This is due to the relative densities of the raw materials and the finished products. In particleboard and hardboard production, raw materials are compressed so as to increase the density and reduce the volume of the product relative to its raw material. Insulation board, a low-density product containing considerable air space, requires 0.46 cubic feet of raw material which is expanded to 1 cubic foot of final product.

[1]*The ratio for raw material volume to product volume for hardwood plywood assumes that hardwood plywood is composed entirely of hardwood materials. Bureau of Census data for 1986 indicates that about 38% of the logs, bolts, flitches, and purchased veneer consumed in manufacture of hardwood plywood is softwood material used for backs and inner plies. At a mix of 62.4% hardwood and 37.6% softwood, 66.5 cubic feet of raw material would be required per thousand square feet, 3/8-inch basis, of hardwood plywood—40.1 cubic feet of hardwood and 26.4 cubic feet of softwood.*

Sources: Derived from tables B-10, B-11, and B-12; and from Maloney 1981; USDA FS 1982; and USDC BC 1987b, 1987d, 1987g.

Table B-7.—Weights of timber products in the United States, 1986.

Product	Standard unit	Weight of wood per standard unit
		Short tons
Roundwood products[1]		
Softwood[2]	Thousand cubic feet	15.500
Hardwood[3]	Thousand cubic feet	20.000
Softwood[2]	Cord (80 cubic feet)	1.400
Hardwood[3]	Cord (80 cubic feet)	1.600
Lumber		
Softwood	Thousand board feet	0.974
Hardwood	Thousand board feet	1.680
Structural panels		
Softwood plywood	Thousand square feet, 3/8-inch basis	0.544
Waferboard and OSB	Thousand square feet, 3/8-inch basis	0.866
Nonstructural panels		
Hardboard	Thousand square feet, 3/8-inch basis	1.140
Insulation board	Thousand square feet, 3/8-inch basis	0.275
Particleboard	Thousand square feet, 3/8-inch basis	0.289
Hardwood plywood	Thousand square feet, 3/8-inch basis	0.657

Note: Lumber weights are weighted averages for the species and volumes of production as reported by the Bureau of the Census for 1986. Average weights per thousand board feet, at 15% moisture content (USDA FS 1987) were used to convert volumes, by species, to tons. The weight of dressed lumber was used for softwoods because the product is ordinarily sold as surfaced-dry, while rough-dry hardwood lumber weights were used because this product is ordinarily marketed in that form.

Plywood weights are averages for the species and volumes of production for 1986. Average weights per cubic foot (15% moisture content) were used to convert volume, by species, to tons at 31.25 cubic feet per thousand square feet, 3/8-inch basis. The weight of hardwood plywood was adjusted for a raw material mix of 62% hardwood and 38% softwood (table B-6).

Particleboard weight is based on a bone-dry weight of 46 pounds per cubic foot of product, and is adjusted to air-dry moisture content and to delete the weight of resins, waxes and additives (8.5% of bone-dry weight). Hardboard and insulating board weights are those reported by the Bureau of the Census in 1986, with the weights of resins, waxes and other additives deleted.

[1]*Logs, bolts, pulpwood, fuelwood, and miscellaneous industrial roundwood.*

[2]*At 35 pounds per cubic foot, air dry.*

[3]*At 40 pounds per cubic foot, air dry.*

Sources: USDA FS 1955, 1987b; USDC BC 1987b, 1987d, 1987e, 1987g.

Table B-8.—Woodpulp conversion factors in the United States, by species, pulpwood consumption, and pulping process, 1986.

Pulping process	Species composition of pulpwood		Pulpwood consumption					
	Softwood	Hardwood	per short ton of pulp produced			per metric ton of pulp produced		
	Percent	*Percent*	*Cords*	*Cubic feet*	*Cubic meters*	*Cords*	*Cubic feet*	*Cubic meters*
Chemical	72.0	28.0	1.615	127.62	3.614	1.781	140.68	3.984
Sulfite	53.9	46.1	1.950	154.07	4.363	2.150	169.83	4.809
Bleached	53.9	46.1	1.950	154.07	4.363	2.150	169.83	4.809
Unbleached	53.9	46.1	1.950	154.07	4.363	2.150	169.83	4.809
Sulfate	72.8	27.2	1.585	125.20	3.545	1.747	138.01	3.908
Bleached and semibleached	58.6	41.4	1.529	120.80	3.421	1.686	133.16	3.771
Unbleached	87.5	12.5	1.480	116.95	3.312	1.632	128.92	3.650
Dissolving	71.6	28.4	2.294	181.26	5.133	2.529	199.80	5.658
Groundwood	90.8	9.2	0.986	77.92	2.206	1.087	85.89	2.432
Semichemical	4.7	95.3	0.968	76.50	2.166	1.067	84.33	2.388
Defibrated or exploded	52.3	47.7	1.008	79.66	2.256	1.111	87.81	2.486
All processes	69.5	30.5	1.486	117.40	3.324	1.638	129.41	3.664

Source: USDC BC 1987e.

Table B-9.—Cubic volume of solid-wood per standard unit of roundwood output in the United States, by softwoods and hardwoods, product, region and subregion, 1986.

Region and subregion	Softwoods: Sawlogs	Softwoods: Veneer logs and bolts	Softwoods: Pulpwood	Softwoods: Fuelwood	Hardwoods: Sawlogs	Hardwoods: Pulpwood	Hardwoods: Fuelwood
	Cubic feet per						
	Thousand board feet, International 1/4-inch log scale	*Thousand board feet, International 1/4-inch log scale*	*Standard cord*	*Standard cord*	*Thousand board feet, International 1/4-inch log scale*	*Standard cord*	*Standard cord*
North							
Northeast	160.1	207.6	85.0	80.0	161.5	85.0	80.0
North Central	178.5	207.6	79.0	69.8	171.9	79.5	69.9
Average	169.3	207.6	82.0	74.9	166.7	81.7	74.9
South							
Southeast	186.2	173.6	74.6	74.5	179.2	75.2	74.5
South Central	164.5	196.8	81.0	75.0	184.4	80.1	75.0
Average	175.4	185.2	77.5	74.6	181.8	78.0	74.6
Rocky Mountains							
Great Plains	141.3	180.2	NA	72.5	196.3	NA	70.0
Rockies	141.3	180.2	79.7	78.7	196.3	75.0	78.8
Average	141.3	180.2	79.7	78.5	196.3	75.0	72.4
Pacific Coast[1]							
Pacific Southwest	164.1	164.2	86.0	80.0	221.0	79.3	80.0
Pacific Northwest	165.8	154.1	86.0	80.0	221.0	78.0	80.0
Pacific Northwest-West	166.8	166.6	86.0	80.0	221.0	78.0	80.0
Pacific Northwest-East	164.8	141.6	NA	80.0	221.0	NA	NA
Alaska	161.8	166.6	86.0	80.0	221.0	NA	80.0
Average	163.9	161.6	86.0	80.0	221.0	78.7	80.0
United States	162.5	183.7	81.3	77.0	191.5	78.4	74.5

Note: Cubic volume of solid-wood per standard unit of roundwood output for hardwood plywood, cooperage logs and bolts, pilings, posts, and poles was not available for 1986. Conversions for 1976 can be referenced in USDA FS (1982).

[1]*The export log recovery factor for the Pacific Coast regions is 0.1818 cubic feet per board foot, Scribner log scale.*

Sources: Adams and Haynes 1980, Waddell et al. 1989, USDA FS 1982.

Table B-10.—Recovery factors and overruns for softwood lumber production in the United States, as used in the RPA projections, by region and subregion, 1986.

Region and subregion	Recovery factors		Overruns	
	Cubic feet per thousand board feet, local log scale[1]	*Cubic feet per thousand board feet, lumber tally*	*Board feet, lumber tally, per thousand board feet, International 1/4-inch log scale*	*Board feet, lumber tally, per thousand board feet, local log scale*[1]
North				
Northeast	176.1	174.6	1,376	1,361
North Central	176.1	174.6	1,376	1,361
Average	176.1	174.6	1,376	1,361
South				
Southeast	217.1	166.4	1,796	1,361
South Central	217.1	166.4	1,796	1,361
Average	217.1	166.4	1,796	1,361
Rockies				
Great Plains	158.5	145.8	1,578	1,407
Rocky Mountains	158.5	145.8	1,578	1,407
Average	158.5	145.8	1,578	1,407
Pacific Coast				
Pacific Southwest	160.0	136.2	1,434	1,292
Pacific Northwest	164.7	140.2	1,608	1,449
Pacific Northwest-West	146.3	124.6	1,782	1,605
Pacific Northwest-East	183.0	155.8	1,434	1,292
Alaska	146.3	124.6	1,782	1,605
Average	157.0	133.7	1,608	1,449
United States	183.9	155.1	1,612	1,394

[1]*Local log scale for softwoods is Northeast—International 1/4-inch, North Central—Scribner and Doyle, Southeast—Scribner, South Central—Doyle, Rocky Mountain and Pacific Coast regions—Scribner. For hardwoods, it is Lake States—Scribner, other North—Doyle, South—Doyle, Rocky Mountain and Pacific Coast regions—Scribner.*

Sources: Adams and Haynes 1980, Haynes and Adams 1985.

Table B-11.—Recovery factors and overruns for hardwood lumber production in the United States, as used in the RPA projections, by region and subregion, 1986.

Region and subregion	Recovery factors		Overruns	
	Cubic feet per thousand board feet, local log scale[1]	*Cubic feet per thousand board feet, lumber tally*	*Board feet, lumber tally, per thousand board feet, International 1/4-inch log scale*	*Board feet, lumber tally, per thousand board feet, local log scale*[1]
North				
Northeast	205.9	162.5	1,670	1,310
North Central	205.9	162.5	1,670	1,310
Average	205.9	162.5	1,670	1,310
South				
Southeast	244.1	179.2	1,734	1,310
South Central	244.1	175.8	1,734	1,310
Average	244.1	177.5	1,734	1,310
Rockies				
Great Plains	230.2	212.4	1,463	1,248
Rocky Mountains	230.2	212.4	1,463	1,248
Average	230.2	212.4	1,463	1,248
Pacific Coast				
Pacific Southwest	238.3	212.4	1,345	1,248
Pacific Northwest	238.3	212.4	1,345	1,248
Pacific Northwest-West	238.3	212.4	1,345	1,248
Pacific Northwest-East	238.3	212.4	1,345	1,248
Alaska	238.3	212.4	1,345	1,248
Average	238.3	212.4	1,345	1,248
United States	253.5	191.2	1,657	1,279

[1]*Local log scale for softwoods is Northeast—International 1/4-inch, North Central—Scribner and Doyle, Southeast—Scribner, South Central—Doyle, Rocky Mountain and Pacific Coast regions—Scribner. For hardwoods, it is Lake States—Scribner, other North—Doyle, South—Doyle, Rocky Mountain and Pacific Coast regions—Scribner.*

Sources: Adams et al. 1988, Adams and Haynes 1980, Haynes and Adams 1985.

Table B-12—Recovery factors and overruns for softwood plywood production in the United States, as used in the RPA projections, by region and subregion, 1986.

Region and subregion	**Recovery factors**		**Overruns**	
	Cubic feet per thousand board feet, local log scale[1]	*Cubic feet per thousand square feet, plywood, 3/8-inch basis*	*Square feet, plywood, 3/8-inch basis, per thousand board feet, International 1/4-inch log scale*	*Square feet, plywood, 3/8-inch basis, per thousand board feet, local log scale*[1]
North				
Northeast	207.6	74.3	2,446	2,446
North Central	207.6	74.3	2,446	2,446
Average	207.6	74.3	2,446	2,446
South				
Southeast	262.9	71.6	3,268	2,446
South Central	262.9	71.6	3,268	2,446
Average	262.9	71.6	3,268	2,446
Rockies				
Great Plains	201.6	70.0	2,837	2,537
Rocky Mountains	201.6	70.0	2,837	2,537
Average	201.6	70.0	2,837	2,537
Pacific Coast				
Pacific Southwest	190.9	69.6	3,810	3,278
Pacific Northwest	179.1	65.3	3,591	3,089
Pacific Northwest-West	193.6	70.6	3,448	2,966
Pacific Northwest-East	164.6	60.0	3,734	3,213
Alaska	193.6	70.6	3,448	2,966
Average	187.9	68.5	3,616	3,111
United States	216.7	71.1	3,201	2,635

[1]*Local log scale for softwoods is Northeast—International 1/4-inch, North Central—Scribner and Doyle, Southeast—Scribner, South Central—Doyle, Rocky Mountain and Pacific Coast regions—Scribner. For hardwoods, it is Lake States—Scribner, other North—Doyle, South—Doyle, Rocky Mountain and Pacific Coast regions—Scribner.*

Sources: Adams and Haynes 1980, Haynes and Adams 1985.

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