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Economic potential of North American timber resources

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Abstract

The economic potential of North American timber resources can be achieved, in part, through minimizing the timber cost component of wood products in end-use applications. Two examples of how research and investment can decrease timber costs are presented. The first example describes the timber market impact of current wood utilization research in the United States. The second discusses the timber market impact of increased forest management in the United States. A review of the timber trends and prospects for North America is also presented. Conclusions are that both research and investment provide opportunities for achieving the economic potential of North American timber resources.

The economic potential of the timber resource can be defined as maximizing the use of timber and can be achieved, in part, through minimizing the timber cost component of wood products in end-use applications.* Decreasing timber costs allows wood products to maintain or expand current markets as well as expand into new markets.

This paper has two objectives. The first objective is to examine how public and private research and investment can be used to help achieve the economic potential of North American timber resources. Two examples of how research and investment can decrease timber costs are presented. The first example describes the timber market impact of current wood utilization research in the United States. This example is taken from work conducted at the USDA Forest Service, Forest Products Laboratory, North Central Forest Experiment Station, Pacific Northwest Forest and Range Experiment Station, and the University of Washington (6). The second example discusses the timber market impact of increased forest management in the United States and is taken from the 1989 Resources Planning Act (RPA) Timber Assessment (8). The second objective is to review the timber trends and prospects for North America, thus providing the necessary background for the discussion of research and investment opportunities that follow in this paper.

Trends and prospects for raw material supply

This section is based on a joint study by Dave Darr, USDA Forest Service, and Dave Boulter, Forestry Canada, the national forestry agencies in these two countries.[2] Information from the 1989 RPA Timber Assessment (8) was excerpted and used throughout the U.S. section of the analysis. The 1989 RPA Timber Assessment was prepared at the USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Forest Products Laboratory, other Forest Service locations, and the University of Washington. Canadian domestic consumption and offshore trade flows are projected on the basis of multiple regression analysis. Projections of timber supply in Canada largely rely on provincial analyses as reflected in allowable cut calculations.

U.S. harvest trends

For the contiguous United States, the softwood harvest increased by 58 percent between 1962 and 1986. Much of this increase occurred after 1970, reflecting the large demand for wood use in housing and other forest products in the United States since that time. The softwood harvest increased in all U.S. regions during this period, but the majority of the increase occurred in the South where the softwood harvest more than doubled (Fig. 1). The softwood harvest in the North and Rocky Mountains increased slightly more than 30 percent. In contrast, increases in the Pacific Coast area were slightly greater than 15 percent during this period.

[1] **Other means include decreasing cost components, such as capital, labor, and energy, and reducing the impact of environmental regulations on timber processing.**

[2] **Most material in this section is taken directly from references (3) and (7).**

The United States has always relied on private lands for much of its timber supply. The private land ownership category includes forest industry and other private ownerships. Forest industry ownerships are generally managed with timber supply as the main objective. Other private ownerships may be managed with a variety of objectives in mind, in addition to or instead of timber supply. Since 1962, the softwood harvest from all ownership classes has increased. In 1986, about 74 percent of the softwood harvest came from forest industry and other private lands. However, the share from forest industry lands has increased, while the share from national forestlands has decreased (Fig. 2).

Trends in the hardwood resource are dominated by private lands in the East (Fig. 3). Between 1962 and 1986, hardwood harvests increased by nearly 72 percent. This increase was proportionately spread among all ownership groups (Fig. 4). Factors contributing to this increase included an increased demand for fuelwood, increased pulping of hardwoods, and development of a hardwood structural panel industry in the North.

Despite the harvest increases, both softwood and hardwood inventories have, for the most part, increased during the period. One exception is softwood inventories on the Pacific Coast where a draw down of old growth timber during the period resulted in a growing stock reduction. This liquidation of old growth timber resulted in a substantial increase in net annual growth in this area. As a result, net annual growth has increased more dramatically than has the harvest rate during the period.

Major factors affecting U.S. supplies

The current growth removal balances for timber show that the hardwood forests and eastern softwood forests can support additional harvest. However, these balances are only one indicator of the future harvest potential. The actual harvest during the next 20 years will depend upon ownership objectives, past invest-

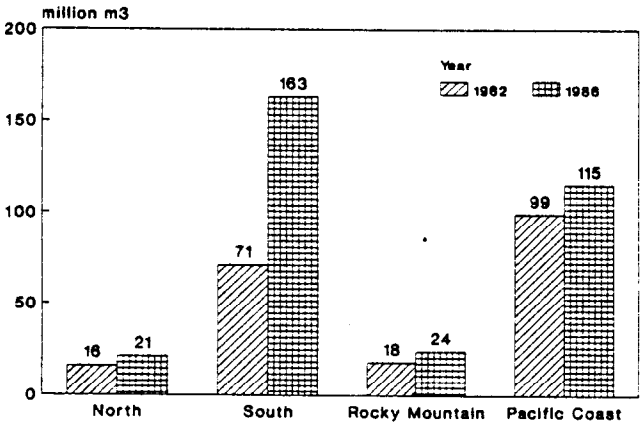

Figure 1. -U.S. harvest trends, softwood, 1962 and 1986 (7).

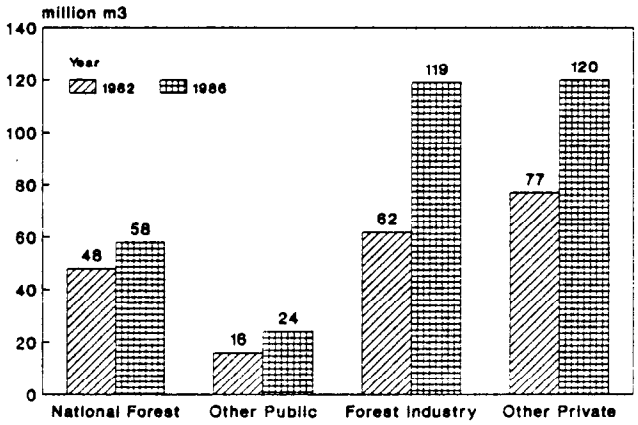

Figure 2. - U.S. harvest trends, softwood, 1962 and 1986 (7).

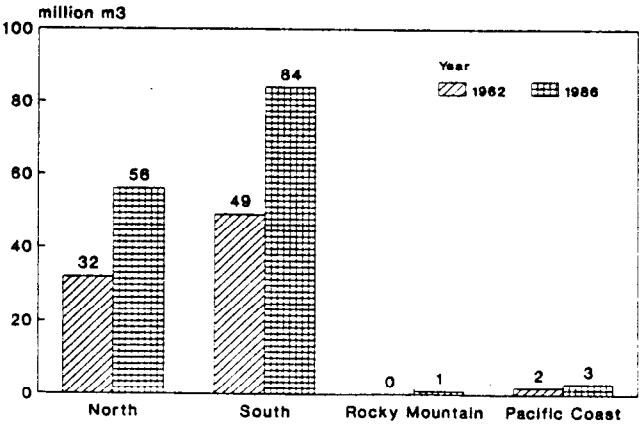

Figure 3. - U.S. harvest trends, hardwood, 1962 and 1986 (7).

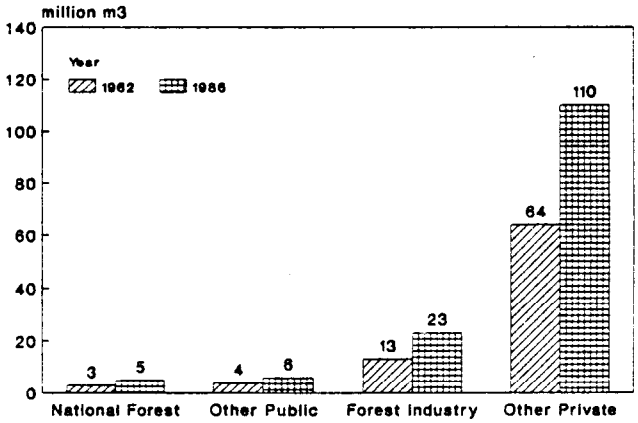

Figure 4. - U.S. harvest trends, hardwood, 1962 and 1986 (7).

ments in forest management, stumpage prices, and institutional constraints.

For private lands, market forces will be a predominant factor. Stumpage prices in the United States have shown wide fluctuations in the past several decades but have generally followed an upward trend. Demand rather than supply shifts were the predominant factor in these movements. Demand increases, which cause further upward movement in stumpage prices, will influence ownership behavior and facilitate further increases in timber supply where inventories are sufficient.

Timber sale offerings on public lands are generally determined by institutional constraints rather than by the market. As a general rule, these institutional constraints are aimed at a sustained volume of timber output. On this basis, harvests from national forestlands may gradually increase over time. However, there is a degree of uncertainty in this forecast. In both the West and South, these lands provide habitat for a number of animal species considered threatened or endangered.

Timber management activities must be altered to account for these species' habitats. The number of species listed as threatened or endangered may increase in the future and have the effect of reducing timber sales.

Other technical factors will also influence the timber supply. For inventory purposes, logging residues are counted as part of the growing stock inventory removed in harvest operations, although by definition, they are not removed from the site. Over time, logging residues as a percentage of removals have decreased as logging and processing technologies have improved and the value of wood has increased. Although the rate of change may decrease in the future, there is still room for marginal improvement.

Also, some timber supply comes from nongrowing stock sources such as tops and limbs, fence rows, and forested land other than timberland. In recent years, timber output from nongrowing stock sources has increased, mainly because of increased demand for fuelwood. In 1986, this represented 9 percent of total softwood output and fully 38 percent of total hardwood output. Although nongrowing stock sources are not expected to be a major factor with respect to the industrial roundwood market, they are extremely important in meeting fuelwood demand.

Future prospects for **U.S. timber supplies**

Given the constraints on supplies from U.S. public lands, increased harvests to the year 2005 must almost entirely originate on private lands. In the East, the timber inventories on private ownerships have been building for decades, and there is volume to respond to demand increases. In the West, the old growth inventories on private ownerships are rapidly being depleted, and by the year 2000 will be largely gone.

During the decade beyond 2000, there may be an unprecedented age class situation for softwood inventories in the United States. The United States, since European settlement, has had large reserves of virgin softwood timber as exploitation moved from the North to the South and then to the West. By 2000 or thereabouts, large diameter softwood timber will have been harvested on private lands, and the harvest on public lands will be constrained by nonmarket forces. The effects of this situation on timber availability will depend to a large degree on the size and timing of forest product demand growth over the next 20 years. There is the potential for fluctuations in roundwood prices if demand cycles as in the past.

After 20 10, plantations initiated in the past 10 years will reach merchantable size in the South and the Pacific Northwest. Given the level of planting and forest management in the past decade, there is every reason to be optimistic about the longer run timber supply. In the interim, high demand could create opportunities for more intensified use of hardwoods and trade opportunities for other suppliers such as Canada.

Canadian harvest trends

During the past 25 years, the Canadian harvest has increased steadily with the exception of two recessionary periods, one in the mid-1970s and one in the early 1980s (Fig. 5). Total Canadian roundwood production increased from about 97 million m^3 in 1960 to about 169 million m^3 by 1985. This represents an average rate of increase of 2.1 percent per annum. Production increases have been general throughout the country

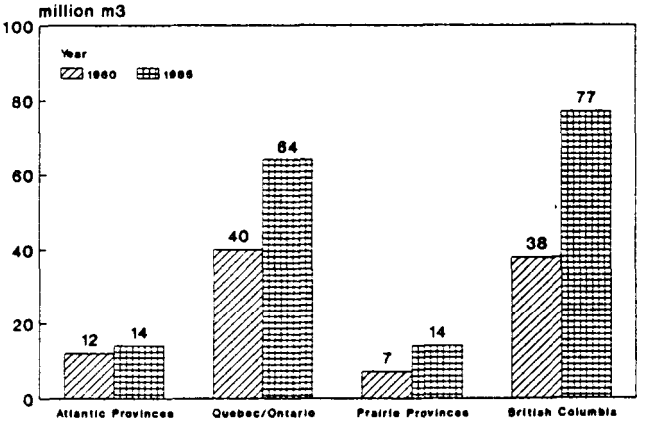

Figure 5. - Canadian roundwood production, 1960 and 1985 (7).

but have been more dramatic in western Canada. The harvest in both British Columbia and the Prairie Provinces has virtually doubled during the period. The harvest in the Ontario/Quebec subregion has increased at a somewhat slower pace but has still increased by more than 50 percent. The harvest in the Atlantic Provinces has shown the slowest rate of increase during the period. Total removals have only increased by approximately 15 percent between 1960 and 1985.

A breakdown of total removals between softwood and hardwood is available only since 1970. However, it is clear that the majority of the production increase has been in softwoods. In 1970, softwoods amounted to about 90 percent of total production. By 1985, this ratio was basically unchanged. While total softwood production increased to about 154 million m^3, hardwood production amounted to only 14 million m^3. The vast majority of production, and the production increase during the period, was industrial roundwood. Until the mid- 1970s the fuelwood harvest in Canada was declining. Although this trend has now reversed, fuelwood production in 1985 attained only the same level as in 1960. Currently, fuelwood represents about 4 percent of total roundwood production and about 34 percent of total hardwood production.

Major factors affecting Canadian supplies

In contrast to the United States, Canadian forests still have an unbalanced age-class structure with the inventory heavily weighted towards old growth natural forests. Currently, considerable quantities of mature and over-mature timber are available for harvest. The estimated volumes are theoretically sufficient to maintain current average harvest rates for many decades or to permit continued expansion of the harvest at least in the short term. Unfortunately, this largely physical assessment gives a somewhat unrealistic perspective on timber. Competing uses for the land base and growing stock, and the environmental sensitivity of certain areas, may limit harvesting operations although these areas may not be formally reserved for other uses. Thus, only a proportion of the physical resource is commercially exploitable.

A second important factor is that all governments in Canada are committed to sustained yield principles in the harvest of the forest resource. Note that the vast majority of forestland in Canada is under the ultimate management authority of the provincial governments. Each provincial forest management agency bases its harvesting policies on an independent assessment of the potential of its resource to support continuous commercial harvesting. These assessments attempt to incorporate the economic as well as the long-term physical limitations of the resource. This has significant implications for the speed with which the current mature and overmature inventory can be depleted. The potential growth rates on the second growth forest act to a greater or lesser extent as a constraint on current harvesting operations.

The limitations and constraints imposed by provincial government policy are reflected in Allowable Annual Cut (AAC) calculations. These AACs can be described as the average volume of timber that "may" be harvested annually from the provincial forestland base given the available timber inventory, the growth capability of the forest, and the specific objectives of the forest management authority. In effect, they reflect the judgment of each provincial government on the advisable maximum harvest in the near future, given assumptions about the current and future harvestability of its forestland base and management preferences with respect to the sustainability of yields in the long term.

Future prospects for Canadian timber supplies

Atlantic Provinces

The Atlantic Provinces encompass New Brunswick, Nova Scotia, Newfoundland, and Prince Edward Island. Each province independently manages its public timberland. In addition, each province assesses the potential of private timberland within its jurisdiction to provide sustainable quantities of timber.

For the Atlantic Provinces as a whole, about one-third of the productive and available forestland base is in mature and overmature age classes. This is somewhat less than the Canadian average. The total estimated volume available for harvest on this land base is 688 million m^3. On an aggregate basis, the estimated AAC for the entire region (including both private and public land) amounts to some 22.8 million m^3. Just over two-thirds of this (15.7 million m^3) is softwood and the balance is hardwood. The 1985 harvest level for the entire region amounted to 14.2 million m^3. However, close to 90 percent of this (12.5 million m^3) was softwood. On the basis of these figures, a relatively small apparent surplus of softwood and a relatively large apparent surplus of hardwood are available to facilitate expansion of the harvest over the next 20 years.

Quebec-Ontario

The Quebec-Ontario region is typical of most Canadian regions. More than half the productive and available forestland base is in mature and overmature classes - 59 percent in Quebec and 46 percent in Ontario. The estimated total volume of timber currently available for harvest is 4.8 billion m^3. The incidence of private ownership is much less in this region

than in the Atlantic Provinces but is much greater than in western Canada.

It is difficult to derive an aggregate AAC for the entire region. Unlike other provinces, Ontario public land harvests are controlled on a total area depletion basis. To translate the allowable area depletion into volume terms requires assumptions regarding gross timber yields by species groups. This exercise has been performed by a number of analysts with somewhat varying results. Estimated AACs range from 34.0 to 45.5 million m^3. In this analysis, a midrange figure of 41.4 million m^3 was used.

On this basis, the total AAC for both provinces amounts to 89.8 million m^3 not including private lands in Ontario. Approximately two-thirds of this allowable cut (59.7 million m^3) is softwood. The 1985 harvest for the two provinces amounted to 63.6 million m^3. About 82 percent of this (52.7 million m^3) was softwood. These figures imply that only a small surplus of softwood exists to facilitate further harvest expansion, although relatively substantial surpluses of hardwood are available. While the apparent surpluses of hardwood are reasonably equally divided between the two provinces, the softwood situation in Quebec appears to be particularly tight.

Prairie Provinces

The Prairie Provinces encompass Alberta, Saskatchewan, and Manitoba. The specifics of timber supply planning differ substantially throughout the region, but some common elements are apparent. All three provinces eliminate a certain portion of their productive forestland base as "economically inaccessible." In addition, a further reduction of the productive forestland base for supply planning is performed by eliminating certain stands because of low volume per hectare, high elevation, steep slope, or inappropriate species mix.

In terms of age class distribution of the forest, Alberta is fairly typical of most Canadian regions, because more than 50 percent of the productive forestland base is in mature and over-mature classes. In contrast, Saskatchewan and Manitoba have only 18 to 20 percent of their productive forestland base in these categories, largely as a result of the high incidence of wildfire in these two provinces. The total estimated volume available for harvest in mature and overmature stands is 2.6 billion m^3. On an aggregate basis, the estimated AAC for the entire region (for provincial lands only) amounts to 35.4 million m^3. About 57 percent of this (20.1 million m^3) is softwood. The 1985 harvest for the entire region amounted to 13.7 million m^3. About 90 percent of this (12.3 million m^3) was softwood. On the basis of these figures, large surpluses of both softwood and hardwood are available to facilitate continued expansion of the prairie harvest.

British Columbia

Fully 63 percent of the productive and available forestland in British Columbia is in mature and overmature age classes. The estimated volume currently available for harvest on these lands is 7.3 billion m^3. Provincial public lands represent approximately 96 percent of the productive and available forestland in British Columbia. This provincial land is divided for administrative purposes among 35 Timber Supply Areas and 31 Tree Farm Licenses. An AAC is calculated every few years for each of these administrative divisions. Comprehensive planning documents (dating from 1985) indicate a total AAC for all regulated lands in the province of 70.8 million m^3. More recent information from the provincial government indicates that the AAC has increased to 72 million m^3. The harvest from regulated land in the province has averaged about 71.5 million m^3 per annum over the last several years. An additional average harvest of approximately 9.1 million m^3 has been realized from unregulated, largely private lands in the province. Virtually all harvest in the province is softwoods.

Little can be said with respect to the future prospects for the harvest from unregulated lands. During the past few years, the unregulated harvest has increased dramatically from 7.6 million m^3 during the 1984-1985 fiscal year to 11.5 million m^3 during the 1987-1988 fiscal year. However, these harvests are not considered sustainable in the long term once the existing old growth inventory is depleted, and little information exists on the size of the existing inventory or the sustainable level of harvest in the long term.

With respect to regulated lands, the previous figures imply little surplus available to facilitate continued harvest expansion in the province. However, the methods used by the provincial government to arrive at the AAC are more intensive than in other jurisdictions. For each administrative area, a detailed analysis of the productive forestland base and timber inventory is performed. On the basis of these analyses, a considerable proportion of the productive forestland base in the province is removed from consideration in supply planning. Some areas are removed because of environmental sensitivity or where nontimber resource management is a priority. However, the majority of the areas removed reflect a variety of economic judgments. For example, until recently all deciduous forest types were 100 percent removed from the land base under the assumption that there would be no future demand for hardwoods in the province. Also, large areas of forestland are eliminated because of location, terrain,

poor stocking, low average height, or over maturity that reduces the quality, volume, or value of the stands.

The extent of these land base reductions for planning purposes is very large. In aggregate, it amounts to approximately 50 percent of the productive forestland in the province. In effect, the current AAC is calculated on the basis of half the physical land area currently available for commercial harvesting. In short, considerable additional supplies of timber are physically available beyond the economic margin identified by the provincial government. It is the stated policy of the provincial government to add these additional volumes to the supply base if and when they are actually harvestable. This clearly depends upon market trends and future improvements in technology and transportation infrastructure.

The extent to which AACs may increase as a result of positive factors is difficult to determine. Sensitivity analysis performed in conjunction with some recent provincial regional supply studies indicates potential increases in the harvest during the next 20 years of about 24 percent, mainly as a result of increased utilization of the land base. Further increases may be feasible as a result of increased silvicultural expenditures. Although these expenditures will not affect the stock of timber available for harvest during the next 20 years, the resulting increased productivity of the land base may encourage more rapid depletion of the present inventory.

Trends and prospects for forest products demand

North America is self-sufficient for most timber products. The main exception is hardwood plywood, which consists mainly of panels from tropical species, especially those from Indonesia. Imports account for some two-thirds of the North American consumption of hardwood plywood.

The North American region is a net exporter of softwood lumber, paper, paperboard, wood pulp, pulpwood, and logs. Pulpwood and softwood logs have the Pacific Rim as a major market. Lumber and fiber-based products have a more diversified market that includes Europe. European and, increasingly, Pacific Rim countries are the major destinations for hardwood logs.

Factors influencing domestic and export demand

Although various factors affect markets for individual products, in general, demands for forest products are tied to the population and the economy. Thus, the overall trend in North American consumption has been upward. Projections of population and economic activity underlie projected North American consumption of forest products.

Consumption of softwood lumber is expected to increase to 129.3 million m^3 in 2005 or about 10 percent more than 1985 consumption, and nearly two-thirds greater than 1960 consumption (Fig. 6). Hardwood lumber consumption will increase from 15.5 to 26.8 million m^3. Oriented strandboard (OSB)/waferboard consumption will increase nearly threefold from 1985 to 2005, with softwood plywood increasing nearly 45 percent (Fig. 7). Hardwood plywood consumption is expected to increase at just over 50 percent for this period. For paper and paperboard, consumption will increase at a rate slightly below that experienced historically, with paper and paperboard consumption at 64.3 and 43.8 million m^3, respectively (Fig. 8).

Demand in the export market depends on demand conditions in the importing countries, exchange rates, competing sources of supply, the supply and demand situation in North America, and tariff and nontariff factors. Export markets for North America have traditionally been the industrialized countries and this

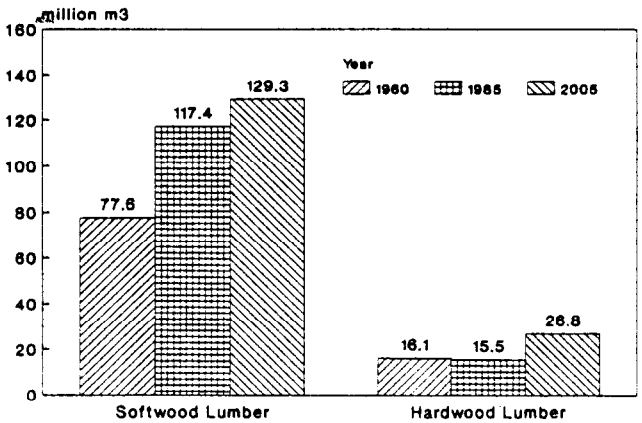

Figure 6. - North American consumption of lumber (3).

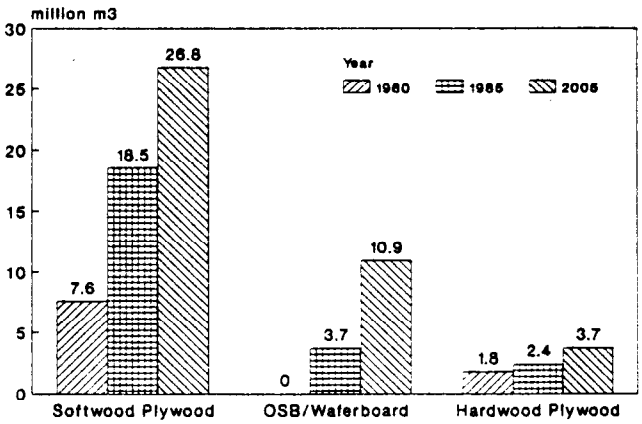

Figure 7. - North American consumption of panels (3).

should continue, with Japan and Europe as the main sources of offshore demand. Offshore exports from North America are expected to increase for softwood lumber, but a 20 percent decrease in softwood log exports is anticipated by 2005 (Fig. 9).

Implications for raw material demand

For solid wood products, trends have been toward improvements in conversion efficiency, with more veneer and lumber being recovered from the same volume of roundwood. For example, in Canada in 1970, an average of 2.67 m^3 of roundwood was required to produce 1 m^3 of lumber and plywood. By 1984, the roundwood input requirement had declined to 2.14 m^3. Increased recovery was facilitated by the installation of computer-assisted scanning devices that permitted optimization of log lengths and cutting patterns, thereby maximizing processing recovery. Utilization has also improved at the logging site. For example, in the United States in 1962, 37 percent of the softwood growing stock volume remained as residue at a logging site; in 1986, less than 10 percent remained.

For fiber-based products, there are differences in utilization patterns between pulp-based products and various panel products. The amount of wood required per tonne of pulp varies from about 2.5 m^3 for mechanical processes to more than 5 m^3 for chemical sulphite processes. Over time, the mix of pulps produced has changed considerably. These changes were partially brought on because of an increased awareness of water pollution, changes in energy costs, and an increased use of hardwood species in the United States. Improved mechanical pulping processes such as chemothermomechanical pulp (CTMP) may be substituted in the future for low-yield chemical pulps. Nonetheless, the average consumption of wood per tonne of pulp in North America has changed little, and major changes in average wood use up to 2005 are not expected.

The roundwood required for paper and paperboard production depends in part on the recycling of these products. Compared to European and Japanese standards, recycling of paper and paperboard in North America is low. The United States paper industry, represented by the American Paper Institute, has recently announced a goal of 40 percent recovery of paper and paperboard by 1995, compared with about 30 percent recovered today. The achievement of this ambitious goal could have major effects on the demand for roundwood pulpwood, with effects building up with time. However, potential market responses to significant increases in recycling are numerous and complex. For example, if the United States increased exports of waste paper, the implications for domestic roundwood markets would tend to be minimized.

North American roundwood demand

Taking into account utilization trends, the projected increases in production of the various end-products imply substantial increases in the demand for roundwood, especially softwood species. By 2005, the total demand for roundwood is expected to be about 76 percent greater than it was in 1985.

Until 2005, the increased output is expected to come from existing inventories. In the decades immediately following 2005, substantial volumes of southern pines will come from plantations in the southern part of the United States. The increased demands projected through the turn of the century imply increased prices for roundwood when considered in relation to supplies. In the United States, for example, the price (net of inflation and deflation) for softwood species in Washington and Oregon is projected to increase by about one-third between 1985 and 2005; for the south-

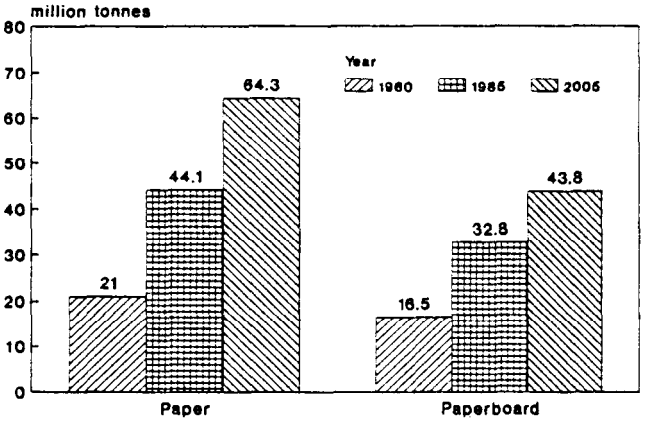

Figure 8. - North American consumption of paper and paperboard (3).

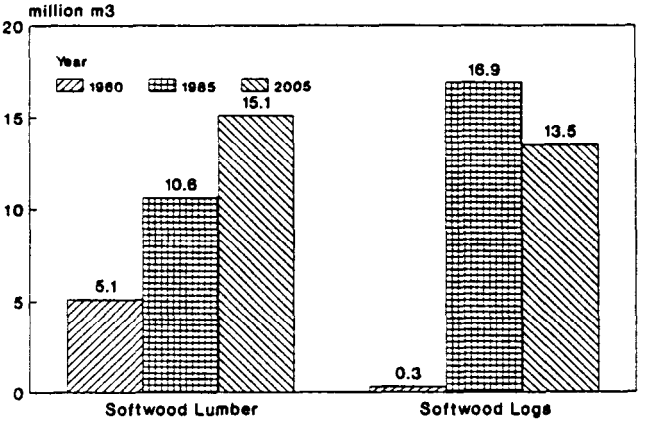

Figure 9. - North American offshore exports (3).

ern United States, the price increase is forecast at more than 50 percent. These price increases are expected to provide the basis for increased output from private lands in the United States and from public lands in Canada. These price increases will also reinforce incentives to the forest industry to maintain plantation programs that will be the basis for an expansion in supplies after 2005.

Implications for offshore trade

In the market economy of North America, supplies of timber products will meet demands. The question is at what price. The west coast of North America has had a comparative advantage over the rest of the world owing to its high-quality indigenous softwood timber resource. Although this situation is changing on private lands in the United States, the softwood resource will still be a major factor in world trade in 2005 and will still enjoy a comparative advantage because of its unique qualities. The temperate hardwoods of the United States also have unique properties that would maintain their presence in world markets despite upward pressure on prices.

Even if roundwood prices increase somewhat in North America, offshore exports should be minimally affected. Market development activities for the sale of softwood products in Japan and Europe mainly involve the promotion of platform-frame housing. The cost of wood in such housing is a small fraction of the final structure cost and of the land upon which it is built. Therefore, price increases for roundwood in the United States would have some effect on the success of these promotion efforts but would not be critical.

Money exchange rates are probably the most important determinants in the price of North American wood delivered to offshore markets. Exchange rates in the 1990s will be affected by strong forces as in the past, and the net effect is impossible to predict.

The projections of North American trade and consumption of timber products that have been presented still show the region to be relatively self-sufficient in timber supplies. Some expansion of offshore trade is indicated, but markets are dominated by domestic demand. It is this strong domestic market, and not offshore trade, that will determine the course of North American demand and supply in the 1990s and through 2005. North America has the supply capability to support increased harvests. If there is growth in trade to offshore markets, domestic supply will still equal demand in North America. Technological development, wood substitutes, and exploitation of currently inaccessible resources are all strong and plausible responses to the increased demand for timber products.

Timber market impact of current wood utilization research in the United States

In the USDA Forest Service,[3] managers of wood utilization research are asked to justify their research in terms of its potential impact. The areas of concern vary widely, but the impact of research on timber and wood products markets is of particular interest to the Forest Service. This is because the public is interested in how utilization research may alter the relative adequacy of timber supplies, the health of the forest products industry, and the cost of wood products to consumers.

To evaluate the potential impact of current wood utilization research that is partially conducted by the Forest Service, seven research areas were identified that, if successful, would influence prices and consumption in timber markets: 1) harvesting; 2) lumber, plywood, and veneer processing; 3) expanded use of timber bridges; 4) development of new or improved composite products using wood; 5) design and performance of wood structures; 6) development of improved adhesives from renewable resources; and 7) pulp, paper, and paperboard processing.

Scientists at the Forest Products Laboratory (FPL) and other USDA Forest Service research stations identified how successful completion of research development-adoption efforts may alter timber processing or demand for timber products. With the exception of harvesting research, the analysis assumed complementary research and development would be done by universities and industry In **some** cases, universities and industry are expected to contribute as much or more than the Forest Service in terms of basic and applied research. It is assumed that most engineering development will be done by industry.

For each research area (except 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. The TAMM model, which was used to make timber market projections for the 1989 RPA forest and rangelands assessment (1), was used for simulation runs to project timber market conditions that reflect successful completion, development, and adoption of research in each research area. The TAMM projections of timber and wood product consumption and prices were then compared for the base case and the altered case projections.

[3] Most of the material in this section is taken from reference (6).

For pulp, paper, and paperboard research, the FPL Pulpwood Model was used to make market projections (4). Scientists estimated the technical characteristics (pulp yield and processing costs) of new ways to make various grades of paper, and they projected when industry would begin using these techniques. These new processes were inserted in the FPL Pulpwood Model to alter projections of pulpwood and paper/paperboard production and prices. Altered projections of pulpwood and paper/paperboard price and production were compared to the base case projections. Altered projections of pulpwood consumption were then inserted in the TAMM model, and the resulting sawtimber and solid product projections were compared to the TAMM base case projections.

The following sections describe the results of this analysis for three of the research areas examined: harvesting, design and performance of wood structures, and pulp, paper, and paperboard processing.

Harvesting

Two kinds of harvesting research were evaluated for their potential impact on softwood sawtimber and veneer log harvesting: 1) research on transferring analyses and ideas about the best types of existing equipment for various situations; and 2) research on improving the efficiency of equipment and systems with new types of hardware or new designs. The effect of these changes on harvest costs was estimated using a harvest technology projection model developed by Bradley (2). To implement the effect of the first type of research activity, the pace of change in the mix of harvesting systems used was increased. The change is small; we assumed the base case system mix for the year 2001 would be achieved by 2000. For the second type of research activity, cost efficiency improvements were estimated in various equipment systems in 2040 assuming continued research by the Forest Service, universities, and industry. It was assumed that the Forest Service would produce about one-third of the efficiency gains (in rough proportion to total harvesting research expenditures). The harvesting model estimated that the combined effect of the two research activities, after accounting for projected changes in stand density and stem diameter, would reduce harvesting cost 5 to 7 percent by 2040 depending on the U.S. region.

Design and performance of wood structures

Ten Forest Service research activities were evaluated that can improve the design and performance of wood structures:

1. Development of more reliable engineered wood structural components such as wood 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.
10. Development of lumber grading that is independent of species to enhance use of diverse species.

Success in these research activities could 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, it was assumed that by 2010 and thereafter, research will increase the use of lumber, plywood, and OSB-waferboard by 15 percent over levels in the base case by increasing the number of nonresidential buildings where wood is used. For single and multifamily homes, it was assumed that 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 percent 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 percent 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 the research will be to increase both lumber and structural panel consumption above levels in the base case projections.

Pulp, paper, and paperboard processing

Research on pulp, paper, and paperboard processing will include mechanical and peroxymonosulfate pulping, wastepaper recycling, production of newsprint, and development of FPL Spaceboard I.

Mechanical pulping. - Research on mechanical pulping for hardwoods in linerboard could lead to the use of pulp with yields of 85 to 95 percent compared to yields of 50 to 55 percent for conventional unbleached kraft pulp. With CTMP and press-drying,

linerboard could be made from 100 percent hardwoods with 80 percent yield by the year 2015. Mechanical pulping could also increase the use of hardwoods in making printing and writing papers.

Peroxymonosulfate pulping. - 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 percent 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.

Wastepaper recycling. -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 to develop a disk separation process to separate contaminants from recycled fiber, to improve the means to remove ink from printing and writing papers, and to develop chemical and biological treatments to restore bonding strength to recycled fibers.

Production of newsprint. - Research on CTMP and biomechanical pulping (BMP) with press drying may be successfully combined to make newsprint from 100 percent hardwoods. Mills using CTMP or BMP with press drying may be possible beginning in 2015 and 2025, respectively. Combining CTMP with press drying may achieve increased sheet strength, previously attainable only with softwoods. (Bleaching may be needed when using hardwood species.) Combining BMP with press drying may increase strength and also retain optical properties for low- and medium-density hardwood species.

FPL Spaceboard. - A new product, FPL Spaceboard, could replace some corrugated fiberboard for boxes. Spaceboard is a sandwich of two or more pulp-molded structures. It was assumed that manufacturing plants for Spaceboard will be built near large cities by 2000; the plants will use 100 percent recycled corrugated containers as raw material. It was estimated Spaceboard may replace 25 percent of corrugated container board by 2040.

Findings

The impacts of pulp, paper, and paperboard research stand out when compared to that of harvesting or wood structures research: 1) the effects are expected to occur further in the future (after 2010); 2) both pulpwood and sawtimber harvest and prices will be substantially affected; and 3) the potential changes in price and harvest will be much greater.

Softwood pulpwood harvest is 33 percent lower by 2040 when compared to the base case (Fig. 10). This decrease in softwood pulpwood harvest is equal to 27 percent of the projected softwood sawtimber harvest in 2040 (Fig. 11). With lower pulpwood harvest, softwood sawtimber harvest would increase by 17 percent

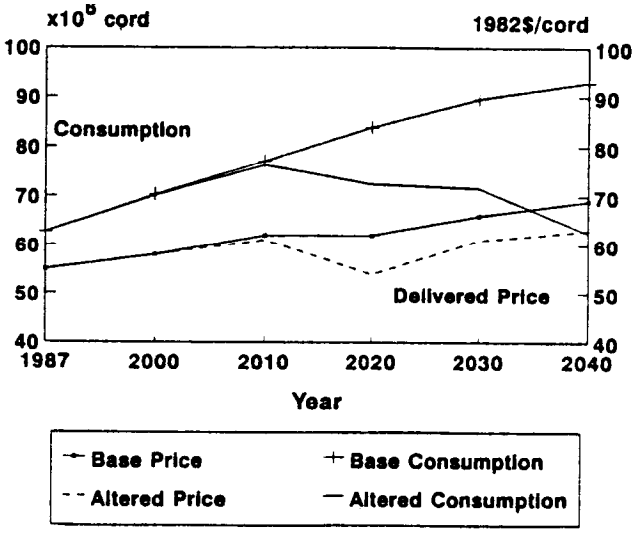

Figure 10. - Softwood pulpwood harvest and delivered price with and without current pulp, paper, and paperboard research (6).

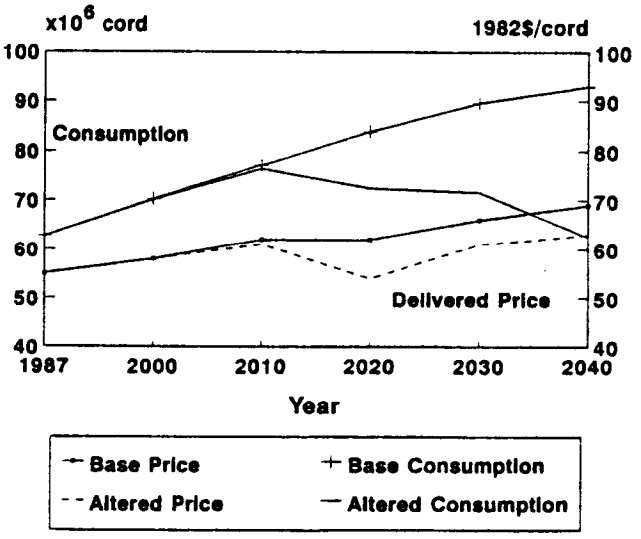

Figure 11. - Softwood sawtimber harvest and stumpage price with and without current pulp, paper, and paperboard research (6).

by 2040. However, combined harvest would decline, overall, leading to lower prices for both softwood sawtimber and softwood pulpwood; prices decline by 43 and 9 percent for softwood sawtimber and pulpwood, respectively.

Research on harvesting and wood structures results in an increase in softwood timber harvest in all periods except 2040. The percentage increase in harvest in all cases is quite small when compared to that of the base case, an increase of 0.5 percent or less (Fig. 12). With respect to softwood sawtimber stumpage price, both areas of research result in percentage increases when compared to the base case (Fig. 13). By 2040, softwood sawtimber stumpage prices are 3.2 percent greater for research on harvesting and 5.5 percent greater for wood structures research.

Research on pulp, paper, and paperboard processing has the greatest long-term potential for reducing timber and wood product prices and harvest. Research on harvesting and wood structures that was evaluated in the study would increase softwood sawtimber price. Its effect on harvest levels would vary.

limber market impact of increased forest management in the United States

Significant gains in productivity of U.S. timberlands have been achieved over the past three decades (8). Growth per acre trends for all owner groups indicate that the biological timber productivity of U.S. forests has increased substantially and continuously since 1952 for both hardwood and softwoods (5).

Still, many opportunities to enhance productivity on existing timberlands remain. Nationwide, many acres could be managed to grow greaterwood 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 investments would yield a return of 4 percent or more in constant dollars (net of inflation or deflation).

Methods and assumptions

The primary statistical base for identifying opportunities to increase timber supplies consists of data on areas of timberland suitable for treatment compiled for each state by the 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 included regeneration with or without needed site preparation, conversion to a preferred management type for acres with offsite species, harvest of financially mature timber followed by regeneration, partial harvest of merchantable timber with natural regeneration, and salvage of damaged timber followed by regeneration.

Harvest timber volumes were based on empirical

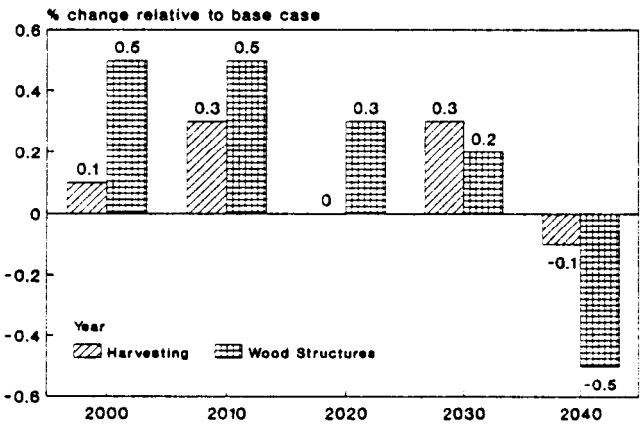

Figure 12. - Projected change in softwood sawtimber harvest resulting from selected current wood utilization research (6).

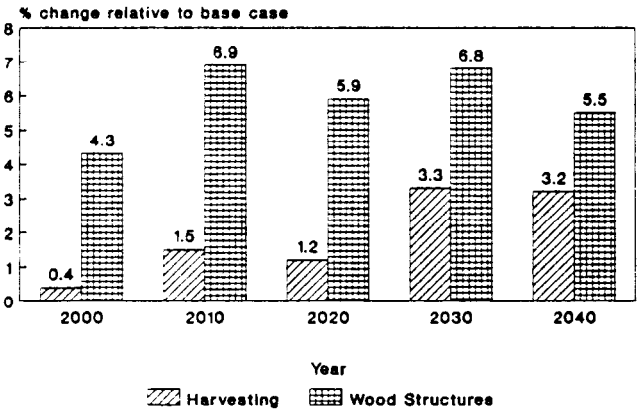

Figure 13. - Percentage change in softwood sawtimber stumpage price resulting from selected current wood utilization research (6).

yield tables for fully stocked stands. Yield tables included growing stock volume, percentage of softwood stocking, and percentage 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.

Management options were combined with treatment cost, yields, and stumpage prices to project cash flows for each investment opportunity. Stumpage prices used for the analyses were projected to rise over the investment period, in keeping with the trend for rising prices. 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.

A 4 percent real rate of return was used for discounting all costs and revenues. Although 4 percent approximates the average long-term 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 of 10 percent or more.

Economic opportunities for increasing timberland productivity

Economic opportunities are available to increase timber growth and/or financial returns from growing timber on over 66 million acres of other private timberland nationwide. 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. About one-third of the opportunities require stocking control measures in existing stands.

Approximately three-quarters of the opportunities are in the South and nearly one-fifth are in the North. The small percentage of opportunities in the western states partially reflects the relatively small proportion of timberland held by other private owners in the West.

Approximately 70 percent of the timberland in the South is in other private ownership. For the evaluation of economic opportunities in the South, 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.

Tmber impact of implementing economic opportunities

Implementing all 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 base case projection prepared for the 1989 RPA Timber Assessment (8). The base case projection assumes a modest increase in the level of management intensity on other

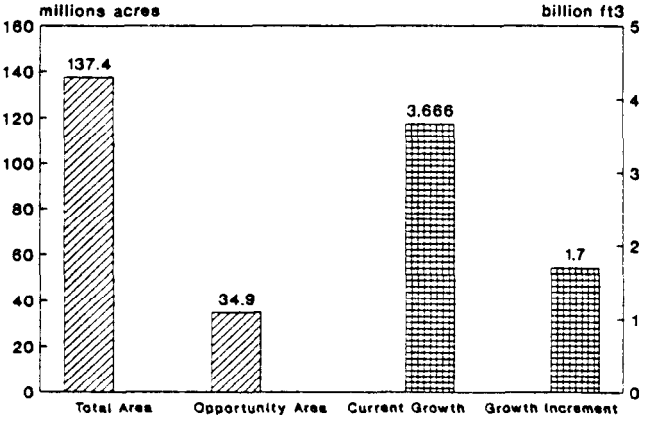

Figure 14. - Regeneration opportunities in the South yielding 4 percent or more, other private ownership, 1987.

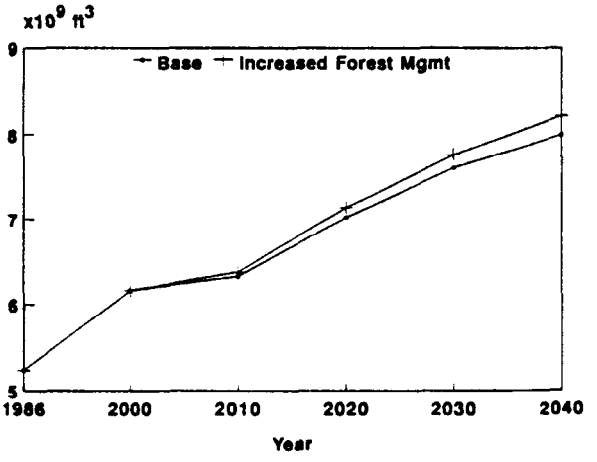

Figure 15. - Softwood harvest in the South, base and increased forest management future (8).

private timberland over the projection period. To examine the impacts of greater levels of investment on other private lands, an alternative analysis was conducted.

Tmber management assumptions in base case projection

Overall, about one-fifth of the current economic opportunities described in this chapter for other private ownerships are already captured in the base case projection. Most 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. Increases in management intensity are also assumed in the Pacific Coast because of its inherent productivity for timber, and to **a** lesser extent in the North.

The base case projection provides for continuing increases over the projection period in the area of timberland managed as softwood plantations in the regions and subregions previously mentioned. 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 base case projection assumes that nonindustrial private owners will plant trees at a rate comparable to that of the recent decade. In total, the acreage of planted pine on nonindustrial private ownerships in the South is projected to increase 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 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 a result of land being converted from agriculture and other rural land uses. The remaining increase represents the projected enrollment of approximately 30 percent of the 35 million acres of regeneration investment opportunities on existing timberland in the South (Fig. 14). Compared to the South, relatively small changes in levels of other private reforestation are projected for other regions of the country.

Increased investment over base case projection

As previously described, substantial economic opportunities exist to increase timber growth on timberland in other private ownership. For many reasons, it is unlikely that all these opportunities will be implemented. However, some are likely to be implemented if current management trends on other private lands continue. This portion of the opportunities was incorporated in the base case projection. Capturing all 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 case projections of stumpage prices. As additional investments are implemented, timber inventories increase, causing stumpage prices

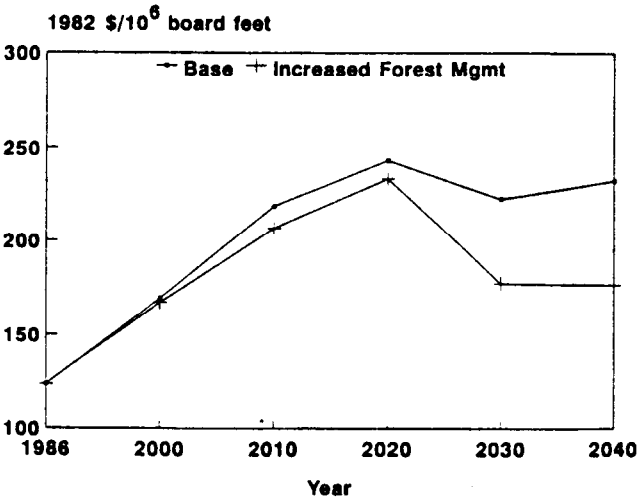

Figure 16. - Softwood sawtimber stumpage prices in the South, base and increased forest management future (8).

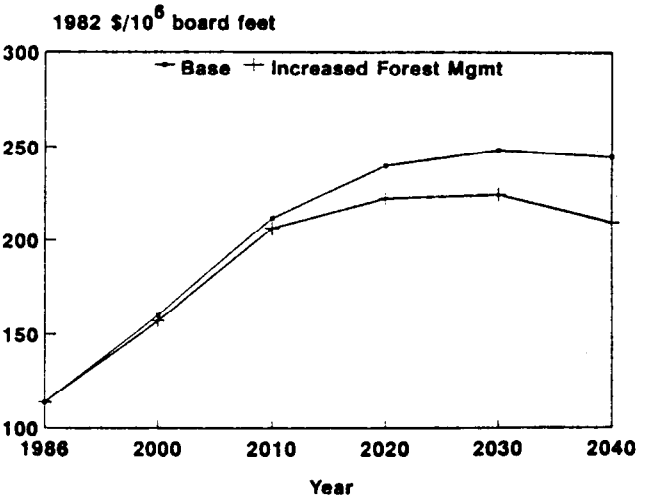

Figure 17. - Stumpage prices in the Pacific Coast, base and increased forest management future (8).

to decrease. This reduces the economic incentive for implementing opportunities. In addition, although the opportunities to increase timber growth are defined in terms of current stand conditions, regeneration and/or stocking control treatments would probably be implemented over an undetermined 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. This scenario assumed that regeneration opportunities with a rate of return of 10 percent or greater would be implemented uniformly over the projection period. Opportunities with a 10 percent rate of return are likely to remain attractive even if prices do not increase to the levels in the base case projection. Almost all these opportunities are in the South.

Timber impacts

The impacts of increased investments on other private timberlands are substantial. Softwood timber harvests, net annual growth, and inventories are higher than the base case projection. Softwood inventories are 7 percent 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 increases 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 the increase in softwood harvest in the South (Fig. 15). By 2040, harvests in the South will have increased by 3 percent but stumpage prices will have decreased by 24 percent (Fig. 16). Lower stumpage prices lead to higher solidwood production and consumption. By 2040, increased lumber production will also lead to a 20 percent reduction in softwood lumber imports from Canada.

As a result of the increase in inventories and harvest, stumpage prices for sawtimber will be reduced below those for the base case in all regions. This is most evident in the South where stumpage prices will be 5 percent lower in 2010 and 24 percent lower in 2040. Stumpage prices in the Pacific Coast will be reduced by 14 percent by 2040 (Fig. 17).

Concluding remarks

This paper discusses how public and private research and investment can be used to help achieve the economic potential of North American timber resources. Two examples of how research and investment can lower timber costs were presented. Research on pulp, paper, and paperboard processing was found to have long-term potential for reducing timber prices. The impacts of increased investments on other private timberlands are also substantial, with significant reductions in timber prices. Both research and investment can contribute to achieving the economic potential of North American timber resources.

The projections of North American trade and consumption of timber products that have been presented show the region to be relatively self-sufficient in timber supplies. Some expansion of offshore trade is indicated, but markets are dominated by domestic demand. If there is growth in trade to offshore markets, domestic supply will still equal demand in North America. Technological development, wood substitutes, and exploitation of currently inaccessible resources are strong and plausible responses to the increased demand for timber products.

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