1988. *In:* Healthy forests, healthy world: Proceedings of the 1988 Society of American Foresters national convention; 1988 October 16-19; Rochester, NY. Bethesda, MD: Society of American Foresters: 332-336.

THE IMPACT OF TECHNOLOGICAL CHANGE ON PROJECTIONS OF COSTS AND RECOVERIES IN WOOD PRODUCTS PROCESSING[1]

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ABSTRACT.--The purpose of our paper is to display projections of product recovery factors and manufacturing costs for softwood lumber, panels, paper, and paperboard being made for the 1989 Renewable Resource Planning Act timber assessment. In the coming decades, the quality of timber entering mills will decline, as indicated by average log diameter, size of growth rings, specific gravity, and knots. Yet average softwood lumber recovery, currently estimated at just over 40 percent of the cubic volume, is projected to rise to about 47 percent and higher in some regions. Likewise, softwood plywood recoveries are projected to rise from about 50 percent to over 55 percent. Consumption of pulpwood per ton of paper and paperboard, around 1.2 tons during the last decade, is projected to decline by 8 percent. The underlying reasons for these changes are explained, and their implications for forestry are discussed.

In 1988, the Forest Service conducted an analysis of the U.S. timber situation as part of its periodic resource assessment for the Renewable Resource Planning Act (RPA). Our group at the Forest Products Laboratory (FPL) was assigned to review the status of current and prospective technologies available to the forest products industries, from timber harvesting to end product uses. This paper is focused on the changes in technology occurring in processing of timber into lumber, panels, and paper.

If we were to summarize our findings into a single theme, it would be this: more, faster, and cheaper. More, because a growing economy will require increased supplies of products from our timber resources. Faster, because declining log sizes mean that the rate of processing will have to increase to maintain productivity. Cheaper, because competition from alternative technologies will increasingly erode markets unless we invest in ways to streamline processing.

We might add a fourth item, Quality, for we should recognize that the timber processed from managed forests will not have the same characteristics as those from natural stands. New technology will help us adapt to the changing resource, but the forester must also strive to grow trees with qualities that are suitable for the intended end use.

Let us first review timber manufacturing changes and then consider some implications for forestry in the coming decades.

TECHNOLOGICAL CHANGES IN TIMBER PROCESSING

We will review major technological changes in sawmilling, manufacture of structural panels, and pulp and paper processing.

Sawmilling

The sawmilling industry in North America has traditionally been made up of a large number of operations, ranging from small two-man outfits to those with several hundred employees. Recovery standards have varied between small and large producers. Most small mills have used heavy circular saws for primary log breakdown. Larger mills have typically used bandsaw headrigs. The

[1]A paper presented at the E6 Working Group at the SAF National Convention held at Rochester, NY, on October 16-19, 1988.

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heavy circular saws have been popular among smaller producers because they require little maintenance; such saws can often be used without the services of highly skilled sawfilers. But, these saws also waste lumber, producing kerf from 9/32 inch to as much as 16/32 inch in contrast to the <8/32 inch with bandsaws. Over the past several decades, more industry output has come from more efficient, larger mills, which has tended to raise overall industry recovery standards.

Over the years, the U.S. timber resource has gradually become smaller. In response to the increasing availability of smaller timber, a third kind of saw appeared around the 1960s, the Chip-N-Saw. Sawmills that use this machine do not quite achieve the recovery standards of conventional mills, but compensate by increased throughput of a lower cost resource with less handling. Today, over 200 mills in North America use the Chip-N-Saw.

Inflation in the cost of wood, labor, and energy has offered incentives for mills to install equipment to conserve costly inputs. Improvements to increase log recovery have included better scanners to measure log size and shape; computer control for optimal log breakdown based on the Best-Opening-Face (BOF) concept; saws with thinner blades, longer wearing teeth, and better guides to reduce kerf and sawing variation; and more closely controlled drying using improved moisture sensing and removal to reduce energy use and lumber degrade.

The effect of some of these technologies can be seen in the projections of two important components of sawmill performance, sawkerf and dressing (planing) allowance. We characterized sawmills by size (yearly output <5 million and >5 million board feet) and output (stud lumber, dimension lumber, and boards). We then specified four levels of technological performance represented by parameters indicating processing efficiency. The effect of the parameters was simulated in a process model. The results for each mill were weighted by the projected share of output for that type of sawmill to arrive at overall industry recovery and cost estimates.

For small sawmills with current levels of technology, kerf of 0.280 inch was assumed, reflecting the use of heavy circular saws. Dressing allowance was assumed at 0.119 inch. Large mills with current technology typically achieve headsaw kerf of ~0.200 inch, resaw kerf of ~0.175 inch, and dressing allowance of 0.114 inch. With current best technologies, we believe that headsaw and resaw kerfs of 0.120 inch can be achieved. The use of thin-rim circular sawblades for resawing cants for pencil slats has resulted in kerf as low as 0.051 inch (Szymani et al. 1987). For future technology levels, kerf is projected to fall to 0.110 inch, but because of the replacement of planing by touch sanding for board finishing and greater control over sawing variation, dressing allowance is projected to fall to 0.063 inch.

In a typical projection of the mix of output by mill technology level for the South, we expect that small sawmills with older technologies will have a decreaslng share of lumber, although this share will be significant (close to 20 percent), and that large sawmills with current technologies will be modernized within a decade and will achieve current best technology levels by the year 2000. Future technologies, involving such exotic features as x-ray scanning for defect detection, are expected to appear around the turn of the century and by 2040, to account for more than half the lumber produced.

In response to these developments, lumber recoveries are projected to increase (Table 1), but by a slower rate than in the past because we also project a large decline in average sawlog diameter. Other things being the same, recovery declines with log diameter because of the configuration of the log. Industry manufacturing costs, excluding wood costs and assuming real labor and energy costs, are projected to decline moderately (Table 2).

Alternative technologies are now producing new structural wood products. Two notable products are wood I-beams and laminated veneer lumber (LVL), which are manufactured from veneers glued together with heat and pressure. These products replace conventionally sawn lumber products such as joists and rafters. Their main advantage is that they can be manufactured from smaller, lower grade timber and yet achieve superior strength because defects are spread out rather than concentrated at a point, such as a knot.

Structural Panels

Perhaps the most dynamic changes in technology over the past decade have occurred in the area of structural panels. The birth and rapid growth of the nonveneered structural panel industry in the United States and Canada have been followed by changes in plywood processing that have reduced costs and improved competitiveness.

Nonveneered structural panel production relies on little used low-density hardwoods and pulpwood-sized Southern Pine. Because the wood is chipped and mixed, defects such as knots, spiral grain, and crook are less critical. Wood costs are consequently lower. However, improvements in veneer peeling techniques have significantly reduced this cost advantage by permitting the veneer to be peeled from similarly sized timber. Some key improvements have included hydraulic carriage drives that produce more uniform, smoother veneer; high moisture content glues that permit greater throughput through veneer driers, traditionally the bottleneck in most plywood mills; and the use of peripherally (spindleless) driven lathes that enable peeling to core diameters of as little as 1-7/8 inches.

In our opinion, the key feature of spindleless lathes is the change in knife angle as the diameter declines. In general, veneer quality, in terms of surface roughness and depth of lathe checks, deteriorates as bolt diameter declines. One variable available to the lathe operator for counteracting this is the knife angle. Most lathes have built-in pitchrails that automatically change the knife angle as the knife advances into the bolt. However, an incorrect setting can lead to large reductions in recovery. A range of knife angles has

Table 1.--Recovery factors[a] for wood products for 1952, 1976, and 1986, with projections to 2040.

Product and region or category	1952	1976	1985	Projections 2000	2010	2020	2030	2040
SOFTWOOD LUMBER	Board feet lumber tally, per cubic foot, log scale							
South	5.06	5.74	5.82	6.36	6.54	6.69	6.86	7.06
Pacific Northwest								
Douglas-fir subregion	5.72	7.27	7.14	7.38	7.38	7.45	7.56	7.65
Ponderosa pine subregion	5.35	6.13	6.05	6.46	6.68	6.93	7.20	7.50
Pacific Southwest	6.25	6.89	7.06	7.13	7.25	7.38	7.53	7.67
Rocky Mountains								
Northern Rocky Mountains	5.74	6.76	6.67	6.92	7.02	7.14	7.26	7.41
Southern Rocky Mountains	5.48	6.61	6.67	6.92	7.02	7.14	7.26	7.41
SOFTWOOD PLYWOOD	Square feet, 3/8 inch basis, per cubic foot, log scale							
South	NA	12.5	14.0	16.9	17.1	17.2	17.3	17.4
Rocky Mountains	NA	16.1	16.7	17.7	17.9	18.0	18.0	18.0
Pacific Northwest								
Douglas-fir subregion	14.5	16.1	16.7	17.7	17.9	18.0	18.0	18.0
Ponderosa pine subregion	14.3	16.1	16.7	18.0	18.1	18.2	18.2	18.2
Pacific Southwest	14.5	16.1	16.7	17.7	17.9	18.0	18.0	18.0
ORIENTED STRANDBOARD AND WAFERBOARD	Square feet, 3/8 inch basis, per cubic foot, log scale							
North	NA	NA	17.9	18.3	18.3	18.3	18.3	18.3
South	NA	NA	16.9	17.3	17.3	17.3	17.3	17.3
PAPER, PAPERBOARD, AND RELATED PRODUCTS	Tons per ton of paper and board							
Recycled wastepaper	0.32	0.20	0.23	0.23	0.24	0.25	0.25	NA
	Cords of wood per ton of paper and board							
Pulpwood								
Hardwood	NA	NA	0.37	0.45	0.45	0.46	0.47	0.46
North	NA	NA	0.39	0.45	0.45	0.45	0.44	0.43
South	NA	NA	0.43	0.49	0.51	0.51	0.54	0.54
West	NA	NA	0.10	0.14	0.14	0.14	0.14	0.14
Softwood	NA	NA	0.85	0.74	0.71	0.68	0.66	0.65
North	NA	NA	0.23	0.16	0.16	0.15	0.16	0.15
South	NA	NA	1.05	0.96	0.92	0.89	0.88	0.87
West	NA	NA	1.72	1.64	1.61	1.61	1.60	1.61
Total	1.08	1.20	1.21	1.18	1.16	1.14	1.13	1.11

[a]Preliminary projections. Paper and paperboard figures under 1985 are for 1986.

been identified over which veneer of satisfactory quality can be produced even from wood with very small diameters. This has major implications for the plywood industry because plywood can be produced from smaller logs that are lower in cost than traditionally sized peelers, and yet recoveries can be kept high enough to make the processing of such logs economical.

Plywood product recovery projections mirror these developments (Table 1). Recoveries are projected to rise sharply between now and 2000. Despite much lower diameter logs that we expect will be processed in 2000, the gain in plywood product recovery should persist. Manufacturing costs will fall (Table 2) during this time. If we were to include wood costs as well, total costs would reach levels near those for nonveneered structural panels because of the smaller, cheaper timber that we project will be utilized.

Pulp and Paper

We also looked at technological developments in the pulp and paper industry. We identified many (29 categories) likely developments in pulp and paper process technology that range from ongoing commercial developments, such as changing market requirements for corrugated boxes, which stress higher compressive strength, to distant future developments, such as biological pulping (biopulping), which could be used as a pretreatment, lowering energy needs for mechanical pulping.

Table 2.--Processing costs[a] for wood products for 1952, 1976, and 1986, with projections to 2040.

Product and region or category	1952	1976	1985	Projections 2000	2010	2020	2030	2040
SOFTWOOD LUMBER	1982 dollars per thousand board feet							
South	60	89	89	79	77	74	70	68
Pacific Northwest								
Douglas-fir subregion	100	112	130	131	117	116	102	100
Ponderosa pine subregion	77	100	117	108	103	98	92	87
Pacific Southwest	118	120	119	107	107	99	96	94
Rocky Mountains								
Northern Rocky Mountains	68	105	113	111	111	107	103	94
Southern Rocky Mountains	112	114	125	111	111	107	103	94
SOFTWOOD PLYWOOD	1982 dollars per thousand square feet, 3/8 inch basis							
South	NA	91	82	81	81	80	80	79
Pacific Northwest								
Douglas-fir subregion	123	110	103	99	98	97	97	96
Ponderosa pine subregion	120	95	92	88	88	87	87	86
Pacific Southwest	NA	110	103	99	98	97	97	96
ORIENTED STRANDBOARD AND WAFERBOARD	1982 dollars per thousand square feet, 3/8 inch basis							
North	NA	NA	90	87	87	86	86	86
South	NA	NA	87	85	84	84	84	84
PAPER AND PAPERBOARD	1982 dollars per ton of paper/paperboard							
Newsprint	NA	NA	368	367	365	363	361	361
Unbleached kraft board	NA	NA	173	169	166	162	159	158
Semichemical board	NA	NA	206	206	206	205	205	204
Recycled board	NA	NA	234	234	234	234	234	234
Solid bleached board	NA	NA	460	437	428	419	412	408

[a]Preliminary projections. Processing costs exclude wood cost and revenue from sale of mill residue. Paper and paperboard figures under 1985 are for 1986.

Some of the more significant developments, which are judged by industry experts as very likely to occur, are as follows:

1. Gradual displacement of chemical wood pulps (produced using the sulphate or sulphite pulping process) by modern mechanical wood pulps, such as those produced by the thermomechanical (TMP) or chemithermomechanical (CTMP) process. These processes have significantly higher pulp yields than the older processes and thus result in lower pulpwood requirements, and they can process a higher proportion of hardwoods, such as aspen.

2. Improvement in recovery and use of recycled fiber. Examples of ongoing developments include improved screens, improved deinking systems, better removal of contaminants (as with the disk separator developed at FPL), and high-consistency refining. Also, chemical and enzyme treatments are being developed to restore bonding strength of recycled fibers. These and other improvements will lead to much greater use of recycled fiber and less use of virgin wood fiber, especially in products such as tissue, newsprint, kraft linerboard, and corrugating medium.

3. In the printing and writing paper grades, especially coated papers, market competition is increasingly based on print quality; print quality requirements and standards are rising. Technological developments aim toward providing higher quality papers by increasing the amounts and types of clay coatings, pigments, and other fillers. To some extent, these developments reduce the amount of wood fiber used. But the use of hardwood fiber, which improves the printing quality of paper, is increasing.

These process changes and improvements will lead to two general consequences important for forestry: (1) increased recovery of pulp from a given amount of timber and (2) ability to utilize a greater variety of timber species, especially hardwoods, in the manufacture of paper products.

IMPLICATIONS OF TECHNOLOGICAL CHANGES FOR FORESTRY

Because of the growing competition facing wood products, foresters will need to be aware of the end uses of timber. Moreover, technological changes in sawmilling, manufacture of structural

panels, and pulp and paper processing will require changes in forest management prartices.

Factors Affecting Timber End Use

Wood can be categorized into three general types of end use: substance (e.g., pulp, wafers) structure (lumber, plywood), and surface material (furniture, paneling). The end use of wood is important because best management practices for growing wood differ for various end uses. For example, if wood is to be grown for substance only, then the best management is to maximize the volume of fiber produced per unit of time. If wood is to be grown for structural and surface uses as well, then volume maximization may not produce the desired results.

Factors that affect the end use of wood include growth rate, presence of juvenile wood, and tendency of small diameter wood to warp.

Growth rate affects the properties of timber peeled for veneer. Experiments conducted at FPL (Lutz 1964) indicated that fast grown wood, in contrast with slow grown wood, tended to produce rougher veneer because of shelling (separation of springwood from summerwood as wood passes under the pressure nosebar ahead of the knife) and deeper, more pronounced lathe checks. Furthermore, the veneer delaminated more easily. In general, fast grown softwood timber with a higher proportion of lower density springwood tends to be weaker than slower grown timber.

The presence of juvenile wood also affects the end use of wood. Juvenile wood refers to the wood near the pith, which is markedly different in texture and lower in density than wood laid down in the outward rings. In many species, the density of the wood increases until the 10th to 15th ring. At this point, the rate of density change slows and the wood subsequently is termed mature. Juvenile wood is the wood located behind the mature wood (back to the pith). When dried, wood shrinks very little lengthwise, but juvenile wood is an exception. A board consisting partly of mature wood and partly of juvenile wood shrinks unequally during drying, which causes it to bend toward the side with the juvenile wood. Even if the entire board consists of juvenile wood and remains stable, the strength of the piece will be lower than accepted values for the species. A few such pieces in a structure such as a wall should not cause a problem, but many such pieces can compromise building integrity, leaving the structure prone to failure under severe loads.

Sawmills and plywood mills will be increasingly able to economically process smaller timber, but they will not be able to strengthen weak wood. Live sawing and drying flitches before ripping them to final dimensions could help produce straight lumber from warp-prone wood, but the cost of processing may increase.

Forest Management Practices

Consider how stands of timber develop in nature. Typical old-growth trees grew slowly in dense initial stockings with consequent small, confined juvenile cores and many narrow growth rings. If our purpose is to grow timber for structural applications, shouldn't we try to follow some aspects of this natural model in our management? One way is to overlap rotations: one crop is planted and established on the site while trees from the previous crop still occupy much of the canopy. This may or may not be economically feasible. One matter is clear--the end user of structural wood is not interested in obtaining so many board feet of lumber per se. Rather, he or she wants so many board feet of lumber with specific physical characteristics, such as a certain level of compressive strength, tensile strength, and dimensional stability. If timber producers are unable or unwilling to provide this, then should we be surprised if users turn to other sources to meet these requirements, such as Canadian Spruce-Pine-Fir, reconstituted structural wood products, or even nonwood materials?

Another management issue concerns species selection. We spend large sums on site preparation to ensure the establishment of single species conifer stands. In view of the increasing ability and even requirement to use hardwoods in papermaking, this practice may need to be reconsidered.

Finally, for the purpose of growing wood for surface applications in a plantation setting, it may be worthwhile to consider artificial pruning. Pruning is expensive and not amenable to mechanization, and it is not generally practiced in U.S. forestry. However, data on the benefits of pruning, in terms of higher grade recovery, are appearing (Cahill et al. 1988), which indicate that pruning may be worth considering as a silvicultural tool.

CONCLUSION

Foresters need to think about projected changes in timber utilization. They need to consider how management regimes can impact on timber quality in terms of the final intended use for the timber. A great many variables play a role, and analytical models (e.g., Briggs et al. 1987) may need to be used to determine the optimum strategy for various intended applications.

LITERATURE CITED

Briggs, David, Roger Fight, and Craig Buhler. 1987. The role of utilization in planning silvicultural regimes. In Proc., 1987 SAF annual convention.

Cahill, James, Thomas Snellgrove, and Thomas Fahey. 1988. Lumber and veneer recovery from pruned Douglas-fir. Forest Prod. J. 38(9):27-32.

Lutz, John. 1964. How growth rate affects properties of softwood veneer. Forest Prod. J. 14(3):97-102.

Szymani, R., L. Trinchera, and J. Turner. 1987. Use and maintenance of thin circular saws at California Cedar Products Company. Holz als Roh- und Werkstoff 45:319-322.