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RED ALDER: OPPORTUNITIES FOR BETTER UTILIZATION OF A RESOURCE

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Helmuth Resch

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Introduction

The volume of native red alder (*Alnus rubra* Bong.) in stands along the Pacific coast of the northwestern United States has increased during the last two decades, but utilization of the wood has not kept pace, although both commercial practice and studies have shown that alder wood has properties suitable for many products. Processors and users need to know these properties in order to find the best uses for the wood and the optimum ways of converting it and marketing it for profit.

This paper describes opportunities for better utilization of the alder resource in the Pacific Northwest and identifies specific research needed before such opportunities can be realized (Resch 1982). It is a compendium of information from conversations, correspondence, and reports of people in industry, universities, and research organizations. The following researchers responded to the author's request for suggestions for future research: D.G. Briggs and W.R. Smith, C.A. Eckelman and D.A. Cassens, C. Kozlik, M.L. Laver, H.A. Huber, and J.B. Wilson (see Suggested Research, page 14).

Access to the Resource

Suggested research activity:

- **Determine optimum locations for conversion plants**
- **Improve timber-sale procedures**
- **Develop yield tables**
- **Determine optimum size and combination of machines for felling, bucking, yarding, and transportation.**
- **Determine logging costs for different sta nd configurations**
- **Implement a quality-control program for the manufacture of lumber**
- **Construct a computer-based decision-making program for optimum bucking, sawing, and edging.**

Inventories

Inventory statistics for red alder have been published in a series of resource bulletins by the USDA Forest Service Pacific Northwest Forest and Range Experiment Station (Table 1) and have been summarized for western Oregon by Gedney (1982) and for non-federal forest land in southwestern and northwestern Oregon by Gedney, Bassett, and Mei (1986a,b).

Red alder invades areas that have been logged, cleared by fire, or abandoned. It regenerates easily and quickly and often dominates within a few years. Currently, it covers 13% of the commercial forest land along the Pacific coast of Washington and Oregon and comprises 13% of the net annual growing stock. Although the volume of growing stock is only 7% of the total timber available in the coastal area, and the volume of sawtimber is only 4% of that of all stands, net annual sawtimber growth is 10%.

During the last two decades, the average per-acre volume of hardwood increased significantly on timber lands held by the forest industry and other private land owners, who now hold about 76% of the area stocked with alder trees, 72% of the volume of growing stock, and 79% of the sawtimber volume. Washington has a larger area stocked by alder and a far greater volume available for growth and harvest than Oregon. Of six northwest subregions (Table 1), the Puget Sound area contains the most acreage and volume of alder wood. The greatest volume of growing stock is in the three classes ranging from 9- to 14.9-inch diameter at breast height (dbh). Most sawtimber volume is contained in the diameter classes between 11 and 14.9 inches, although much timber grows to 29-inch dbh.

A close look at the inventory data will be needed before planning new utilization plants. It would be helpful if economists and timber-inventory specialists would analyze the existing data base and, if necessary, obtain more information with the purpose of determining optimum locations for alder conversion plants. Transportation facilities, population, employment, income, and property evaluation will need to be considered. Potential timber availability has to be compared to mill technology, efficiency, and capacity. The availability of timber in the vicinity of a proposed site may not be the most important factor for small sawmills; however, for production of pulp, structural flake-

TABLE 1.

RED ALDER COMMERCIAL FOREST LAND IN THE COAST AREAS OF OREGON AND WASHINGTON.

Region	Area (thousand acres)	Growing stock: Volume	Growing stock: Growth	Growing stock: Mortality	Sawtimber volume (billion bd ft, Scribner)	Source
		(million cu ft)				
OREGON						
Southwest	350	680	22.8	7.2	2.5	Bassett 1977
West-central	389	753	22.2	8.5	2.8	Jacobs 1978
Northwest	554	1,113	50.0	8.6	3.5	Mei 1979
WASHINGTON						
Southwest	550	1,318	55.0	6.9	4.4	Bassett and Oswald 1981
Olympic Peninsula	47	1,610	62.5	8.9	5.3	Bassett and Oswald 1981
Puget Sound	68	1,726	65.8	9.3	5.9	Bassett and Oswald 1982
TOTAL NORTHWEST COAST	3,016	7,200	278.3	49.4	24.4	Gedney 1982

board, or oriented strandboard, large amounts of wood must be available over long periods.

Mill owners almost never control sales, which are made mainly for conifer logs, with alder logs being only a by-product. Administrative hurdles appear to block sales of pure alder stands on U.S. Forest Service lands. Even where roads are in place, areas of less than 15 to 20 acres often cannot be sold efficiently because of the costs of administration and reforestation. Apparently Forest Service managers cannot justify such small sales. Alder-mill owners believe that even 5 acres could be sold if there were road access and if the reforestation goal was not pure conifer stands. The complexity of purchasing timber from the federal government might be overcome by changes in procedure and attitude, although measuring and pricing difficulties will still exist, and loggers will have to overcome a lack of enthusiasm for harvesting what they have perceived to be "junk" materials.

Harvest and Transport

Although a harvest-inventory assessment has recently been made for Oregon and Washington (Funck et al. 1986), information on the harvest and transport of Pacific Northwest hardwoods is not yet sufficient. Research must focus on the size and form of products to be manufactured, on silvicultural goals and constraints, and, of course, on stand characteristics. There appear to be no data on the broad range of forest conditions, such as slope and stand density, or on such things as tree size and branching form. The economic constraints that may limit the type of harvesting and its location should be investigated.

With ground-, skyline-, or helicopter-based operations, planning is difficult because the proportion of sawlogs to total available alder is difficult to judge. "Grading-out of sawlogs" is important when selecting stands for harvest. For this, yield tables are needed. Tariff tables, published by the Department of Natural Resources in Olympia, Washington, do not include a grade or quality component, only cubic-foot volume. Log segregation and number of landings cannot be determined accurately without knowing the relationships between log size, weight, and ultimate product.

Felling, limbing, and bucking is more difficult with a brittle wood such as alder than with conifer wood. Breakage is high during handling; tree form may cause difficult handling and loading; and--with ground operations--it is difficult to maximize cycle times and loads of mechanized equipment. If hardwood stands are to be managed as a commercial enterprise rather than be eliminated as a pest species, data on felling, bucking, loading, processing, and hauling must be acquired. George Brown and John Garland of the Department of Forest Engineering, Oregon State University, have identified the following research needs (personal communication 1982).

Felling

Logging on steep slopes is a high-cost operation that is very difficult where the slope exceeds 40% at the stump. In the slope range from 20% to 30%, heavy equipment is underutilized and logging with it is costly. Use of three kinds of existing equipment should be investigated: feller-bunchers that could also be used for prebunching; small skylines, such as those used in Europe; and helicopters, such as those used in Philomath, Oregon in 1982 for production of pulp chips.

Felling production with a chain saw on steep terrain should be investigated where alder is being clearcut or partially cut--especially where it is being removed from mixed conifer-hardwood stands or where it may fall among conifers.

Bucking

Briggs (1980), summarizing studies of bucking hardwoods and conifers, estimates that common practices reduce the potential value of a tree by about 20%, but the actual difference between typical and optimum practice is unknown. Buckers may waste volume and value by selecting a poor combination of end uses, or they may not properly apply log-grading rules, overlooking defects or variations in tree shape, which can seriously reduce product recovery. To optimize bucking, some investigators have used linear programming and others, dynamic programming (Briggs 1977, 1980). The latter seems to be more flexible and to allow comparisons of marketing strategies based in part on tree and log shape. University of Washington researchers have developed a dynamic program combining bucking, live sawing, and lumber edging.

The capability of a computer to determine various Douglas-fir log mixes has been shown in a test of computer-aided bucking at the stump. Log grades were predicted from surface characteristics (Garland et al. 1988). Although increase in log volume was negligible with the computer solution, a greater percentage of the volume was in high-value logs.

Bucking and limbing should be guided by costs and production rates. Most important, therefore, is research that would compare the advantages of different sized yarders and crews, and the production of yarding systems that process logs at the landing versus those that process them in the woods. Such comparisons should be made for full trees, whole trees, log lengths, and tree lengths. An analysis of bucking trees and rebucking long logs into finished log sizes has been suggested (Briggs and Smith 1982). Alder trees and long logs would first be characterized by dimensions and defect. The data obtained could then be digitized, statistically assembled in a computer, and analyzed for optimum bucking solutions. Actual bucking operations could then be compared with the theoretical results.

Yarding

A detailed time and motion study by Kramer (1979) provides information on yarding, but production data need to be expanded to include harvesting conditions that span the range of obtainable yarding production rates. This assessment should include damage to residual trees where alder is removed from mixed hardwood-conifer stands. Yarding mechanics should also be defined. The weight of red alder of various sizes, including tree-length logs, and the weight of whole trees should be calculated and verified in the field, then entered into payload analyses for yarding systems. The buckling length of alder trees must be determined, if they are to be used as intermediate supports. Information is needed to guide the design of intermediate supports for multi-span yarding systems, and the stability of trees to be used for tail trees and tail-hold anchors should be determined as important criteria for the design of skyline configurations and for analyses of payload.

Loading, Chipping, Hauling

Loading is difficult when alder trees are crooked and therefore do not pack well onto trucks. A variety of sorting and loading schemes should be defined in order to make loading procedures more efficient.

If logs are to be chipped instead of hauled directly, methods should be developed for balancing production of the yarder, skidder, and chipper in the most efficient combination. Whole-tree chipping may offset the piece-count problem and may yield 5% to 35% more chip volume than chipping of boles alone.

Researchers have recently assessed the availability of wood fuel in the Pacific Northwest in order to determine the best location for a 10-megawatt power plant (Wilson et al. 1987, Funck et al. 1986). In the Lake States, hauling of different-sized material in various vehicles has been well investigated for energy-processing facilities. Adaptation of the findings to conditions in the Pacific Northwest would be useful.

Sawmilling

Suggested research activity:

- **Refine information on lumber grade recovery from different log grades and diameters**
- **Test sawing techniques for optimum lumber recovery and mill efficiency**
- **Improve kiln schedules to reduce residence time and the development of defects, especially chemical staining**

The Northwest Hardwood Association of Portland, Oregon, founded in 1955, now has more than 100 members engaged in sawmilling, logging, remanufacturing, and marketing lumber. Its members produce and market materials for household furniture, commercial and office furniture, kitchen cabinets and vanities, pallets and containers, specialty products and turnings, and mill work and dimension lumber. They have developed a quality-control program to assure uniform grades, and, after working with the Pacific Lumber Inspection Bureau, have qualified for grade stamping of their lumber.

An assessment of the Pacific Northwest hardwood industry (Cunningham and McMahon 1977, Beachy 1986, R.O. McMahon personal communication) shows an increase in lumber production and output of residual products, resulting in increased total value of sales from primary and secondary manufacturing operations (Table 2).

Lumber Grade and Volume Recovery

To meet market demands and to produce items for targeted markets, the sawmill manager must know and control the details of conversion. Lumber grade recovery appears to be correlated with log diameter. The Department of Natural Resources of the State of Washington has investigated that relationship with the help of producers, some of whom believe that the lumber and monetary yields that were found are too high.

During recent years, logs have been purchased under Puget Sound Log Scaling Rules (grades 1, 2, 3; diameter classes 4-7, 8-9, 10-11, 12-14, 15+ inches) or under Columbia River Grading Rules, which are used in resale. Most sawmillers convert their logs to lumber graded

TABLE 2.

ECONOMIC ASSESSMENT OF THE HARDWOOD SAWMILL INDUSTRY IN THE PACIFIC NORTHWEST.

Production and employment	1977	1980 (estimate)	1985
Lumber production (million bd ft)	146	159	229
Residue production (1,000 dry tons)	328	320	407
Sales ($ million)	53.6	76.9	95.0
Value added by manufacture ($ million)	28.1	--	48.9
Value added (percentage of shipments)	52	--	52
Employment by sawmills	1,085	1,240	971
Payroll ($ million)	11.9	18.1	19.6

KD-Shop, KD-Select, #1, #2, #3, and framing--or to chips and pallets.

Statistics on end-product recovery are strongly influenced by the different breakdown techniques used by the industry. In some mills, the head rig may be a large circular saw; in others, the bandsaw is the main component for log breakdown. Edging, trimming, kiln drying, and planing of boards generally follow common practice, but one company uses abrasive planing (sanding), claiming it is superior to knife planing, which apparently causes splits and thereby loss of value.

Managers generally believe that the highest value is obtained by sawing "around" for the highest yield in grade, but to accomplish this, an experienced sawyer familiar with hardwood grades is needed. Apparently, models for hardwood-log sawing are not yet found in the Northwest hardwood industry. The grades of the National Hardwood Lumber Association, which have been used in the mathematical description of models for hardwoods, don't describe alder lumber grades. Nevertheless, the deviation is not great and would not prohibit implementation. It would be worthwhile to implement a recently published procedure and computer program for calculating individual machine contribution to sawmill recovery and thus to total mill efficiency (Steele 1981).

An investigation of production of stud grade material from red alder logs (Smith and Layton 1982) showed that warp due to inherent growth stresses is a major problem in recovering high yield. The saw-dry-rip conversion process in which the lumber is live-sawn into flitches, dried at high temperature, and then ripped to final dimensions, appeared to reduce warp approximately 90%. The process relieves a great portion of the growth stresses within a flitch during high-temperature drying. When ripped, the lumber is therefore straighter. If this result, which was obtained on 2-inch dimension material, could also be obtained on 1-inch lumber, total yield of volume and grade could be increased.

Determination of potential recovery and grade could lead to economic analysis of the various conversion processes available. One such study proposal (Briggs and Smith 1982) is for a three-part evaluation: first, of conventional manufacturing practices of alder sawlogs into furniture and pallet lumber; second, of conventional technologies with a theoretical model; and, third, of the saw-dry-rip process for increasing yield and upgrading the lumber.

Kiln Drying

Most hardwood mills of the Pacific Northwest have insufficient kiln capacity to handle sawmill production. For lumber producers who wish to increase their sawmill production or to custom-dry lumber, a reduction in kiln residence time would be advantageous. A large capital investment in new kilns may be unnecessary if some kiln operations and kiln schedules can be modified.

One project of the USDA Forest Products Laboratory in Madison, Wisconsin, has been to improve drying technology and reduce the cost of drying hardwoods. In a cooperative study, Kozlik (1987a) tested a high-temperature (230°F) kiln schedule on unseasoned 4/4-inch red alder lumber and produced good lumber with minimal degrade at 7% average moisture content in somewhat less than half the drying time needed with conventional low-temperature schedules. The boards were a uniform dark tan. They shrank more than is normal, but excessive shrinkage could be removed with a steaming cycle. High-temperature drying might be an alternative to low-temperature drying, with the advantage of reducing kiln residence time 20% to 50%.

Red alder is prone to natural chemical staining immediately after sawing or when it is stored unseasoned. If the stain is deepened on mottled individual boards, the value of boards originally graded "Select" and "Number One" may be reduced. The uniform light brown preferred by furniture manufacturers could be obtained by kiln drying the lumber immediately after sawing, using a high initial humidity and an initial dry-bulb temperature between 130° and 150°F at relative humidity of 90% and higher. In the cooperative study (Kozlik 1987a), sticker stain was eliminated in this way, but some mottling was still serious enough to cause degrading.

Unfortunately, most dry kilns do not have the capacity to reach 212°F with saturated moisture conditions. For this reason, Kozlik (1987b) investigated presteaming of partially air-dried lumber to reduce or eliminate mottling. Because most commercial kilns can reach only 150°-180°F, presteaming was in that temperature range. Kozlik found that color was most uniform with a presteaming treatment lasting 24 to 30 hours at 170°F dry-bulb temperature and 5°F wet-bulb depression.

Secondary Manufacture

Suggested research activity:

- **Determine furniture-manufacturing trends and how alder can be marketed most advantageously**
- **Develop a computer-based furniture-cutting program that will meet specific cutting schedules and increase yield**
- **Test alder furniture parts--especially joints--in order to be able to predict the performance of furniture frames and case goods**
- **Develop techniques for bending alder for furniture parts such as chair backs**
- **Determine if heat conditioning of bolts before peeling veneer will improve veneer quality**
- **Promote acceptance of plywood and composite panel products under performance standards published in 1981**
- **Determine the merit of hot-press drying of veneer for use in decorative plywood**
- **Investigate the feasibility of a western Oregon or Washington wafer or flakeboard plant designed especially for utilizing smaller trees not suitable for lumber production**

Secondary manufacturing operations are estimated to have about 6.4 times the employees and 5.8 times the payroll of sawmills. The contraction in employment in the past recession was apparently mitigated by increased efficiency of mills, and the industry should continue to grow as the general economy improves.

A significant amount of overlap in uses of hardwoods, softwoods, particleboard, hardboard, fiberboard, and plywoods has to be considered in marketing. Hardwoods are traditionally marketed through wholesale distribution yards that generally supply small manufacturing operations and only occasionally large ones. Trends in the furniture market certainly affect the hardwood mills in the Pacific Northwest. The North American Furniture Manufacturers reported annual furniture sales of about $18.6 billion in 1979 and 1980, of which 27% and 17% were shipments of manufactured wood and upholstered furniture, respectively.

Furniture Manufacturing

Mass production of furniture originated in the central and eastern United States because of the availability of hardwoods and the proximity of population centers. In the traditional furniture manufacturing areas, relatively inexpensive but attractive materials such as alder have become substitutes for high-value woods. During the last decades, the population shift to the west and southwest has created an opportunity for the use of alder wood near its growth areas in the Pacific Northwest. Alder has become attractive not only for its price but also for its anatomical and physical characteristics (Resch 1980). A close-grain texture ideal for printing, ease of working, and good dimensional stability with little change in moisture content make it desirable.

Cutting Yield

Good yield of cuttings from different grades of lumber is the key to profitable marketing. A satisfactory sale rests largely on matching different lumber grades with the cutting schedule of items and the specific surplus needed for a final product, such as a piece of furniture. Sellers and buyers determine the best lumber grade for a given product. Once the buyer knows the amount and grade of lumber needed to meet a specific cutting schedule, the lumber mill must assure that the grade remains consistent. Quality control may thus provide the necessary competitive edge. When a hardwood user knows the specific size of parts yielded by the grade of lumber purchased, he can make his own cost calculations. The costs of cutting labor or board foot per piece for different species and products will influence the purchasing decision.

Schumann (1972) published yield tables on alder lumber that may be compared with those for dimension stock lumber of maple (Englerth 1969) and walnut (Schumann 1971), pointing the way to potential yield improvements. In 1977, Huber (H.A. Huber, personal communication 1982) developed a computer program using the basic yield table in conjunction with a linear program that included costs. This made possible an economic evaluation of hardwood lumber species by grade. This "Optimum Furniture Cutting Program" has been modified and has found wide use by industry and the U.S. Forest Service for resource-efficiency analyses. However, it has not been used for alder. A sample calculation made for 4/4-inch alder lumber and a portion of the output is given in Table 3.

TABLE 3.

OPTIMUM FURNITURE CUTTING PROGRAM FOR RED ALDER, 4/4-INCH THICKNESS.

COST SUMMARY

Net cost of cutting bill	$8,096

GRADE UTILIZATION SUMMARY

Grade No. 1 Shop

Amount to be purchased	9,448 fbm
Amount to be cut in mill	9,448 fbm
Yield from grade	59.3%
Salvage yield from grade	3.0%
Cost	$6,261

Length (in.)	Width (in.)	No. cuttings
48 0/8	2 6/8	1,500
39 0/8	3 0/8	1,387
28 0/8	3 0/8	1,000
21 0/8	2 4/8	1,500
16 0/8	14 0/8	1,265
12 0/8	3 0/8	1,134

Grade No. 2 Shop

Amount to be purchased	3,408 fbm
Amount to be cut in mill	3,408 fbm
Yield from grade	48.2%
Salvage yield from grade	4.4%
Cost	$1,879

Length (in.)	Width (in.)	No. cuttings
39 0/8	3 0/8	613
16 0/8	14 0/8	735
12 0/8	3 0/8	605
12 0/8	3 0/8	605

COST AND BOARD FEET

Cost/piece	Fbm/piece	Total fbm	Fbm, %
$0.53	0.58	583	7.6
1.06	0.92	1,375	17.9
0.98	0.81	1,625	21.2
0.39	0.36	547	7.1
1.72	1.56	3,111	40.5
0.02	0.25	7,676	100.0

TOTAL YIELD AND SALVAGE

Total amount to be cut	12,856 fbm
Yield from all grades	56.3%
Salvage yield from all grades	3.4%

In order for alder to become competitive with other furniture-grade hardwood species, economic comparisons must be made by grade. The first step is to determine comparative yields of clear pieces produced by equivalent grades of each species. Cost for transportation, kiln drying, inventory, and stacking could then be added to cutting costs for a realistic estimate. Earlier data developed for alder lumber could be verified in re-manufacturing plants. The competitive position of alder can then be established and realistic guidelines can be drawn for marketing.

Strength Properties

The designer of furniture must consider three separate but closely related aspects (Eckelman and Cassens 1982): first and most important is aesthetics, second is function, and third is engineering. The aesthetic requirements of a piece of furniture will dominate in most cases; however, consumer demand for more reliable and economical products make engineering increasingly important.

Alder wood may have drawbacks. Its low specific gravity, an advantage when working and staining the material, means lower strength properties. This must be considered when alder wood is substituted in furniture parts for woods of higher strength. Especially critical are joints constructed with adhesives and mechanical fasteners. Often, alder is not available in the desired long length. Shorter cuttings have to be doweled, finger-jointed, or connected in other ways.

Eckelman and Cassens (1982) of the Furniture Research Center at Purdue University have proposed mechanical testing of the strength of red alder furniture parts and furniture joints constructed with adhesives and mechanical fasteners. A further research objective would be to develop performance-test data on furniture frames and case goods and to compare the data with that for more traditional species. The experimental design would be based on all available information on the suitability of red alder for manufacturing furniture and on substitutions made to determine the modifications in size and fastening techniques required for safe use of this wood.

In the Pacific Northwest, the several furniture manufacturers who use alder face the costs of long-distance transportation, which is expensive because of the large volume of the finished product and the expensive protection and special loading required. These difficulties have been overcome by shipping semi-finished furniture parts or by producing "knock-down" or unfinished furniture. Such production has been successful for manufacturers near Longview, Washington and in Eugene, Oregon. Investigation of opportunities to expand secondary manufacturing facilities in the Pacific Northwest is overdue.

Bending Characteristics

The capacity of solid wood to be bent to a permanent form is important in furniture manufacture. With such capacity, bent alder might be used for chair backs. In general, wood members can be bent to form various curvatures when plasticized by heating or by softening with chemicals. The treatment medium may be steam, hot water, or liquid ammonia. With the first two treatments, the shape is retained after a setting period in a restraining form. Di-electric heating in a forming press is also possible. With liquid ammonia, the form is retained upon evaporation of the ammonia.

The bending property is based on the capacity of plasticized wood to tolerate compression strain and, to a lesser degree, increased deformation under tension. Variations may occur between and within species in wood structure, moisture content, and response to the plasticizing treatment. The method of bending, the dimensions of a piece, and the radius to which it is to be bent must also be considered.

Moisture content of the bending pieces is important. Wood in which cell walls are nearly water saturated but in which the lumina is free of water can be softened and bent most easily. If free water is present in the lumina, more bending force is required. After wood is steamed or boiled, grain may raise or splinter on the concave side during drying. The higher the initial moisture content during bending, the longer the time required for drying and setting the bend afterward. If the moisture content is low, water must be added to the wood, principally to the surface fibers that undergo the greatest stress in the bending operation. In most cases, plasticizing with hot water or with steam at atmospheric pressure has been the most practical approach. Steaming is suggested for wood above 25% moisture content, and boiling in water for wood below 20% moisture content. Steaming or boiling periods must increase with the thickness of the piece. Because of all these considerations, conditioning the bending pieces to moisture contents between 12 and 28% is often recommended.

There is virtually no literature on the steam-bending properties of red alder; however, some steam bending has been accomplished industrially. Research on the potential for red alder use in bent-wood products is needed. The bending quality may be judged by the percentage of pieces that fail and by the nature of failure. Compression marks should not exceed one-third of the thickness of a piece. All failures should be classified as compression or tension failures due to brashness, splintering, or cross grain; and the cost of the bending operations with the three plasticizing treatments should be evaluated.

Panel Products

Structural Plywood

More than 70 species of wood of varying strengths are used in plywood manufacture as guided by U.S. Product Standard PS1-83 for construction and industrial plywood. Engineering grades are used where physical and mechanical properties are most important and where appearance is secondary to strength. The species are grouped by stiffness and strength into five classifications. Group I contains the stiffest and strongest woods. Red alder falls in Group III.

Some plywood plants now produce structural plywood panels with alder veneer peeled mainly on 4-foot lathes. The veneers are graded A, B, C, D by appearance, A-veneers being the best. Plywood panel grades are generally designated by the grade of face and back veneers, as well as by glueline quality. Alder veneer may be used in any panel governed by PSI-83 except for faces, backs, or cores in Structural I or Class I Plyform. In these panels, alder veneer is permitted for use only as centers. Marine grades do not permit alder at all. The Products Standard is a prescription for manufacture of the minimum product. It excludes alder from some important uses. The standard, however, does not define product use or application.

Performance Standards recently specified for plywood (O'Halloran 1979) are oriented toward end use of the product and do not prescribe how it is to be manufactured. Performance standards assure that the product will satisfy the requirements for a particular end use; therefore, they must define performance criteria and test methods.

In the event that a plywood manufacturing company wishes to use alder veneer in lieu of another wood for flooring and sheeting panels, it could do so provided that it defines the quality and assures adequate performance. To accomplish this, it must conform to "Performance Standards and Policies for APA Structural-Use Panels" published by the American Plywood Association in 1981. Testing includes structural performance under concentrated and uniform loads; wall racking and fastener holding; physical properties such as linear expansion and stability; durability performance of the glue bond; and resistance to molds, bacteria, and elevated temperatures. Product evaluation, reexamination, and trademarking follow a defined outline.

Use of the performance standards may be equally important, or more important, for gaining acceptance of composite panels consisting of reconstituted wood cores with veneer faces and backs.

Observations on manufacturing veneer from alder have been substantiated by interviews. From small-diameter logs, only low-grade veneer for cross bands and core stock have been produced. It has been suggested that the tendency of red alder veneer to split and develop deep lathe checks might be overcome by preheating the bolts in a hot water bath or steaming chamber. The suggestion has apparently not been tried, although a relatively small study could verify a preheating advantage.

Decorative Plywood

Paneling-grade veneer can be produced from bolts with diameters greater than 12 inches. However, knots, especially dead knots, are still apparent in such material and must be patched for face-stock application.

Because of inherent growth stresses in alder trees, the veneer has a tendency to warp, especially during drying in conventional hot-air veneer dryers. Press drying of panel-grade veneer might overcome this problem. At this time, only a few plants have the drying technology for sizable production; however, an investigation of press-drying alder veneers appears to have merit.

Alder-faced plywood could also be used advantageously by western manufacturers of furniture parts who now buy eastern veneers, mainly white fir, to overlay softwood cores and crossbands.

Waferboard and Oriented Strandboard

The waferboard industry, located mainly in the northeastern United States and in Canada, has expanded its share of the structural sheathing market impressively during the last decade. Waferboard is currently manufactured from an abundant supply of aspen roundwood, rather than from residues from sawmilling or plywood production of species used in making particleboard.

Oriented strandboard is an even newer product. Some manufacturing plants began using aspen for its manufacture during 1981. Oriented strandboard competes well in the sheathing market because it has high bending strength and elasticity.

Both waferboard and oriented strandboard are best produced from wood with low density. The wood properties of alder are similar to those of aspen; thus alder is considered to be an easily glued wood. In manufacturing both kinds of boards, technologists conclude that panel density should be at least as high as the density of the naturally grown wood (Larmore 1959; Suchland 1967; Hse 1975) because compaction of the mat to a density higher than that of the original wood assures the necessary contact between particles during pressing, and, therefore, assures efficient resin usage. Excellent interparticle bonding with panels can be assured with a species with low density. In addition, the wood should have tensile and compression strength.

About two decades ago, waferboard was produced commercially in the state of Washington from a mixture of western red cedar and alder roundwood. Later, research by Maloney (1978) showed convincingly that flakeboard can be manufactured from alder with board properties exceeding commercial standards. Flakeboard is similar to waferboard; however, it has smaller and thinner flakes with higher resin content. In that particular study, boards with 6%

phenolic resin and with flakes 0.015-inch thick were produced and tested for physical properties.

Zylkowski (1984) showed that red alder has the desired properties to make good waferboard or oriented strandboard. The latter, at 39 lb/ft^3 density and 3% resin, had properties superior to those of a commercial oriented strandboard made of western softwood. Zylkowski examined process parameters and identified the most efficient combination for meeting commercial standards. A follow-up study by Wright (1987) laid the groundwork for determining manufacturing costs, which are needed for establishing the economic feasibility of board production in the Pacific Northwest. A sensitivity analysis showed that wood and labor costs are the largest components of total costs, but selling price has the greatest effect on the feasibility of establishing an oriented-strandboard plant in western Oregon. The example was a plant with an annual capacity of 75 million ft^2, 3/8-inch basis, that produced a panel with a density of 40 lb/ft^3 and resin and wax contents of 5% and 2%, respectively.

The establishment of a waferboard or oriented-strandboard plant using alder wood depends partly on the availability of a steady supply of raw material. In the northeastern United States and Canada, annual production in various plants may be between 130 and 210 million ft^2, 3/8-inch basis. A smaller plant may require approximately 300 oven-dried tons of aspen wood per day. The raw material is mainly in the form of pulpwood, with some tree-length material ranging from 6 inches to 11 inches in diameter. The productivity of older aspen stands is about 1/3 ton (oven-dry basis) per acre annually. A plant may need 1/2 million acres to supply its raw material.

In the coastal areas of Washington and Oregon, red alder yield may be 2 to 10 times greater than the aspen yield in Minnesota and Wisconsin. Nonetheless, a large area for sustained alder growth must be in the immediate vicinity of a proposed structural-board plant. An advantage may be the possibility of utilizing younger trees with a higher growth rate than the more mature timber used for lumber production. If sufficient forest is available, flakeboard and lumber production, utilizing timber from different diameter classes, could be carried out in the same area.

Energy

Suggested research activity:

• Determine the economic feasibility of converting alder wood and bark into different forms of energy after products of higher value have been extracted from the raw material

• Compare the alternatives of combustion and conversion into methanol or ethanol

Relative to most other North American species, red alder has high forest productivity, with biomass production ranging from 4 to 33 dry tons per acre annually. Commercial harvesting of alder wood for fuel has been considered during the last decade. In general, the market structures determine the form of wood products to be harvested from forest lands. Wood for energy has usually been a by-product of timber harvested for structural or paper products. The marginal cost of harvesting for energy alone was, and still is, high in the Northwest. Even with subsidies, it may be difficult to extract round wood for energy, although this is not true in areas close to population centers where fuelwood can be marketed at prices equal to, or sometimes higher than, the price of logs to be cut into lumber.

In 1974, it was recommended that more accurate productivity figures be established for managed forest plantations. At that time, on Vancouver Island in British Columbia, a thermal-electric generation plant with 150 MW output was considered possible with a sustained-yield plantation of 65 square miles. The technological obstacles still to be overcome are related to loading, hauling, and sorting of coarse residues (and sometimes chipped material); yarding of small material from steep slopes; and multi-piece and multi-function harvesting systems. After 1974, in view of the energy situation, the idea of growing trees for energy only lost much of its attractiveness. Most planners believe that greater economic value can be obtained by first extracting high-value products from the logs and then converting residues into energy, mainly by direct combustion.

In 1986, researchers at Oregon State University completed an in-depth evaluation of generation of electricity from forest biomass. They believed that plants of advanced design and small sizes, specifically 10 MW, would have an advantage in utility planning and plant location. The best estimate of the levelized bus-bar power cost, with a ceramic heat-exchanger system, ranged from $0.051 to $0.102 per kWh for fuel costs ranging from $0 to $2.25 per MBtu. The roughly 55,000 oven-dry tons needed annually for such a plant would have to be made up of residues from logging, plants, and silvicultural treatments. At any one possible location, only about 10% would be from alder.

Methanol

Should energy become scarce again, the conversion of wood into alcohol is still a possibility. Methanol at one time received the name "wood alcohol" because of its production from wood by destructive distillation. A rather small amount, 5 to 12 gallons per cord of hardwood, may be recovered through fractional distillation and other steps.

A better technology for producing methanol from wood is gasification, thermal combustion in the presence of a limited amount of air, to yield producer gas containing mainly hydrogen, carbon monoxide, and nitrogen. Heating values for this gas range from 100 to about 200 Btu's per standard dry cubic foot. Higher heating values ranging around 350 Btu's per standard dry cubic foot are contained in gas that is produced with oxygen instead of air. This gas consists mainly of hydrogen and carbon monoxide. Through additional processing steps, it can be converted to synthesis gas, which contains relatively pure hydrogen and carbon monoxide; and from synthesis gas, high yields of methanol may be obtained by reaction with water and high temperatures in the presence of a catalyst.

The production of methanol from wood appears to require better chemical engineering and a better understanding of fundamental chemical mechanisms as influenced by catalysts. This research need is important not only for utilization of red alder but for conversion of any kind of wood into methanol.

Ethanol

Ethanol is the major raw material used by the petro-chemical industry for synthesis of large quantities of industrial ethanol. Sugar, usually glucose, is the source of ethanol obtained through fermentation with microorganisms. Cellulose, which is abundant, is not as easily converted as other raw materials. Breakdown of the polymer is also possible through hydrolysis by acids or enzymes, the latter being most difficult.

Acid hydrolysis requires a strong acid. Sulfuric acid in a concentration of 72% or more has been used successfully to dissolve the fibrous cellulose. The technology exists to produce ethanol from wood; however, the process has been slow. Karchesy (1982), reviewing methods available for producing alcohol and furfural from southern hardwoods, concluded that fuel alcohol, produced on a small scale by continuous fermentation, might be used for converting hexose sugars to ethanol and pentose sugars to furfural by acid-catalyzed dehydration after ethanol recovery. Even when the lignin residues were burned to meet process-steam requirements, production costs for ethanol were greatly above the prevailing market price.

Research beyond improving the engineering also seems to be required for the hydrolysis step. Different solvent systems for bringing cellulose into solution must become available in order to facilitate more rapid hydrolysis.

The State University of New York at Syracuse carried out research with a twin-screw extruder reactor originally designed by the Werner and Pfleiderer Corporation. The pilot unit with a capacity of 1 ton of raw material per day uses a single-step process to make a fermentable sugar solution as feedstock for alcohol production. Material not converted to sugar is combusted and can be used for producing electricity. Researchers at Georgia Technical University used a Canadian reactor with a pretreatment stage for the production of alcohol, and researchers at Dartmouth University in New Hampshire have investigated the use of a plug-flow reactor.

The USDA Forest Products Laboratory in Madison, Wisconsin, theoretically considered the material balances and by-products obtainable with a two-step process for producing fermentable sugars from southern red oak. In this process, pentose is converted first, as xylose does not ferment readily to alcohol. A second step utilizes the remaining xylose.

To guide large-scale experiments, it appears we should determine kinetic-reaction orders and reaction rates for the production of simple sugars, especially glucose and xylose, from red alder wood. A long-term goal of such research should be the determination of conditions of acid concentration, liquid-to-solid ratio, temperature, and time required for the production of maximum quantities of simple sugars.

Fuelwood for Home Heating

The demand for firewood is no longer restricted to rural areas but has spread to urban areas as well. As a consequence, forests surrounding cities and towns are heavily utilized. Small entrepreneurs near Seattle have bid log prices for alder appreciably above those quoted by manufacturers of lumber. Still, at current prices, wood may be less expensive than other fuels on an effective-Btu basis, provided wood-burning stoves have already been installed.

The development of the fuelwood industry would not only make homes more self-sufficient, but might promote more intensive forestry policies and encourage small-scale operations.

The problems associated with felling, bucking, yarding, and transporting have already been mentioned. What may be needed in addition is an analysis of potential firewood supplies and manufacturing capabilities in key areas. An econometric study for several scales of operation might determine the investment needed, the transportation radii, and the general profitability of operations designed to work in conjunction with conifer logging and thinning operations to convert small-diameter trees not yet useful for lumber production.

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