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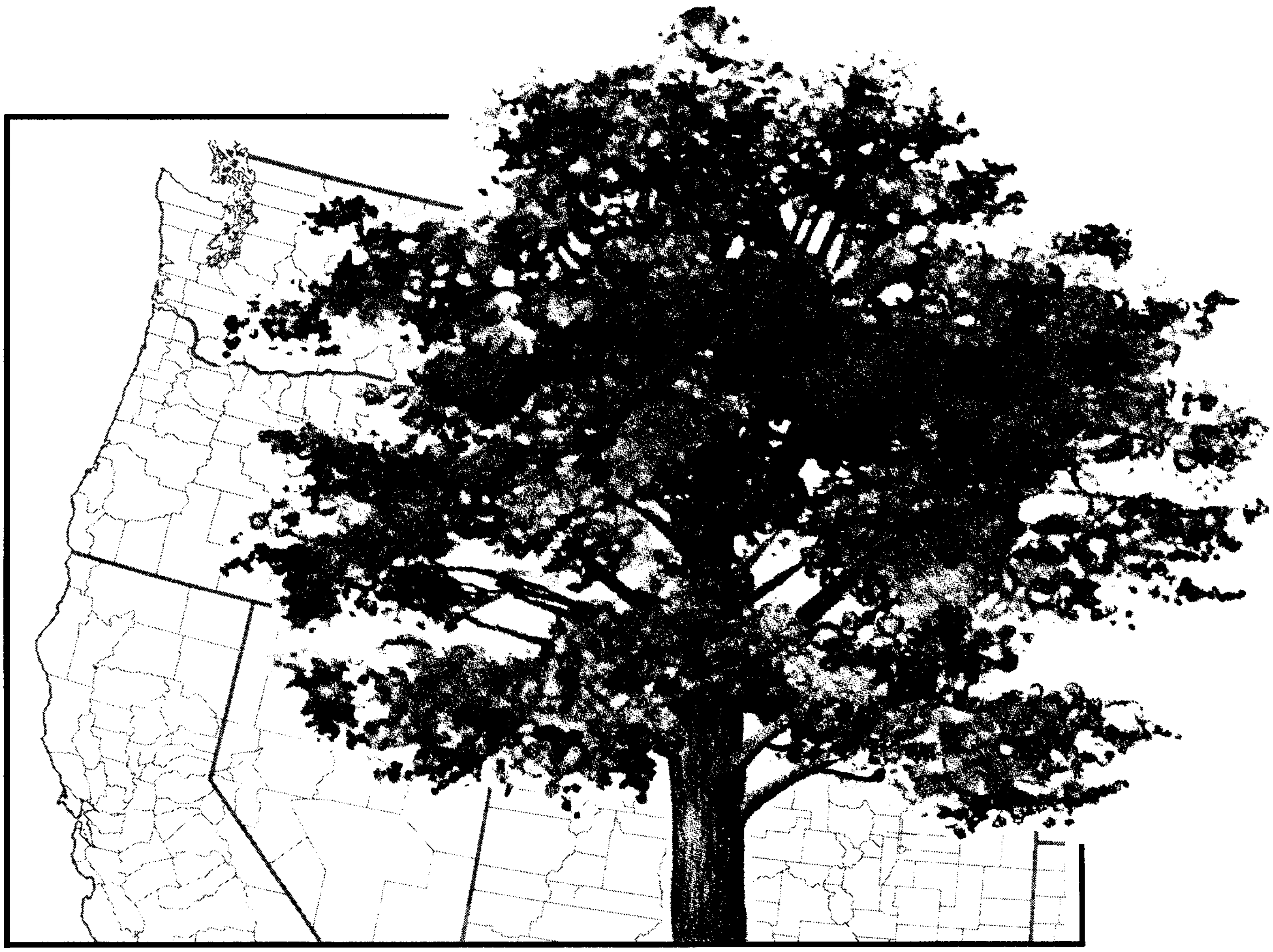
Western Hardwoods
Value-Added Research and Demonstration Program



Abstract

Research results from the value-added research and demonstration program for western hardwoods are summarized in this report. The intent of the program was to enhance the economy of the Pacific Northwest by helping local communities and forest industries produce wood products more efficiently. Emphasis was given to value-added products and barriers to increased utilization. The program was coordinated by the Pacific Northwest Research Station, the Pacific Northwest Region of State and Private Forestry, and the Forest Products Laboratory.

Keywords: Western hardwoods, Pacific Northwest, products, properties, markets, management, policies, pricing, red alder, Oregon, Washington

September 1995

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Highlights

In 1992, a Congressionally funded research and demonstration program was established to help communities and industries in the Pacific Northwest more efficiently use western hardwoods. Studies in this program evaluated several products and processes. The following are the more promising conclusions regarding these products:

- Modem pallet designs require more accurate design data than has been available for red alder pallets. Results of the red alder pallet study, already incorporated into the Pallet Design Software of the National Pallet and Container Association, indicate that pallet load capacity will increase as a result of this new information.
- Studies indicate that red alder and bigleaf maple can be used to produce oriented strand lumber (OSL), a composite product, with properties that equal or surpass those of solid-sawn lumber made from commercial softwood species. OSL may replace nonstructural solid members in the furniture industry or millwork stock in the housing industry.
- Blockboard, a composite product that combines high-value face veneer with low quality wood in the panel core, was successfully produced on a trial basis using red alder, bigleaf maple, and Pacific yew. Results indicate that blockboard be considered as a new value-added product for the Pacific Northwest.
- New edging strategies for red alder lumber indicate that significant revenue could be generated in large vertically integrated mills by removing less material during edging.
- California black oak, Oregon white oak, Pacific madrone, and tanoak may be used for products that would perform similar to existing flooring materials. Typically, these species are left in the woods as slash after a logging operation or end up as firewood or pulpwood.

Lack of information about western hardwoods also hinders efficient use. This research program provided the following:

- Data on drying three hard-to-dry species: chinkapin, madrone, and tanoak.
- Calibration factors for two common types of hand-held moisture meters for nine hardwoods. Precise control of moisture content is critical; previously, only approximate factors could be determined using data from other species.
- A compendium on the biology, management, and processing of 10 western hardwoods. This information had been scattered among many, sometimes obscure, publications.
- Significant information on policy, pricing, and harvesting issues affecting Northwest hardwoods.

The success of this program will be measured by the continued health and diversity of the western hardwoods and the community that depends upon this resource.

Western Hardwoods
Value-Added Research and Demonstration Program

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Preface

To enhance the economy of the Pacific Northwest, a research and demonstration program was established in 1992 to help communities and local forest industries become more efficient in the production of wood products from western hardwoods. Emphasis was given to value-added products and barriers to increased utilization. Funding for the program was provided in the Congressional appropriations process. The program was coordinated by the U.S. Department of Agriculture, Forest Service, specifically the Pacific Northwest Research Station (PNW) in Portland, Oregon, Pacific Northwest Region of State and Private Forestry (S&PF), and the Forest Products Laboratory (FPL) in Madison, Wisconsin.

To craft a program that would create the most benefit, initial input was sought from researchers at the PNW, Oregon State University, Washington State University, and the FPL. Input was also sought from representatives of the western hardwood industry, the Western Hardwood Association, Forest Service rural development coordinators, State Foresters, and state and local economic development organizations. Once general needs were established, proposals were solicited from the researchers and industrial representatives. Follow-up meetings were held with the Western Hardwood Association, the Washington Hardwood Commission, and the Oregon Hardwood Forest Products Research Committee. Critical input and research and demonstration opportunities came from networks and S&PF technology transfer specialists.

Proposals were screened by the steering committee to make sure that they addressed the needs of hardwood producers and had the potential to create job opportunities. Emphasis was given to projects that would create knowledge or products in direct partnership with users. Prior to initiation of the projects, a one-day workshop was held at the World Forestry Center in Portland, Oregon, so that all interested parties could learn about and comment on the scope and intent of the planned studies.

This publication summarizes results of the studies that were conducted as part of the program. The studies are presented in two groups. The first relates to specific products from hardwoods. The second group presents information about the hardwood resource or discusses policy questions. Each summary discusses the objectives and results of a particular study. Contributors are listed in the Appendix as sources of additional information.

Success of this program will be measured by the continued health and diversity of the western hardwood resource and the communities that depend upon it.

Contents

Flexural Strength and Stiffness of Red Alder Pallets

An In-Grade Study

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Red alder has been used for pallet construction for a number of years. During this period, pallet design has evolved through a consensus process. As pallet design has become more sophisticated, a need for proven design values has developed (Loferski and McLain 1987). Experiences with other preferred pallet species and structural lumber have demonstrated that the best way to establish design values is by an in-grade testing program, whereby the materials are sampled from production and tested in the real sizes and grade distributions (McLain and others 1986, Green and others 1989). Therefore, this in-grade project was designed to evaluate the structural properties of red alder for use in pallet applications. This is the first of two studies to optimize the performance of red alder pallets. The second study, Optimizing the Performance of Mechanical Connections and Pallets, follows.

Most pallets are assembled while the lumber is green. For most of their useful life, however, the lumber in pallets is at a moisture content (MC) below the fiber saturation point. In addition, some pallet specifications call for materials to be at or below the 20 percent MC level. Because the effect of MC on the flexural strength and stiffness in lower grades of hardwoods is not well documented, a study of this relationship in wood pallet parts was also undertaken.

For this study, red alder samples were taken over virtually its entire growth distribution in the United States and Canada. The materials were sampled from five different sawmill cooperators, each piece was graded, and the properties for the material determined at three MC levels-green, conditioned (approximately 15 percent), and air dried (approximately 8 percent). The study included deckboards (1 by 4 by 40 in. and 1 by 6 by 40 in.) and one stringer size (2 by 4 by 48 in.). More than 4,500 samples were tested in bending (ASTM 1993a, ASTM 1993b) to develop the data base. Modulus of elasticity (MOE), modulus of rupture (MOR), and the estimated fifth-percentile lower exclusion limit were the primary dependent values of interest. An array of supporting data concerning grade distribution, specific gravity, ring count, and percent earlywood was also developed.

Data from the green moisture condition were immediately applied in the Pallet Design System (McLeod 1995), an internationally recognized program for pallet design supported by the National Wooden Pallet and Container Association.

Summary

Grade Distribution: Grade distributions for stringers and deckboards are given in Tables 1 and 2. The percentage of No. 2 & btr is about the same for stringers and deckboards, approximately 17 percent of production in grades above the expendable and chip materials. There are more stringers (57.5 percent) than deckboards (47.5 percent) in the combination of grades No. 3 and No. 4. As a result, fewer stringers (24.9 percent) were graded as Cull as compared to the number of deckboard (35.8 percent) Cull. The different mill sources varied in the proportion of production within each grade for the stringers. For the combined deckboards, however, no real difference existed in the grade distribution among the five mills.

Effectiveness of Grading: The effectiveness of grading was similar for MOE and MOR in both stringer and deckboard sizes. A Tukey's w-procedure (Steel and Torrie 1960) was used for statistical comparison of means. Results suggest that the grading scheme based on visual characteristics separates the material into only three distinct classes based on the mechanical properties (Tables 3 and 4). A likely three grade system would be No. 2 & btr, No. 3 combined with No. 4, and Cull.

Effect of Moisture Content: The strength and stiffness data are given in Tables 5 and 6 for stringers and combined deckboards at three MC levels. In general, the strength and stiffness increased for all grades and sizes as the pallet lumber dried from fiber saturation to an 8 percent MC level. The rate of strength and stiffness increase was greater for drying between 15 and 8 percent than between fiber saturation and 15 percent. The exception to this was in the stringer Cull grade, where the strength and stiffness was apparently unchanged when the material dried from 15 percent MC to 8 percent MC. In effect, for both deckboards and stringers, each moisture condition had a unique set of strength and stiffness properties.

Drying negatively impacted the estimated 5 percent lower exclusion limit in the lower three grades of the stringer size, but positively influenced the deckboard size. The MOR and MOE distributions became more variable with drying, and in the stringer size, the change in variability more than compensated for the increased strength between 15 and 8 percent MC levels.

The results of this in-grade study of red alder pallet shook have been incorporated in the Pallet Design System, the primary tool for engineering design of pallets. The data from the green testing condition were accepted and integrated into the most recent version of the Pallet Design Software. It is expected that subsequent versions of the software will use the data from the drier conditions. Initial indications using the strength and stiffness of green wood properties suggest that, in general, pallet load capacities will increase by a moderate amount.

Acknowledgment

The assistance of five industrial cooperators-Cascade Hardwoods, Diamond Wood Products, Inc., Goodyear Nelson Hardwood Co., Inc., Morton Alder Mill, and Northwest Hardwoods-is gratefully acknowledged as they made this project possible. They provided the materials, and two of them, Diamond Wood Products, Inc. and Northwest Hardwoods, also provided funds in support of the testing.

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Table 1—Grade distribution by mill source and combined for 2 by 4 stringers

Mill source	Number of specimens	No. 2 & btr (%)	No. 3 (%)	No. 4 (%)	Cull (%)
1	320	20.0	29.0	24.4	26.6
2	344	22.1	32.3	25.3	20.3
3	315	15.6	25.7	39.3	19.4
4	301	13.3	18.3	30.2	31.5
5	320	10.0	31.6	30.9	27.5
Combined	1,600	17.6	27.6	29.9	24.9

Table 2—Grade distribution by mill source and combined for deckboards

Mill source	Number of specimens	No. 2 & btr (%)	No. 3 (%)	No. 4 (%)	Cull (%)
1	633	16.4	21.9	26.5	36.0
2	676	16.4	27.3	22.7	33.4
3	628	18.9	25.0	21.0	36.5
4	606	17.5	24.6	22.9	34.9
5	647	15.3	22.6	22.6	39.6
Combined	3,190	16.7	24.3	23.2	35.8

Table 3—Summary of Tukey's w-procedure for strength and stiffness of pallet stringers at three different moisture conditions

	Green		Conditioned		Dry	
Grade	MOR	MOE	MOR	MOE	MOR	MOE
No. 2 & btr	A	A	A	A	A	A
No. 3	AB	B	AB	AB	AB	AB
No. 4	BC	B	BC	BC	B	B
Cull	C	B	C	C	B	B

Table 4—Summary of Tukey's w-procedure for strength and stiffness of pallet deckboards at three different moisture conditions

	Green		Conditioned		DV	
Grade	MOR	MOE	MOR	MOE	MOR	MOE
No. 2 & btr	A	A	A	A	A	A
No. 3	B	B	AB	AB	AB	B
No. 4	B	B	B	B	B	BC
Cull	B	B	C	C	C	C

Table 5—In-grade properties for red alder pallet stringers, 2 by 4, at three moisture conditions, having all mill sources combined

	Number of	MOE (lb/in^2)		MOR (lb/in^2)			MC[a]	
Grade	specimens	μ[c] (×10^6)	σ[d]	μ	σ	5%	(%)	G[b]
Moisture condition: green								
2 & btr	92	1.118	133,518	5,466	1,008	3,802	47.7	0.44
3	176	1.019	133,449	4,947	986	3,320	49.5	0.44
4	131	1.002	134,213	4,666	1,054	2,927	48.2	0.44
	131	0.910	157,588	4,166	1,154	2,262	48.2	0.45
Moisture condition: conditioned, ~15%								
2 & btr	93	1.234	149,139	6,410	1,094	4,605	16.4	0.44
3	159	1.157	136,452	5,732	1,147	3,839	15.8	0.44
4	181	1.131	158,737	5,395	1,275	3,291	15.9	0.44
Cull	114	1.031	189,875	4,857	1,342	2,642	15.4	0.45
Moisture condition: dry, ~8%								
2 & btr	96	1.356	204,326	8,098	2,039	4,733	8.3	0.44
3	106	1.268	175,032	6,795	1,911	3,641	8.4	0.44
4	167	1.218	154,886	6,385	1,882	3,279	8.3	0.44
Cull	154	1.165	205,909	5,709	2,257	1,985	8.3	0.44

[a]MC: moisture content.
[b]G: specific gravity based on oven-dry weight and dimensions.
[c]μ: mean.
[d]σ: standard deviation.

Table 6—In-grade properties for red alder pallet deckboards, 1 by 4 and 1 by 6, at three moisture conditions, having all mill sources combined

Grade	Number of specimens	MOE (lb/in^2) μ[c] (x10^6)	σ[d]	MOR (lb/in^2) μ	σ	5%	MC[a] (%)	G[b]
Moisture condition: green								
2 & btr	173	1.418	272,242	6151	1,216	4,144	48.8	0.44
3	303	1.256	240,404	5542	1,178	3,598	49.1	0.44
4	246	1.243	222,463	5451	1,263	3,367	48.9	0.45
Cull	315	1.157	226,368	5095	1,202	3,112	48.2	0.45
Moisture condition: conditioned, ~15%								
2 & btr	196	1.550	263,844	8127	1,574	5,530	14.1	0.44
3	254	1.464	209,357	7568	1,393	5,270	14.1	0.44
4	246	1.418	226,891	7121	1,489	4,664	14.3	0.45
Cull	396	1.271	229,966	6171	1,626	3,488	14.4	0.45
Moisture condition: green								
2 & btr	170	1.787	244,767	10,656	1,972	7,402	7.8	0.45
3	219	1.653	247,726	9385	2,003	6,080	8.0	0.45
4	247	1.562	228,028	8516	1,881	5,412	8.0	0.45
Cull	442	1.535	797,022	7413	2,005	4,104	8.0	0.45

[a]MC: moisture content.
[b]G: specific gravity based on oven-dry dimensions.
[c]μ: mean.
[d]σ: standard deviation.

Red Alder Pallets

Optimizing the Performance of Mechanical Connections and Pallets

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Introduction

This summary reports the results from the second of two studies that were conducted to evaluate the performance of red alder pallets. The two-phase project reported here quantified and optimized the performance of red alder as a pallet material. Phase I determined the basic strength and stiffness of typical pallet connections using threaded nails. Phase II evaluated the effect of lumber and nail quality on the resistance of red alder pallets to damage by rough handling. These two phases are discussed separately below.

Phase I-Predicting the Strength and Stiffness of Red Alder Pallet Connections Fastened With Helically Threaded Nails

Density is currently used as input to models that predict the connection strength and durability performance for pallets. These models were originally developed from data for higher density wood species and have not been tested for lower density species such as red alder. Consequently, an empirical study was developed to predict the strength and stiffness of laterally loaded, helically threaded nail joints that are typical in block pallet connections.

Objectives

The objectives of this phase of the project were to develop methods to measure and predict the strength and stiffness of red alder nailed pallet connections that were subjected to repetitive loading, to determine the effect of different deckboard thickness on the strength and stiffness of the connections, and to determine the effect of other variables, such as friction, moisture content, nail pattern, and number of nails per joint, on joint performance.

Methods

Three thicknesses of red alder deckboards (1/2 in., 5/8 in., and 3/4 in.) were tested. The pallet block specimens were 3-1/2 in. thick, 5-1/2 in. wide, and 6 in. long. Four types of helically threaded nails, commonly used by the pallet industry, were tested. Each nail type had different wire stiffnesses and thread types. Fifteen replications of each joint configuration were tested, resulting in more than 375 joint tests.

Repetitive, cyclic loading was used to simulate the loading that pallets are commonly subjected to when used. This involved applying successive increments of displacement to the nail joint and reversing the load to simulate cyclic loading.

The response after cyclic loading was compared to joints that were tested with only a single application of load up to failure. Some joints were assembled and tested in the green condition; some were assembled in the green condition and allowed to dry to approximately 16 percent moisture content (MC); and some joints were assembled in the dry condition and tested in the dry condition. This allowed us to evaluate the effect of MC at the time of assembly and the changes in MC on the stiffness and strength of the nailed connections.

Two different nailing patterns were used to determine if nail location caused a significant difference in the strength and stiffness of the joints. This information will help optimize pallet connections design. Joints with one, two, and three nails per joint were tested to determine the effect of the number of nails on the strength and stiffness. All variables tested included 15 replications per test, and all joints were tested to failure.

Results and Discussion

After testing, the data were analyzed to determine the effect of the variables on joint strength and stiffness. Also, mathematical models were developed from the data to predict strength and stiffness of the connections while accounting for the selected variables. The mathematical models were used as input in the Pallet Design System (PDS), the computerized pallet analysis design procedure developed at Virginia Polytechnic Institute and State University (VPI&SU).

Phase II-The Effect of Lumber Dimension and Nail Quality on the Resistance of Red Alder GMA-Style Pallets to Damage From Rough Handling

Objectives

The objectives of this phase of the project were to determine the structural durability of GMA-style pallets made of red alder parts, to determine the effect of fastener quality on the structural durability of a GMA-style red alder pallet, and to compare measured durability of red alder pallets with the predicted durability using the PDS model.

Methods

Four versions of a 48- by 40-in., GMA-style red alder pallet design were evaluated for durability. Two dimensions of lumber components, Light Duty and Heavy Duty, and two types of nails, 2-1/4-in., 11-1/2 gauge and 2-1/2-in., 11 gauge, were used (Table 1). All stringers had notches at 6 in. from the stringer end, were 9 in. long, 1-1/2 in. deep, and had 1/2-in. fillet radius. Each pallet was assembled with 84 nails (Fig. 1).

Ten replications of each pallet design were tested in the VPI&SU Unit-Load Material Handling FasTrack, an accelerated rough-handling simulator that includes palletizing, shipping and receiving docks, warehouse racking and block stacking, flow racks, idle pallet storage, and shipping. Handling devices used in the FasTrack included a 3,000 lb capacity counter-balanced forklift and a 4,000 lb capacity electric pallet jack. All test pallets supported a 1,500-lb, full coverage, uniformly distributed flexible unit load. Each cycle through the FasTrack included 15 separate handlings. Damage was observed and recorded after each cycle. Thus, the number of handling cycles that represented damage levels requiring repair was determined.

Results and Discussion

Both Heavy Duty designs exhibited a longer life (average 28 handlings to first repair) than either of the Light Duty designs (average 16.5 handlings to first repair) (Table 2). Nail quality had a minimal effect on red alder pallet durability. The percentage of leadboards requiring repair decreased slightly with the better quality nail (20 to 10 percent for Light Duty, 30 to 20 percent for Heavy Duty). The damage to stringers, however, would have required repair anyway. In general, the FasTrack tests suggest that 85 percent of Light Duty pallets will require a stringer repair after about 16.5 handlings, regardless of nail type. About 70 percent of Heavy Duty pallets will require a stringer repair after 28 handlings.

The PDS durability estimates of the same red alder pallet designs are also summarized in Table 2. In general, the predicted number of handlings to first repair was very close to the FasTrack measured number of handlings to first repair for pallets manufactured with the 2-1/4-in., 11-1/2-gauge nail. However, PDS significantly over-predicted the durability of the pallets manufactured with the 2-1/2-in., 11-gauge nail. The PDS durability model contained a fixed weighting method that predicted the relative impact of each pallet design characteristic on durability. It seems that for pallets made of low density woods such as alder, this weighting parameter for fasteners was too sensitive. Based on observations of damages, the life to first repair in these pallets was determined mostly by stringer splitting and not joint integrity. The results indicate that either the weighing parameters in PDS need adjustment, or the durability of a structure may be better predicted using a weak link based modeling procedure. In this case, the weak link was the stringer end foot.

For Additional Information

Sosa, Hector. 1994. Methodology to predict the strength and stiffness of red alder block pallet connections fastened with helically-threaded nails. Master of Science Thesis. Blacksburg, VA: Virginia Polytechnic Institute and State University, Department of Wood Science and Forest Products. 197 p.

Table 1—Description of the four versions of 48- by 40-in., GMA-style red alder test pallets

Pallet ID	Number of replicates	Pallet description
Light duty 2-1/4 in. nail	10	Stringers: 3 at 1.50- by 3.75- by 48-in. Top deckboards: 0.688-in. thick, 2 at 5.75 in. and 5 at 3.75 in. Bottom deckboards: 0.688-in. thick, 2 at 5.75 in. and 3 at 3.75 in. Fastener: 2-1/4-in., 11-1/2-gauge, helically threaded
Light duty 2-1/2 in. nail	10	Stringers: 3 at 1.50- by 3.75- by 48-in. Top deckboards: 0.688-in. thick, 2 at 5.75 in. and 5 at 3.75 in. Bottom deckboards: 0.688-in. thick, 2 at 5.75 in. and 3 at 3.75 in. Fastener: 2-1/2-in., 11-gauge, helically threaded
Heavy duty 2-1/4 in. nail	10	Stringers: 3 at 1.75- by 3.75- by 48-in. Top deckboards: 0.813-in. thick, 2 at 5.75 in. and 5 at 3.75 in. Bottom deckboards: 0.813-in. thick, 2 at 5.75 in. and 3 at 3.75 in. Fastener: 2-1/4-in., 11-1/2-gauge, helically threaded
Heavy duty 2-1/2 in. nail	10	Stringers: 3 at 1.75- by 3.75- by 48-in. Top deckboards: 0.813-in. thick, 2 at 5.75 in. and 5 at 3.75 in. Bottom deckboards: 0.813-in. thick, 2 at 5.75 in. and 3 at 3.75 in. Fastener: 2-1/4-in., 11-gauge, helically threaded

Table 2—PDS durability estimates versus FasTrack testing for four versions of 48- by 40-in., GMA-style red alder pallets

Pallet design	PDS Number of handlings to first repair (PDS trips at 5 handlings/trip)	FasTrack Number of handlings to first repair (FasTrack cycles at 10 handlings/cycle)
Light Duty 2-1/4-in. nail	20	18
Light Duty 2-1/2-in. nail	60	15
Heavy Duty 2-1/4-in. nail	30	26
Heavy Duty 2-1/2-in. nail	115	30

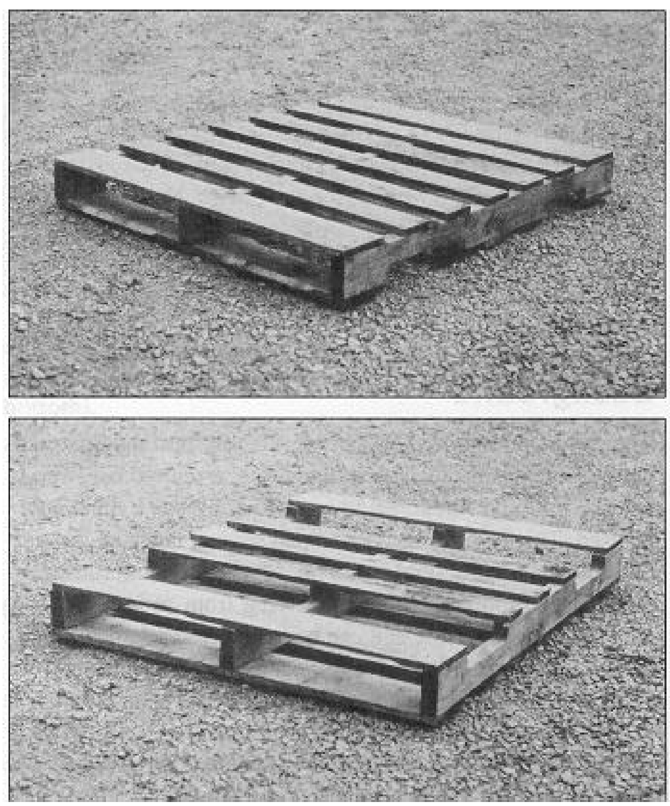

Figure 1—Top and bottom decks of a test pallet.

Upgrading Western Hardwoods Utilization Through High Quality Composites

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In recent years, the quantity and quality of softwood logs available for lumber and plywood production in the Pacific Northwest have steadily declined. Increasing environmental concerns and endangered species have added to this decline by restricting the amount of harvesting. In contrast, the amount of sawtimber produced from western hardwoods, which traditionally have been underutilized, is increasing. Currently, approximately 500 million board feet of sawtimber comes from hardwoods in the Pacific Northwest each year. Red alder, once considered a weed species, now accounts for about 60 percent of this figure and is the most abundant commercial hardwood in the region. The majority of the red alder harvested, however, goes into low value products such as pallet components and wood chips.

The purpose of this project was to find a marketable use for red alder and other hardwoods in the Pacific Northwest as well as to develop an alternative to plywood production in the region. The specific objective was to increase the value of harvested hardwood fiber by using it to produce high quality composite products.

Background

The composition board industry has recognized that materials previously considered substandard, such as unused hardwood forests, mill and forest residues, and young trees, must now be used. The industry has developed several types of composite lumber and structural panel products from numerous species. These products use more material from an individual log than does sawn lumber and can be engineered for specific design purposes. One such composite product is oriented strand lumber (OSL), a composite board that is an alternative to sawn lumber. Oriented strand lumber is composed of relatively long, slender wood particles that are aligned to produce high bending properties in the direction parallel to the flake length. It has strength properties similar to solid lumber, but its variances are lower. Oriented strand lumber evolved from oriented strand board (OSB), a composite structural-use panel that is currently used as sheathing in residential construction.

Research on producing OSB from red alder was conducted in the early 1980s. In two separate studies done at that time, red alder was considered to have excellent possibilities as a material source for composition board in addition to potential for use as construction grade lumber. Given that, the project reported here explored the feasibility of using red alder and bigleaf maple, another hardwood species common to the Pacific Northwest, as raw material sources for OSL. Currently, the primary uses of these hardwoods are furniture stock, pallet components, and wood chips. Because of their growth characteristics, however, only a small portion of the wood goes to the highest-value end product-furniture stock.

Methods

Red alder and bigleaf maple logs were reduced to 2-, 3-, and 4-1/2-in. flakes (Fig. 1). The 2- and 3-in. flakes were combined with phenolic adhesive at 4, 7, and 10 percent levels, while the 4-1/2-in. flakes were combined with 7 percent phenolic adhesive. Panels 3/4-in. thick were then made separately from each length of flake. Some of the panels were laminated together to form a double thick (1-1/2 in.) panel, a thickness that might substitute for sawn lumber. Based on previous hardwood-wax research and concerns about dimensional stability of composite lumber products, a relatively high-wax-content adhesive was selected. All other parameters were established to simulate those currently used in the OSB industry.

Experimental panels were manufactured from each species and tested for various properties including bending, internal bond, durability, interlaminar shear, dimensional stability, and fastener withdrawal (Fig. 2). Testing was conducted according to particleboard and structural panel standards because currently there are no standards for OSL. Bending properties for the panels made from the 4-1/2-in. flakes were compared to allowable values of several selected grades and species of sawn lumber. All other properties were compared to existing particleboard and OSB design values. Stress wave analysis was also conducted to determine bending stiffness.

Conclusions

The results indicated that both red alder and bigleaf maple can be used to produce OSL with properties that meet or surpass solid sawn lumber made from commercial softwood species. All board properties were above existing allowable values or were relatively high when compared to similar products. In general, the properties improved with flake length, whereas little improvement was seen with increased resin concentration. When compared to modulus of rupture (MOR) and modulus of elasticity (MOE) values for common species of structural lumber, the experimental boards made from the 4-1/2-in. flakes performed as well or better.

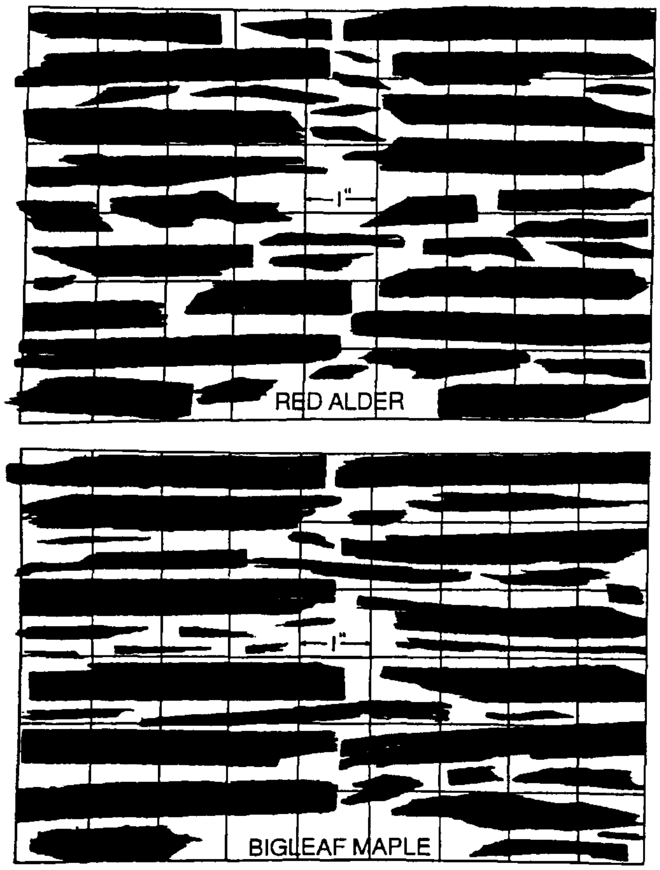

Figure 1-Typical flake dimensions.

Applications

Many possibilities exist for the use of OSL, thereby providing new markets for the historically underutilized hardwoods of the Pacific Northwest. Currently, OSL is being produced by some OSB manufacturers for use as nonstructural lumber in the furniture industry. It is also possible that millwork stock, valued at approximately $2,000 per thousand board feet, could be produced from OSL.

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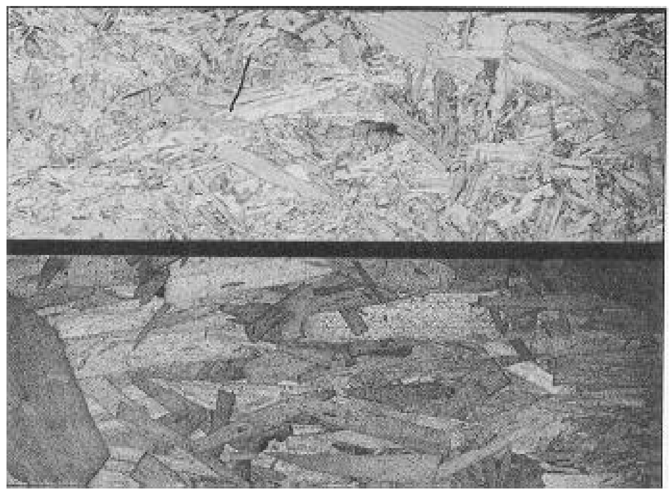

Figure 2—Oriented strand lumber panels using bigleaf maple (top) and red alder (bottom).

Developing High-Value Blockboard Made of Alder and Other Pacific Northwest Hardwoods

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Due to increased timber shortages and the desire to produce value-added products in the Pacific Northwest, this study was undertaken to demonstrate the potential of producing blockboard from regional hardwoods and softwoods. The study's primary emphasis was on use of hardwoods, in particular red alder.

Blockboard, an established product, is composed of narrow wood blocks or strips positioned side by side to form a panel that is crossbanded on both sides with veneer. One version of blockboard, currently produced by at least 14 European plants, uses thin lumber (0.25 in. and thicker) as face material. Blockboard uses high quality lumber for face material, while the core is composed of lower quality material. This solid wood product has many desirable attributes. It is relatively strong, lightweight, and dimensionally stable, and it holds screws well. Hence, it can be used in a variety of applications. Furthermore, deep patterns can be cut in blockboard panels to provide aesthetically pleasing designs.

Blockboard panels were manufactured from several different species (bigleaf maple, Pacific yew, red alder, lodgepole pine, and hemlock). All species yielded acceptable panels.
A sample cut from a blockboard panel is shown in Figure 1. Market experts have examined these samples and given them positive ratings. The pleasing appearance of the finished panels and other favorable attributes were noted in the ratings.

Static bending tests were performed on specimens obtained from the panels. Tables 1 to 4 summarize these results. Panels from each species had acceptable bending stiffness and strength (Fig. 2).

A detailed review of the European blockboard industry revealed that new processing improvements have made manufacture of blockboard panels more efficient. A new plant for blockboard manufacture will cost approximately $13.5 million and can produce about 16,000 ft^2 of blockboard in 8 h.

For existing sawmills with dry kilns, approximately $5 million of additional equipment is needed to produce blockboard panels. In addition, it may be possible to retrofit old plywood presses to manufacture blockboard panels.

Blockboard panels as produced in this study should be considered a new value-added product for the Pacific Northwest. The technology is available, economical production is feasible, the product is excellent for appropriate markets, and it is possible to upgrade lower quality lumber by using blockboard technology.

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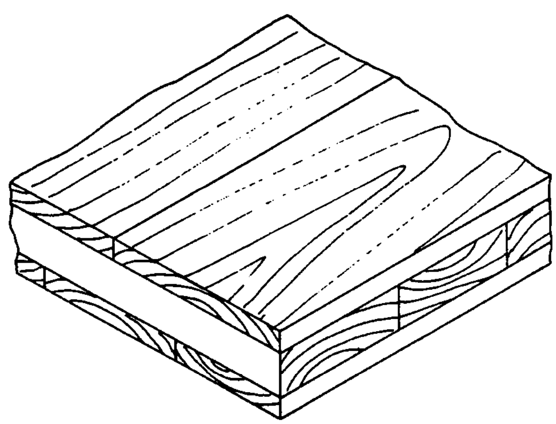

Figure 1—Typical blockboard produced in this study.

Table 1—Modulus of rupture and modulus of elasticity values for cold- pressed blockboards[a]

	Modulus of rupture (lb/in^2) at three board thicknesses			Modulus of elasticity (x 10^6 lb/in^2) at three board thicknesses		
Core species	0.75 in.	1.00 in.	1.50 in.	0.75 in.	1.00 in.	1.50 in.
Alder	13,920	10,620	9,330	1.621	1.284	0.962
Hemlock	12,770	8,960	5,380	1.443	1.039	0.644
Lodgepole Pine	13,190	8,860	6,100	1.510	1.122	0.729
White Fir	12,380	8,890	5,070	1.446	0.996	0.700

"Made with high quality alder faces and four different core species. Testing was performed parallel-to-the-grain of the faces.

Table 2—Modulus of rupture and modulus of elasticity for hot-pressed blockboards[a]

	Modulus of rupture (lb/in*) at two board thicknesses		Modulus of elasticity (x 10^6 lb/in^2) at two board thicknesses	
Glue type	1.25 in.	1.50 in.	1.25 in.	1.50 in.
PVA	7,620	8,910	0.770	1.064
LF	8,610	10,120	0.845	1.101

[a]Made with high quality alder faces and lower quality alder cores. (Glues were polyvinyl acetate [PVA] and urea-formaldehyde [UF]). Testing was performed parallel-to-the-grain of the faces.

Table 3—Modulus of rupture and modulus of elasticity for high-frequency cured blockboards[a]

Modulus of rupture (lb/in^2)	Modulus of elasticity (x 10^6 lb/in^2)
8,300	0.842

[a]Made with high quality aider faces and lower quality alder cores. Board thickness 1.50 in. Testing was performed parallel-to-the grain of the faces.

Table 4—Modulus of rupture values for cold pressed blockboards[a]

	Modulus of rupture (lb/in^2) at three board thicknesses		
Core species	0.75 in.	1.00 in.	1.50 in.
Alder	2,150	3,300	5,270
Hemlock	2,330	3,490	5,720
Lodgepole pine	2,010	3,730	5,890
White fir	1,770	4,380	6,660

[a]Made with high quality alder faces and four different core species. Testing was performed perpendicular-to-the-grain of the faces.

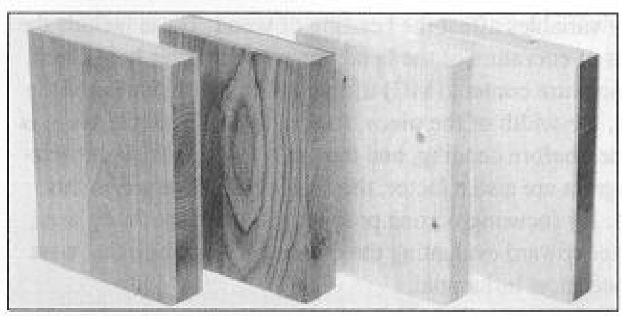

Figure 2—Naturally finished blockboards (left to right: red alder, Pacific yew, lodge pole pine, bigleaf maple).

Steam Bending Red Alder

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The purpose of this project was to determine if solid red alder *(Alnus rubra* Bong.) could be successfully steam bent in a production situation for commercial application. This was a cooperative research project between the Forest Products Department of Oregon State University and Bentwood Northwest, Inc., of Junction City, OR. The objective of this work was to determine the feasibility of using red alder for bow back and bent back furniture parts.

Bentwood Northwest, Inc., currently manufactures a bow back chair of alder materials except for the bow back, which is made of bigleaf maple *(Acer macrophyllum* Pursh). This part consists of a 4/4 square stick 51 in. long that is formed around a mold. When the product was successfully bent, the opposing ends were parallel and there were two quarter-turn curves with 5-in. radii, slightly separated from the longitudinal midpoint. This rate of curvature represents the most extreme bend used by the company.

Other products manufactured by Bentwood Northwest, Inc., are curved back rests and ladder back slats, also associated with chair and seating products. The bending blank dimensions for the back rest are 7/8 in. thick, 4 in. wide, and 16 in. long. Dimensions for the back slats are 5/8 in. thick, 3 in. wide, and 16 in. long. These products are different from the bow back part because they are not as long and, more importantly, they are wider than they are thick.

Many variables affect the bending of wood. These include the radius of curvature of the bend, the wood species being bent, the moisture content (MC) of the wood, the thickness of the piece, the width of the piece, the amount of time the piece is steamed before bending, and the grain angle. While plasticizing agents are also a factor, they were not addressed in this study. By focusing on one product at a time, the study was directed toward evaluating the one or two variables that were deemed most influential.

In the case of the bow back product, the experiment considered only red alder, the radius of curvature was fixed, and the blank was square, so thickness and width were uniform. Grain angle specifications preexisted for bigleaf maple, so those were used for the alder test stock; slope was not to exceed 1 in. in 15 in. Therefore, only MC and steam time would have to be considered in the bow back segment of the project. Two moisture conditions were tested-green high MC and air dried to 20 percent (OD basis). Steam times tested were 40, 30, 20, and 15 min for green material and 25, 20, and 15 min for air-dried material. The flat back pieces were steamed in a similar manner, but based on information obtained from the bow back research, the steaming time was limited to 25 min. The primary variables were the hydraulic pressure used to close the mold and the time the pieces were left in the steam-heated mold to promote drying and setting of the desired shape. Initially, time in the mold was minimal. It was incrementally increased to simplify data collection and prevent overdrying, with the associated damage of checking, honeycomb, and collapse.

In bending wood, failure can be categorized in four ways: one on the inside concave surface and three on the outside convex surface. Compression failure on the concave surface is recognized by various amounts of puckering, folding, or typical short-column failure. The outside surface failure can be recognized by splintering, brash failure, and cross-grain failure. During evaluation, no attempt was made to rate the severity of failure. The piece was deemed either acceptable quality or a failure.

Twelve hundred bow back blanks were processed in the green condition. The highest percentage of acceptable pieces (36 percent) was obtained at 20 min steam time (Table 1). The greatest cause of falldown (54 to 87 percent) was compression failure. An additional 400 blanks were air dried and then steamed and bent. The highest percentage of acceptable pieces (12 percent) was again obtained at 20 min steam time. For equal steam times, the percentage of acceptable pieces was three time greater for the green material than for the dry material.

The data are not yet finalized for the flat back segment of the study. Results have been summarized from observations and from conversations with supervisory staff at the company. Compression failure was not evident in any of the pieces processed. This was a function of the greater radius of curvature (30 in.). In the thicker back rest bending, approximately 25 percent of the pieces exhibited some level of tension failure, exclusively attributable to splintering. This splintering initiated, in all cases, from scratch tooth marks from the circular saw used to mill the wood. The likely approach to reduce these failures would be surfacing the pieces with a planer or by abrasive sanding to a level below the scratch tooth damage.

The desired results of determining optimal processing parameters for bending and press drying red alder wood were not obtained in this study. The bending of red alder for bow backs did not attain the success level necessary for commercial production.

Table l-Failure mode for red alder bow backs

Original condition and steam time (min)	Acceptable (%)	Percentage of failure by type			
		Compression	Brash	Tension cross-grain	Splintering
Green					
40	6	87	0	3	3
30	34	61	0	3	3
20	36	62	0	5	7
15	8	54	10	12	57
Air dried					
25	2	90	11	1	22
20	12	69	1	5	23
15	6	43	7	5	49

Effect of Edging Red Alder Lumber on Cut-Stock Production

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Kermit A. Schott
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The declining availability of softwood lumber in the Pacific Northwest has increased interest in the region's hardwood resource. In 1990, this hardwood resource supported an industry that employed approximately 1,000 people and produced 331 million board feet of lumber, of which 85 to 90 percent was red alder *(Alms rubra)* (Warren 1992). Any effort to extend this resource through better use would benefit the hardwood industry and the Pacific Northwest.

Edging lumber is a significant source of wood fiber loss. Poor edging practices result in lost lumber value, lower lumber recovery, and reduced cutting-parts yield. Lumber producers edge boards to maximize their grade recovery by removing wane and defects. This process also removes sound wood that is at the periphery of the board, and generally it is of high quality and value as cut-stock. Opportunities exist in cut-stock production to more efficiently use our resource while reducing manufacturing costs. One study showed that when lumber used for cutting parts was unedged and untrimmed, yield was 25 percent greater than when the lumber was conventionally edged and trimmed (Kline and others 1993). The fact that cutting yield increases when edging decreases is obvious. What is not obvious is whether the increase offsets the added costs of handling, transporting, and drying unedged flitches. This study compared the increase in costs to the value added through increased cutting yield. Recommendations for edging practices for vertically integrated red alder lumber and cut stock producers are presented.

This project compared the cut-stock yields produced by live different edging strategies for three shop grades (Selects, No. 1, and No. 2) of red alder lumber. A computer vision system produced digital descriptions of 85 flitches for each grade so that they could be repeatedly edged and sawn into cut-stock using computer simulation (Brunner and others 1989). The five different strategies were nominally unedged, light, conventional, mill (actual mill practice), and severe edging (Fig. 1). The program simulated a rip-first then cross-cut operation that produced fixed-width, random-length finger-joint blocks for each edging strategy. In addition, the benefits of a salvage re-rip operation were determined. Typical cutting bill sizes and part values were compiled from industry sources. A differential income analysis incorporating changes in product yields as well as handling, drying, and transportation costs was performed.

The results showed considerable yield differences between the different edging strategies for each of the lumber grades (Table 1). The average percentage increase in cut-stock volume relative to the mill edging practice was -7, 4, 9, and 13 percent for the severe, mill, conventional light, and nominally unedged practices, respectively. While these increases resulted mainly from a greater number of shorter blocks, there was also a notable increase in the number of high-value longer blocks. The differential income analysis also showed a significant difference between edging strategies. The light edging practice produced the greatest increase in income per thousand board feet, even when the additional costs of handling, drying, and trucking partially edged flitches were considered (Table 2). Changing edging practices is probably not practical for mills trading red alder in the open market using standard shop lumber grades. A vertically integrated sawmill/roughmill operation using 20 million board feet of red alder lumber, however, could potentially increase its annual income by at least $2 million by simply reducing the amount of material removed during edging.

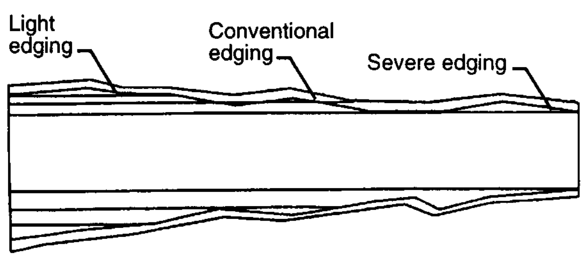

Figure 1—Edger line locations for light, conventional, and severe edging.

Table 1—Volume of cut-stock parts produced by each of the five edging strategies on each sample of boards from the three lumber grades

Lumber grades	Volume of cut-stock parts by edging strategy (board feet)				
	Unedged	Light	Con-ventional	Mill	Severe
Selects	255	242	233	223	216
No. 1	224	215	206	199	179
No. 2	210	203	191	186	167

Table 2—Differential income provided by each of the five edging strategies for each of the three lumber grades

Lumber grades	Differential income by edging strategy ($/1,000 board feet)				
	Unedged	Light	Con-ventional	Mill	Severe
Selects	$117.68	$119.59	$68.08	$0	($45.68)
No. 1	$85.55	$94.49	$54.38	$0	($135.36)
No. 2	$75.28	$102.47	$39.25	$0	($129.84)

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Pacific Northwest Hardwood Flooring

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Introduction

The hardwoods of the coastal forests in the temperate regions of Oregon, Washington, and California are, for the most part, a wasted and underutilized resource. With the exception of red alder *(Alnus rubra)*, most of these hardwoods end up as slash, firewood, or pulpwood. To ensure the presence of these species within the forest structures, long-term regeneration and management practices must be implemented and viable economic uses for them must be found. The dense hardwoods of California and the Pacific Northwest are particularly underutilized. Oregon white oak *(Quercus garryana)*, California black oak *(Quercus kelloggii)*, Pacific madrone *(Arbutus menziesii)*, and tanoak *(Lithocarpus densifloris)* are the most available of these dense hardwoods.

Countless opportunities exist to develop products from these wasted hardwoods. These products represent opportunities for individual entrepreneurs and multinational corporations. Preexisting available markets, resource grade and volume, existing workforce skills, entrepreneurial expertise, and investment potentials have limited the project reported here. Hardwood flooring met the necessary criteria and was determined to be one of the best opportunities for utilization of these species. The objective of this study was to evaluate floor performance for northwest species.

Methods

This project had three distinct parts. The first consisted of purchasing flooring made by existing businesses or using available lumber and milling it into product. This flooring material was used in the second part of the project for testing and analysis. The third part of the project involved a demonstration installation.

Material Acquisition

Kyle Burnett and Sons of Rogue Valley, Oregon, produces and distributes strip flooring products made from Pacific madrone and California black oak. The products are 1/2-in.-thick, tongue and groove strip flooring. The Pacific madrone has a 2-1/4-in. face, and the California black oak has a 3-in. face. Approximately 60 ft^2 of each was ordered. Oregon white oak lumber, available from an associated grade-yield mill study conducted cooperatively by the Forest Service, Oregon State University, Forest Products Department, and Hoskins Lumber Co. located in Philomath, Oregon and experimentally dried at Oregon State University, was used instead of attempting to purchase that material from area sawmills.

Approximately 2,500 board feet of 4/4 Oregon white oak lumber, No. 2 and No. 3 grades, was sent to McKenzie Products Corp., Eugene, Oregon, for custom milling and end matching. The desired product was 2-1/4-in. face flooring that was 3/4 in. thick. The entire order was mismanufactured to a 2-in. face. Subsequently, approximately 300 board feet of No. 1 Oregon white oak was trucked to McKenzie Products Corp. for processing into the desired 2-1/4-in. stock. The 2-in. face material was used for the demonstration installation, while the 2-1/4-in. material was used for testing.

Testing

A primary goal of this project was to obtain reliable test results of flooring performance that could be used for comparative purposes. Priority was given to hardness and dimensional change testing as this was thought to be the most important information. The ASTM standards for side hardness (D-143) and falling-ball impact (D-2394) were thought to provide the best information on how the flooring would behave with the use and abuse of traffic, moving objects across the surface, and the possible effect of dropped objects. Also, because wood dimensions change considerably with ambient temperature and relative humidity fluctuations, dimensional stability data was required to determine if Northwest dense hardwoods would be stable enough to be used. Many of the other performance conclusions can be correlated to these tests or are dependent on the type and application rate of the surface coating.

Rather than consider individual pieces, which would duplicate existing data, sample floors were constructed to more accurately reproduce actual installation conditions. The flooring was fastened to 3/4-in. Douglas-fir plywood underlayment. Two full 4 by 8 sheets (approximately 64 ft^2) were laid with Oregon white oak; single sheets were laid with Pacific madrone and with California black oak (approximately 32 ft^2 of each species).

The strip flooring panels were assembled in the spring of 1994 and allowed to stabilize and equilibrate to ambient conditions at the Oregon State University Forest Research Laboratory (FRL). Initial measurements were taken for determining moisture content (MC), overall dimensions, and gaps between strips. The measurements were repeated for verification of technique. The panels were then placed in a wet-cold conditioning room at the FRL with a target equilibrium moisture content (EMC) of 16 percent and allowed to remain for 6 weeks. The panels were measured to determine MC and high MC dimension. Following this, the panels were moved into a hot-dry conditioning room with a target EMC of 7 percent for a period of 5 weeks and measured again for dimensional change and MC. Change in MC and the resulting dimensional differences were measured. The raw data were transformed into a standardized unit for each species. Falling-ball impact tests were made at four locations on each half panel away from width determination areas. Side hardness tests, actually measured on the face of each strip flooring sample, were done on samples 12 in. long.

Demonstration Installation and Samples

The largest volume of Oregon white oak was manufactured into strip flooring. Much of this flooring was installed in a 450 ft^2 conference room in the newly built city library at Philomath, Oregon. In addition to strip flooring, wood parquet tiles are an integral element of the wood flooring industry. The OSU FRL wood shop assembled 32 tiles in each of three different patterns and prepared them for distribution. The parquet designs for the samples were Haddon Hall, Monticello, and Canterbury. The samples were bonded to plywood backing, finished, and distributed to government agencies and businesses.

Results

The results obtained in the tests indicate that all three species would perform well in flooring applications (Tables 1-3). Side hardness tests results for California black oak, Oregon white oak, and Pacific madrone are similar to values published in the USDA *Wood Handbook* for Southern red oak *(Q. falcata),* Eastern white oak *(Q. alba),* and sugar maple *(Acer saccharum),* respectively.

Continued comparison of California black oak, Oregon white oak, and Pacific madrone with Southern red oak, Eastern white oak, and sugar maple can be made in relation to dimensional stability. The *Wood Handbook* dimensional change coefficients for Western species are all lower than those for their Eastern counterparts, with the exception of the published tangential value for Pacific madrone. The results of this test, however, indicate that the experimental value for Pacific madrone is equal to the radial shrinkage estimate and is therefore also lower than the published figure. The gaps that developed in the Pacific madrone flooring panels were more prominent than those in either of the oak flooring panels. This is partially attributable to the greater change in MC and thereby greater actual shrinkage. The gaps were also more apparent because of the characteristic of the wood. The fine-grained (diffuse porous) structure and more uniform coloration of the Pacific madrone resulted in a smoother face, which tended to accentuate the gaps. With the oak flooring, the graininess and color variation that are associated with earlywood/latewood differences of the wood tended to make the gaps less noticeable. Published tanoak properties are similar to Eastern species as a suitable flooring product.

Table I-Dimensional change characteristics

Species	Number of specimens	Moisture content (% change)	Mean gap between boards	Total gap across 4 ft	Mean shrinkage (per ft per MC)	Calculated shrinkage (per ft per MC")
California black oak	180	2.6	0.016 in.	0.247 in.[b]	0.024 in.	Radial = 0.015 in. Tang. = 0.028 in.
Oregon white oak	480	3.4	0.014 in.	0.285 in.[c]	0.021 in.	Radial = 0.017 in. Tang. = 0.039 in.
Pacific madrone	220	4.4	0.020 in.	0.339 in.[c]	0.023 in.	Radial = 0.023 in. Tang. = 0.054 in.

[a]Determined using radial and tangential coefficients for a 1 ft distance (Wood Handbook-Wood as an Engineering Material. Agric. Handb. 72.)
[b]Represents 16 boards with a 3-in. face.
[c]Represents 21 boards with a 2.25-in. face

Table 2—Falling-ball impact characteristics

Species	Number of specimens	Drop height (in.)	Mean indent depth (in.)	Standard deviation (σ)
California black oak	8	12	0.007	0.0020
		24	0.009	0.0014
		36	0.014	0.0027
Oregon white oak	16	12	0.005	0.0013
		24	0.007	0.0013
		36	0.009	0.0017
Pacific madrone	8	12	0.005	0.0013
		24	0.008	0.0007
		36	0.011	0.0015

Table 3—Side hardness characteristics

		Side hardness (mean values in kg (lb))					
	Number of	Tests results				Published results	
Species	specimens	⊥ to grain	σ	High	Low	Overholser[a]	Wood Handbook[b]
California black oak	60	470 (1,034) (6.8% MC)	93.4	670 (1,474)	330 (726)	500 (1,100) (12% MC)	482[c] (1,060) (12% MC)
Oregon white oak	60	848 (1,866) (7.5% MC)	141.3	1100 (2,420)	575 (1,265)	755 (1,660) (12% MC)	618[d] (1,360) (12% MC)
Pacific madrone	60	711 (1,564) (7.1% MC)	118.2	1020 (2,244)	560 (1,232)	664 (1,460) (12% MC)	659[e] (1,450) (12% MC)

[a]Oregon Hardwoods. 1977. FRL Bull. 16. Edited by James Overholser.
[b]Wood Handbook—Wood as an Engineering Material. Agric. Handb. 72.
[c]Southern red oak.
[d]Eastern white oak.
[e]Sugar maple.

Even though test results demonstrated that Western dense hardwoods can be used for strip flooring, several factors must be recognized and overcome before successful business development can occur. The first is the lack of developed infrastructure to process the available resource. Logging, milling, and drying equipment used for processing softwood or lower-density hardwoods, like red alder and bigleaf maple, cannot be readily adapted to dense hardwood processing without a significant financial investment.

Conclusion

Hardwood flooring manufactured from California black oak, Oregon white oak, Pacific madrone, and tanoak offer the potential to create usable, valuable products that would perform similarly to existing flooring materials. The strength and dimensional stability data collected in this study confirm this conclusion. With this type of wood product industry diversification, the opportunity exists to better use the wood resource as well as to create jobs in local communities.

Hardwood Drying Workshops

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Oregon State University

Primarily because of product use requirements, hardwood lumber must be kiln dried to a lower moisture content (MC) and with more attention to minimizing defects than is required for softwood lumber. For hardwood lumber, different procedures and techniques are used. In the Pacific Northwest, one of the biggest obstacles to utilizing hardwood lumber is proper drying. Because the region is softwood-oriented, drying workshops/shortcourses have always concentrated on softwood techniques. Faculty at Oregon State University (OSU) and USDA Forest Service research/technology transfer specialists determined that a workshop that focused on drying hardwood lumber was needed to enhance local/regional economies and to move forward with a hardwood industry.

On February 1-4, 1993, eighteen people participated in a hardwood drying workshop at OSU. This resulted from a cooperative agreement between the USDA Forest Service and OSU. The workshop director was Michael R. Milota, Assistant Professor in the Forest Products Department at OSU. The USDA Forest Service employees participating as instructors were R. Sidney Boone, Forest Products Technologist, Forest Products Laboratory, Madison, Wisconsin, and Dean W. Huber, Multiregional Utilization and Marketing Specialist, State and Private Forestry, San Francisco, California.

The objective of the workshop was to educate producers and potential producers of hardwood lumber about drying techniques and equipment. The topics included wood and wood-moisture relationships, drying schedules, equipment, mill practices to promote good drying, air drying, and the specific drying characteristics of western hardwood species. All types of dry kilns were discussed including steam, dehumidification (electric), solar, vacuum, and radiofrequency. Energy use and conservation were also addressed.

Participants received an I l-chapter handout containing all course references plus reading materials that went into greater depth than did the classroom instruction. Daily laboratory sessions allowed hands-on experience with lumber kilns. The use of auxiliary kiln equipment, such as moisture meters, ovens, and scales, was also part of the lab sessions. The participants did a first-hand evaluation of the drying quality of a charge of Oregon ash hardwood lumber.

The eighteen participants represented 16 different companies ranging in size from small consulting firms to mid-sized hardwood manufacturers. By profession, the participants included dry kiln operators (11), small retail business owners (4), a consulting engineer, an architect, and a forester. The participants came from California, Oregon, Washington, and British Columbia.

A second workshop was planned for early 1994. It was canceled, however, due to limited enrollment. Most people in the region who can come to a week-long hardwood drying workshop came in February of 1993. In Oregon, hardwood producers tend to be one- or two-person operations, and to leave for a week means shutting down the business. In evaluating this, it was decided that a l-day workshop closer to the producers would be more likely to attract attendees.

To this end, two l-day, one-instructor workshops were held in 1994: June 8 in Roseburg, Oregon, and June 13 in Astoria, Oregon. These workshops attracted an additional 22 participants. The subjects covered were similar to the longer course. Lab periods and some topics, such as equipment, were dropped and other subjects were condensed. For this type of producer, this is probably a better format than a longer workshop. It is also more attractive to the noncommercial (hobbyist) user of wood.

Evaluation of the Drying Characteristics of Chinkapin, Madrone, and Tanoak

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The primary focus of both research and harvesting in the Pacific Northwest has been on softwood species because of their abundance and quality. The emphasis during softwood processing tends to be a high production volume and uniform moisture content (MC). As a result, techniques that are commonly applied in hardwood mills in the Eastern United States, such as moisture sample boards, are almost unheard of in the Pacific Northwest. Similarly, when individuals with considerable softwood drying experience are confronted with hardwood operations, they may not understand the basic parts of a kiln schedule such as drying, equalizing, and conditioning. This can result in surface, end, and internal defects as well as a product that is not stable for secondary manufacturing because of moisture gradients and casehardening.

This work was undertaken to determine the drying characteristics of three hard-to-dry species—chinkapin, madrone, and tanoak—and to develop reliable drying schedules for them. Schedules for all these species currently exist. However, the recommended temperatures and relative humidities (RH) given vary considerably depending on the information source.

Materials and Methods

Small charges of full-size boards were air dried, then kiln dried to determine problems with existing schedules. Small samples were dried from green to determine the combinations of temperature and RH that were appropriate for drying each species. Methods for preventing or recovering collapse were investigated.

Air Drying Followed by Kiln Drying

The wood to be air dried was box piled on 3/4-in. stickers and allowed to dry in a pole building that was open on four sides. The piles were 4 ft wide by the length of the wood (8 ft maximum). Sample boards were placed in the piles and monitored. The boards were weighed and defects noted, daily at first, then at increasing intervals until the wood was repiled for kiln drying. A shade screen material was placed around the sides of the pole building to reduce airflow and to keep rain from blowing on the lumber.

The air-dried wood was kiln dried using two schedules. The first charge of each species was dried using the USDA recommended schedule (Boone and others 1988) for chinkapin and tanoak. This schedule was also used for madrone. The maximum temperature was restricted to 160°F to reduce the maximum wet-bulb depression. A second charge of each species was dried using a slightly more severe schedule.

Drying Small Samples From Green

Ten charges containing four boards of each species were dried under constant dry- and wet-bulb conditions for 6 days or until significant degrade occurred. Dry-bulb temperatures ranged from 100°F to 130°F and the RH ranged from 70 to 90 percent. Samples were removed and inspected daily for drying rate and surface checks.

Steaming to Reduce Collapse

It is well known that the collapse in some species, such as eucalyptus and cedar, can be recovered by steaming. To study this further, samples of collapsed madrone that had been air dried followed by kiln drying were steamed at 200°F, 180°F, and 160°F under the most humid conditions that are obtainable in a kiln, about a 3°F wet-bulb depression.

Some reports from the field state that presteaming or even soaking the logs in hot water can prevent collapse. To test this, green boards were sawn in half. One half was steamed for 24 hours at 200°F. Both halves were then dried together.

Evaluation of Stain and Subsurface Defects

Approximately 20 boards from each kiln charge were surfaced to 15/16 in. and visually evaluated. Stains and any defects that were not visible in the rough form were noted.

Results and Discussion

Air Drying

The time period for air drying each species is shown in Table 1. Chinkapin was dried for the shortest period of time, but it was put out during the warmer months from May to

Table 1—Dates during which each species was air dried

Species	Start	End	Initial MC	Final MC
Chinkapin	May 19	July 5	116	21
Tanoak	April 23	July 5	99	15
Madrone	March 25	June 14	88	25

July. Tanoak was dried the longest, from late April until July.

Based on this, 2 to 3 months should be sufficient to air dry these species in the Willamette Valley during the summer months. It is likely that surface checking in the chinkapin and the tanoak would be significant if air drying was initiated in the summer months.

Chinkapin air-dried with no defects in three of four sample boards. The other sample board had some light surface checks that developed after about 4 weeks of drying. This is coincident with an increase in the drying rate after 2 days of low RH and an increase in temperature. In general, the chinkapin lumber air dried with few, if any, visible defects. The initial MC of the chinkapin sample boards, 116 percent, was close to the published value of 134 percent. Certainly, one could not conclude that this sample of chinkapin had a MC different from the published value given four samples ranging from 99 to 145 percent in MC. The final MC levels ranged from 15 to 25 percent.

Madrone air-dried with no observed defects until the wood was at less than 45 percent MC. During this period, the drying rate ranged from a high of 3 percent per day to approximately 0.5 percent per day. As the wood dried below 40 percent MC, cup was observed in two of the six sample boards. This is a result of the large difference in tangential and radial shrinkage, and it is expected in boards that dry unrestrained like the sample boards. Less cup was observed in the full-sized boards that were restrained by the weight of boards above. Collapse began to occur in four of the six sample boards toward the end of air drying. No surface checks were observed when air drying madrone. The initial MC of the madrone sample boards, 88.5 percent, was higher than the published value of 68 percent. A high MC could contribute to more collapse than normal; however, it was not possible to evaluate that effect in this study. The final MC levels ranged from 22 to 31 percent.

Tanoak samples had surface checks formed in three of the four boards. One board checked after 10 days. Windy days followed by warm weather, however, resulted in light to severe surface checks on all sample boards. Checking occurred in only 10 to 20 percent of all the pieces. Collapse occurred in only one sample board. This was probably typical of the overall load as 20 to 30 percent of all boards showed collapse. All of the sample boards cupped as they dried. The restrained boards, however, did not cup excessively. The initial MC of the tanoak sample boards, 101 percent, was close to the published value of 115 percent. The final MC levels ranged from 14 to 17 percent.

Kiln Drying Air Dried Stock

Chinkapin was dried to a MC of 9 percent in 5-1/2 days by either schedule. This was probably because at low MC levels, the dry-bulb temperature was the most important. The difference between the two kiln schedules was a 3°F greater wet-bulb depression in the second schedule with the same dry-bulb temperatures. Many of the chinkapin sample boards cupped. This was due to the lack of restraint and did not indicate a problem. One board showed significant surface checking. None of the other boards showed defects. The MC was uniform without an equalizing step.

Madrone also had almost identical drying rates in the two schedules. Cup occurred in some sample boards as with air drying; however, as with the chinkapin, these sample boards were not restrained. The rest of the charges displayed acceptable cup-less than what would be observed in tanoak or white oak, but significantly more than what would occur with most softwoods. Of the 16 sample boards in the two charges, 14 showed collapse. This clearly illustrates that collapse is one of the greatest problems encountered when drying madrone. Madrone heartwood had different colors: dark, light, and some streaked, which were very dark. The light areas were reddish and often showed no collapse. The darker areas, areas that had a gray cast, showed considerable collapse. This resulted in skip at the planer. If a plane surface was machined, it was expected that some recovery of the collapse could occur under certain conditions resulting in a non-plane surface. The dark streaks often developed honeycomb in quarter sawn pieces. Other collapsed areas showed rare to occasional honeycomb. These observations were based on cross-cut pieces. Upon planing, no internal defects were exposed. The moisture distribution was greater in the madrone, indicating that an equalizing period is needed for this species.

Tanoak also dried at a similar rate by either schedule. Tanoak showed collapse in 15 of 16 sample boards between the two charges. The degree of collapse was less severe than in the madrone; however, it represented a serious drying defect. Surface checks were observed to open and close. We believed that these checks occurred in air drying and were not new. Most were light enough to plane off and none were observed in the planed product.

Kiln Drying From Green

Chinkapin showed surface checking when the initial wet-bulb depression was greater than 5°F. A 6°F depression at 110°F caused unacceptable surface checking. Surface checking also increased as the temperature increased from 110°F to 130°F. No collapse was observed in this species. The USDA schedule for 4/4 appears to be a good starting point for this species. The 4°F initial wet-bulb depression is not likely to cause significant surface checks.

Madrone—Regardless of the initial dry-bulb temperature (range was 110°F to 130°F) or wet-bulb depression (range was 4°F to 11°F), madrone always showed collapse 2 days after being placed in the kiln. The collapse in the kiln was generally greater than that observed in air drying and increased with temperature from 110°F to 130°F. Collapse was only slightly greater at an 11°F wet-bulb depression than at smaller depressions. Surface checking was not a problem. Based on these observations and past work, the USDA schedule for 4/4 should satisfactorily dry madrone. Collapse, however, will occur during this schedule. It is likely that the wet-bulb depression can be increased somewhat from the recommendation, perhaps to no more than 9°F (an 80 percent RH). Increasing the dry-bulb is not recommended because of an increase in collapse.

Tanoak is likely to surface check under all but the mildest of conditions. We would not recommend the USDA time-based schedule, but rather that of Espenas (195 1). Even under this mild schedule, some degrade, mostly surface checks and collapse, is expected. Of the three species studied, this is the most difficult to dry.

Steaming to Reduce Collapse

Post steaming at 200°F reduced collapse in madrone. The effectiveness of the treatment decreased with decreasing temperature. The recovery was greatest in the areas with the greatest collapse. These results were repeatable. This degree of recovery would considerably increase the recovery of lumber from a given log because the sawing target size could be reduced accordingly-about 3/16 in. This reduction in thickness would, in turn, make the product easier to dry. Presteaming was not successful. Boards that were presteamed showed the same amount of collapse as matched samples that were not presteamed.

Evaluation of Stain

For all three species, there were no differences in the amount of stain between kiln charges. This would be expected since staining occurs early in the drying process when all the boards received the same air drying treatment. Also, there was no difference in defects between the charges.

Chinkapin had patchy areas of what appeared to be an oxidative stain. It also had some sticker stain despite having stacked the wood on dry stickers. This stain might be prevented by restacking the wood on fresh stickers after the first week of air drying. No checks or honeycomb were observed. There was some skip, although this was due to a scant target size rather than collapse.

Madrone took on a greyish cast compared to its color before drying. This grey color was most noticeable in the heartwood and less so in the dark heartwood. The madrone was darker than other madrone the author has seen. An outside observer who cuts and dries madrone, however, said the color was acceptable. Despite large differences in heartwood color off the saw, the regular heartwood and the dark heartwood were much closer in color after drying. Steaming had no effect on the color of the planed boards, although it did make the rough sawn boards look slightly red.

Tanoak had patchy areas of stain and some sticker stain, although less than what was observed in the chinkapin. Planing also revealed some honeycomb in approximately 10 percent of the boards.

Conclusions and Recommendations

Despite recommending schedules by which these species can be kiln dried from green, it is probably prudent to air dry all three species prior to kiln drying, especially the tanoak. If stains become a problem in madrone and chinkapin, kiln drying from green may give a better yield.

Madrone is not prone to surface checking, however, it readily collapses. The drying methods in this study seemed to have little effect on collapse. A prior study indicated that collapse increases with temperature.

Tanoak is prone to surface checks and somewhat prone to collapse. Areas of enzymatic stains formed on the tanoak.

Chinkapin is somewhat prone to surface checking, but otherwise dries easily. The chinkapin in this study did develop some enzymatic stain.

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Calibration of Moisture Meters For Western Hardwood Species

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Introduction

The end uses for hardwood lumber require that moisture content (MC) be precisely controlled to minimize problems such as mismatched sizes and starved glue joints. The MC can be measured gravimetrically; however, electronic moisture meters are faster, more economical, and nondestructive. Meter calibration is based on Douglas-fir. For other species, corrections must be applied. The objective of this work was to determine the species correction factors for several western hardwood species for a dielectric- and a resistance-type meter.

Methods

Sample Preparation

Sixty 1-ft long by random width samples of 1-1/4-in. thick bigleaf maple *(Acer macrophyllum),* California black oak *(Quercus Kelloggii),* golden chinkapin *(Castanopsis chrysophylla),* Pacific madrone *(Arbutus menziessii),* Oregon ash *(Fraxinus latifolia),* Oregon myrtle *(Umbellularia californica),* Oregon white *oak (Quercus garryana),* red alder *(Alnus rubra),* and tanoak *(Lithocarpus densiflorus)* were prepared. The pieces were end-coated with a neoprene seal and air dried to approximately 30 percent MC.

Conditioning

The air-dried samples were placed in a conditioning chamber at 100°F, first at 90 percent relative humidity (RH), then at 80 percent, then 70 percent, and finally at 45 percent RH until practical equilibrium was reached at each condition. This took approximately three months for the first condition and two months for the others. These conditions correspond to wood equilibrium MC levels of approximately 20, 15, 12, and 8 percent, respectively. The samples were trimmed to 11-1/2 in. to remove the coating on each end prior to testing. Each sample was also planed on one face, resulting in a sample thickness of 1 in.

Testing

Two dielectric-type and two resistance-type meters were used in the study. At each of the four conditions, one moisture measurement was made with each of the four meters on the planed face of each sample. The sample was then weighed. Finally, each sample was ovendried at 220°F for 48 hours and weighed again. The sample volume was determined by the immersion method described in D-2395 (ASTM 1992).

Analysis

Specific gravity was calculated from the ovendry weight and volume and was reported based on ovendry weight and volume at 12 percent MC using the conversion method in ASTM D-2395. The MC for each sample at each equilibrium condition was calculated based on its ovendry weight. A linear regression was done for each species and type of meter with the average moisture meter reading as the dependent variable and the ovendry MC as the independent variable:

$$\text{Meter reading} = ß_1 \text{ (Ovendry MC)} + ß_0 + \varepsilon$$

The correction factors were then determined by subtracting the predicted value of the regression from the ovendry MC using

$$\text{C.F.} = [(\text{ Meter reading} - ß_0) / ß_1] - \text{Meter reading}$$

Results

Average specific gravities for the samples of each species are given in Table 1. These are presented because the readings obtained with a capacitance-type meter, and hence the correction factors, depend on specific gravity. Published values for specific gravity are also presented in Table 1. The experimental values agree well with the published values. They are, however, for a 60-piece sample and are not representative of the population. Oregon white oak and Douglas-fir have the largest differences, 0.04.

The correction factors for the pin-type and capacitance-type meters are shown in Tables 2 and 3, respectively.

For the pin-type meter, correction factors for red alder were available from the manufacturer. They are + 1.2 percent at 10 percent MC and + 2.8 percent at 24 percent MC. Our results were close to these, +1.1 percent at 10 percent MC and + 1.6 percent at 24 percent MC.

Correction factors for the capacitance-type meter are large and negative for the species with high specific gravity, which include tanoak, Oregon white oak, and madrone. For California black oak and chinkapin, the correction factors are more positive. Oregon myrtle has a large negative correction factor for its density. This species also showed wide variability in the equilibrated ovendry MC.

Application

These correction factors can be applied to temperature-corrected meter readings taken with any of the common models of pin-type moisture meters or readings from the Wagner L-600 series (Wagner Electronic Products, Rogue River, Oregon) of capacitance-type moisture meters. To estimate the true MC, the meter reading temperature must be corrected, if required, then the correction factor must be added to it. Even when the meter is used correctly, any individual corrected reading may be within ±3 percent of the actual piece MC. The accuracy of the meter may vary with wood source. For these reasons, the ovendry method is also recommended as a standard practice for precise MC control during the manufacture of hardwood components.

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Table 1—Specific gravities based on ovendry weight and volume at 12 percent moisture content

	Specific gravity	
Species	This study	Published
Douglas-fir	0.52	0.48[a]
California black oak	0.58	0.57
Oregon ash	0.56	0.55[a]
Oregon white oak	0.68	0.72
Tanoak	0.68	0.66
Chinkapin	0.46	0.46
Bigleaf maple	0.52	0.48[a]
Oregon myrtle	0.56	0.55
Red alder	0.44	0.41[a]
Pacific madrone	0.61	0.65

[a]Forest Products Laboratory (1987). Other values from Overholser (1977).

Table 2—Correction factors for any pin-type meter calibrated for Douglas-fir. To use the table, first correct the meter reading for temperature if it was not taken at 70°F. Add the number from the table to the meter reading to get an estimate of ovendry MC

Meter reading	Douglas-fir[a]	CA Black oak	OR Ash	OR White oak	Tanoak	Chink-apin	OR Maple	OR Myrtle	Red alder	Pacific madrone
6	–0.5	–0.1	0.0	–1.5	–0.9	1.0	–0.2	–1.2	0.9	–0.1
8	–0.1	–0.2	–0.1	–1.5	–1.2	1.0	–0.4	–1.0	1.0	–0.3
10	0.2	–0.4	–0.3	–1.5	–1.6	1.0	–0.6	–0.8	1.1	–0.5
12	0.5	–0.5	–0.5	–1.5	–1.9	1.1	–0.9	–0.5	1.1	–0.8
14	0.8	–0.7	–0.7	–1.5	–2.3	1.1	–1.1	–0.3	1.2	–1.0
16	1.1	–0.8	–0.9	–1.5	–2.6	1.1	–1.3	–0.1	1.3	–1.2
18	1.4	–1.0	–1.0	–1.5	–2.9	1.1	–1.5	0.2	1.4	–1.5
20	1.8	–1.2	–1.2	–1.5	–3.3	1.1	–1.8	0.4	1.5	–1.7
22	2.1	–1.3	–1.4	–1.5	–3.6	1.1	–2.0	0.6	1.5	–1.9
24	2.4	–1.5	–1.6	–1.4	–4.0	1.1	–2.2	0.8	1.6	–2.2
26	2.7	–1.6	–1.8	–1.4	–4.3	1.2	–2.4	1.1	1.7	–2.4
28	3.0	–1.8	–2.0	–1.4	–4.6	1.2	–2.7	1.3	1.8	–2.6
30	3.3	–2.0	–2.1	–1.4	–5.0	1.2	–2.9	1.5	1.8	–2.9

[a]Wagner Electronic Products, Rogue River, Oregon.

Table 3—Correction factors for L-600 series of capacitance-type moisture meters.[a] Add the number from the table to the meter reading to get an estimate of ovendry MC

Meter reading	Douglas-fir[b]	CA Black oak	OR Ash	OR White oak	Tanoak	Chink-apin	OR Maple	OR Myrtle	Red alder	Pacific madrone
6	–0.8	–3.1	–0.8	–5.2	–1.7	2.4	–0.1	–2.0	3.6	–1.9
8	–0.3	–2.7	–1.1	–4.9	–2.4	2.1	–0.6	–2.2	3.1	–2.1
10	0.1	–2.3	–1.4	–4.7	–3.0	1.8	–1.2	–2.4	2.7	–2.3
12	0.6	–1.9	–1.7	–4.4	–3.6	1.5	–1.7	–2.6	2.2 -	2.5
14	1.1	–1.5	–2.0	–4.1	–4.3	1.2	–2.3	–2.8	1.8	–2.7
16	1.5	–1.2	–2.3	–3.8	–4.9	0.9	–2.9	–3.0	1.4	–2.9
18	2.0	–0.8	–2.6	–3.6	–5.5	0.6	–3.4	–3.2	0.9	–3.1
20	2.4	–0.4	–2.9	–3.3	–6.2	0.3	–4.0	–3.4	0.5 -	3.3
22	2.9	–0.0	–3.2	–3.0	–6.8	–0.0	–4.5	–3.7	0.0	–3.5
24	3.3	0.4	–3.5	–2.7	–7.4	–0.3	–5.1	–3.9	–0.4	–3.6
26	3.8	0.7	–3.9	–2.5	–8.1	–0.6	–5.6	–4.1	–0.9	–3.8
28	4.2	1.1	–4.2	–2.2	–8.7	–0.9	–6.2	–4.3	–1.3	–4.0
30	4.7	1.5	–4.5	–1.9	–9.3	–1.2	–6.7	–4.5	–1.7	–4.2

An Automated Approach to Evaluating the Treatability of Northwest Hardwoods

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"Treatability" is a general term that describes the ease with which preservative solutions penetrate wood and wood-based materials during pressure impregnation. In the Pacific Northwest, some hardwoods are more easily preservative treated than others. This variability, both among and within species, may limit the use of hardwoods in outdoor applications. To help determine which species can be successfully treated, we developed a device that assesses treatability at mill production speed. In this technique, the most treatable pieces of lumber are selected and the treatment process tailored to the characteristics of the material. Thus, time-consuming post-treatment quality control and associated rejection and retreatment costs are minimized.

In this technique, water was forced into pre-punched holes under pressure of 30 lb/in^2, and the resultant volumetric flow was monitored digitally. To reduce the impact of highly localized variability in wood permeability, a bank of six holes spaced 10 mm apart was punched and evaluated simultaneously during each test cycle. The hole-punching rods passed through specially mounted O-ring seals and were retracted just prior to fluid injection. The device to perform these functions is pneumatically powered and digitally controlled with a specially developed software program.

Measurements were made with the device on seven hardwood species (red alder, white oak, red oak, bigleaf maple, Oregon ash, eastern poplar, and eastern cherry) that were subsequently pressure treated with ammoniacal copper zinc arsenate wood preservative at a commercial facility. Transverse preservative penetration was then evaluated **by** observing cross-sections cut 10 mm from each of the test locations. Longitudinal penetration was also evaluated for selected species by viewing surfaces exposed lengthwise after cutting.

In this study, volume uptake after 10 seconds was extracted from each data set and **used** as the predictor of preservative penetration. Plots of injection water volume (mm^3) versus both transverse and longitudinal penetration are shown for two species (Fig. 1). In this format, no distinction is made among data common to any one piece; all data for each species are combined.

Using the device to predict transverse treatability depends on the correlation between transverse and longitudinal permeability for each of the wood pieces tested. Analysis of the data for each species revealed that this correlation varies with species and is not strong for any species (Fig. 1). Thus, confident prediction of a wide range of treatabilities is not possible. It may be possible, however, to separate those pieces that are very permeable from those that are highly resistant to penetration. The device is more accurate in predicting longitudinal permeability. This bodes well for using the device to select treatment schedules for incised pieces and for identifying pieces that are appropriate for such treatment.

Future research will refine data collection and analysis methods. To reduce sampling time to less than 1.5 seconds, a range of methods to extract data from the injection volume versus time plots will be explored. Statistical analyses to explore within-piece variability and to define the number of tests needed for reliable prediction will also be conducted.

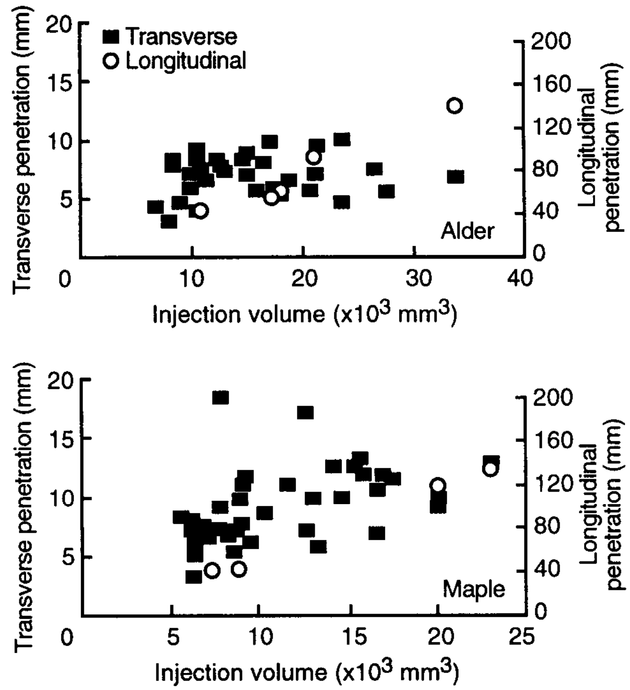

Figure 1—Injection water volume (after 10 seconds) versus transverse and longitudinal preservative penetration for aider (top) and maple (bottom).

Growing Shiitake on Underutilized Hardwoods

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Shiitake, a gourmet mushroom, is grown mainly on Oregon white oak sawdust in the Pacific Northwest. Farming shiitake is a new industry, employing approximately 100 people in western Oregon, primarily in small, timber-dependent towns. Outside the United States, most shiitake is grown on hardwood logs using traditional methods. In the United States, however, most shiitake grows on sawdust enclosed in plastic bags. Continued development of the industry requires a steady and increasing supply of hardwood. Consequently, we tried replacing oak sawdust with whole-log chips of Oregon white oak, tanoak, and bigleaf maple as alternative substrates for shiitake. Our study was intended to expand the supply of raw material by increasing the choice of hardwood species and using whole-log chips instead of headsaw sawdust.

Our. study had three parts. First, we located a supply of suitable hardwood chips. Second, we used the chips in pilot-scale trials to determine how well they grew mushrooms. Finally, we did an economic analysis to determine whether commercial growers could afford to use whole-log chips.

In seeking sources of chips we considered two factors: (1) chip quality (species, particle size, and cleanliness) and (2) chip availability (local sources, quantities, and price). Although we needed relatively small amounts for our experiments, we looked for sources that could supply truckloads of chips. To minimize shipping cost, we looked only in western Oregon. Finally, we looked for prices at or below pulp-chip prices.

We located several commercial producers of whole-log chips in the Willamette Valley and southern Oregon who wanted to expand or diversify their markets for hardwood chips and could supply our species. All were able to resize large chips to our specifications and supply it in chip-truck amounts.

Typical commercial hardwood chips are too coarse for mushroom farm mixers, baggers, and bags. Therefore, we needed to grind whole-log chips to our specifications. After testing several unsatisfactory models of small to mid-sized chipper-grinders, we found a supplier of a satisfactory, light industrial, 20 HP chipper-shredder made by Crary Bear Cat, West Fargo, ND.

During our pilot-scale trials we tested three commercial shiitake strains: CS-41, CS-53, and CS-287. Each strain responds differently to substrate and growing conditions.

We tested these strains on six experimental chip media and two sawdust media (white oak and maple). The six media consisted of two from each of three hardwood species: Oregon white oak, bigleaf maple, and tanoak. For each species, one medium was coarse chip and one fine chip. In each case, the medium contained only one hardwood species, and the chips contained fines.

We incubated the bags for 94 days to allow the fungus to grow through the medium. After incubation, we removed medium and fungus from their protective bag. By then, the fungus had converted the medium into a solid block. To induce each block to produce mushrooms, the block was placed in a fruiting chamber with conditions favorable for mushroom production.

Mushroom production occurs as successive fruitings (flushes) from each block. Following the first flush, the blocks were soaked in tap water, then treated as described above to induce successive flushes.

As the mushrooms developed, they were harvested and the fresh weight and grade produced by each block were recorded. In ideal commercial production, most mushroom production occurs in the first two or three flushes. We harvested mushrooms through four flushes.

All three hardwoods and both sizes of chips produced mushrooms. Yields were generally higher on fine chips than on either coarse chips or headsaw sawdust. Yields were also higher on tanoak than on Oregon white oak or bigleaf maple.

Our pilot-scale trials established that shiitake can be grown on whole-log chips of the hardwood species tested. All three hardwood species are currently available as whole-log chips from commercial sources in Oregon. Actual use of these species by shiitake farmers, however, depends also on economic factors. This involves three basic questions:

- Can the individual shiitake farmer afford to use whole-log chips of these species? The short answer is "Probably."
- Is the market for chips to supply shiitake farms lucrative enough to interest commercial chip suppliers? The issues are price, which is market dependent, and volume (presently 4,000 to 6,000 tons per year). Several suppliers have shown interest in expanding their production of hardwood chips for use in shiitake farming.
- Will the use of whole-log hardwood chips for shiitake farming create or sustain employment in western Oregon? Probably. Broadening the base of available raw materials should help the shiitake farmer, and increasing the market for chips from underutilized hardwood species should benefit the chip supplier.

Juvenile/Mature Wood Effects in Two Western Hardwoods

Anatomy and Mechanical Properties

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Due to the decreased availability of traditional softwood timber resources in the Pacific Northwest, this project was conducted to better characterize the hardwoods that may be of interest to the wood products industry in that region. Utilization of these alternative species in new markets will be difficult if the properties affecting their desired performance are unknown. The goal of this study was to determine anatomical and mechanical property changes from the interior to the exterior of red alder and Oregon white oak sample trees at two different heights. Increased knowledge of wood composition and behavior will allow forest managers and wood products personnel to make informed decisions concerning the growth and utilization of these species.

Red alder, with a natural proclivity for fast and vigorous growth, has the potential to enter the structural market. Thus, it is almost inevitable that alder will be managed for an expected harvest in 30 to 50 years; the result of this short rotation is a relatively large proportion of juvenile wood being formed in a tree. Juvenile wood (often called core wood) is found in the interior of the tree and the vicinity of the crown as the tree grows. Juvenile wood is fundamentally different from mature (outer) wood. Effects of short rotation on softwoods have been well documented. These include decreases in average cell size and mechanical strength and increases in longitudinal shrinkage due to the high incidence of juvenile wood.

Juvenile wood can negatively effect the general wood quality of a species. Thus, knowing the zone of influence of the juvenile wood will allow appropriate management and end-use decisions to be made. The structure of wood cells (anatomy) in the log significantly effects the properties of the lumber and can provide a basis for recommendation as to how a given type of tree should be used. Red alder is a species with uniform wood anatomy within a growth ring; that is, the wood produced during spring (earlywood) appears similar to the wood produced during summer and fall (latewood). In contrast, Oregon white oak produces wood with different anatomy from spring to fall, causing alternating bands of the two types of wood. The magnitude of variation in anatomical or mechanical properties at different heights or from growth ring to growth ring has not been examined in either of these species.

Tissue composition tells what proportion of a sample is made up of vessels, which are relatively weak and porous; fibers, which are strong and thick-walled and have high specific gravity; and ray parenchyma cells, which are thin-walled. Cambial age is the number of growth rings out from the middle of the tree. Properties determined in the mechanical test portion of this study were modulus of elasticity (E), modulus of rupture (MOR), specific gravity (G), growth ring width, and average age per specimen. The E was calculated by measuring the deflection of a small beam under an increasing load, and can be thought of as beam stiffness. The MOR is a measure of the maximum load a beam can support, or breaking strength. Specific gravity was taken on a green dimension/oven-dried weight basis and is a unitless representation of wood density, or the amount of wood substance in a given volume. Growth ring width is based on the measurement of each growth ring from the pith to bark. Average age of each specimen was determined by proportional weighting of the growth rings in each specimen. In previous research, E, MOR, and G have all been used to determine juvenile wood presence with differing degrees of success. In general, E has been shown to be the most sensitive indicator of the transition from juvenile to mature wood within a tree. Determination of the mechanical properties (E and MOR) is important because they significantly effect the structural performance of the wood. These two qualities are of primary consideration in most structural design applications. Knowledge of juvenile wood effects is essential for correct use of these species, especially in the structural market.

Six red alder and six Oregon white oak trees were sampled from a forest in the Oregon coast range. From each tree, one disk of wood was taken at breast height and another higher up the tree, below the first large branch. The top half of each disk was used for anatomical studies, and the bottom half was used for mechanical tests. Sequential samples were taken from a bark-to-bark strip that passed radially through the center of each disk. For mechanical testing, the mini-specimens were 0.25 in. deep and wide and 4 in. long.

In red alder, the wood was relatively constant in tissue composition and specific gravity, but fiber length increased from the center of the disks outward (with increasing cambial age) (Figs. 1-3). Both E and MOR increased from the center outward and showed typical juvenile wood zones (Figs. 4 and 5). In Oregon white oak, tissue composition, specific gravity, and fiber length all changed significantly from the center of the disk to the outside (Figs. 6-8). However, E and MOR showed no significant change, indicating no juvenile wood effect for the mechanical properties (Figs. 9-10). There was little variation in anatomy or mechanical properties between heights for either species. From an anatomical standpoint, the results of this study suggest that lumber cut from an individual red alder will be much more uniform than that cut from an individual Oregon white oak. From a mechanical viewpoint, however, red alder exhibited a typical juvenile wood zone, whereas although the Oregon white oak has changing anatomical properties, it has relatively uniform mechanical properties as growth ring age increases.

This study indicates that red alder has a distinct juvenile wood zone, implying that fast growth and short rotation age (early tree harvest) will have a negative effect on wood quality. Conversely, rate of growth and tree age at harvest will have little significant effect on the strength properties of Oregon white oak.

For Additional Information

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Evans, J. 1995 (expected). Juvenile wood effect in red alder *(Alnus rubra* Bong.) and Oregon white oak *(Quercus garryana* Dougl.). Ph.D. dissertation. Department of Natural Resources, Purdue University, IN.

Gartner, B.L.; Lei, H.; Milota, M.R. 1995. Variation in anatomy and specific gravity of wood in red alder. In: Proceedings, 49th annual meeting; Forest Products Society, p. 9. (Abstract).

Lei, H.; Gartner, B.L.; Milota, M.R. 1995. Effects of growth rate on anatomy, specific gravity, and bending properties, in wood of seven-year-old red alder. In: Proceedings, 49th annual meeting; Forest Products Society; p. 9. (Abstract).

Lei, H. 1995 (expected). The effects of growth rate and cambial age on wood properties of red alder *(Alnus rubra* Bong.) and Oregon white oak *(Quercus garryana* Dougl.). Ph.D. dissertation, Department of Forest Products, Oregon State University, Corvallis, OR.

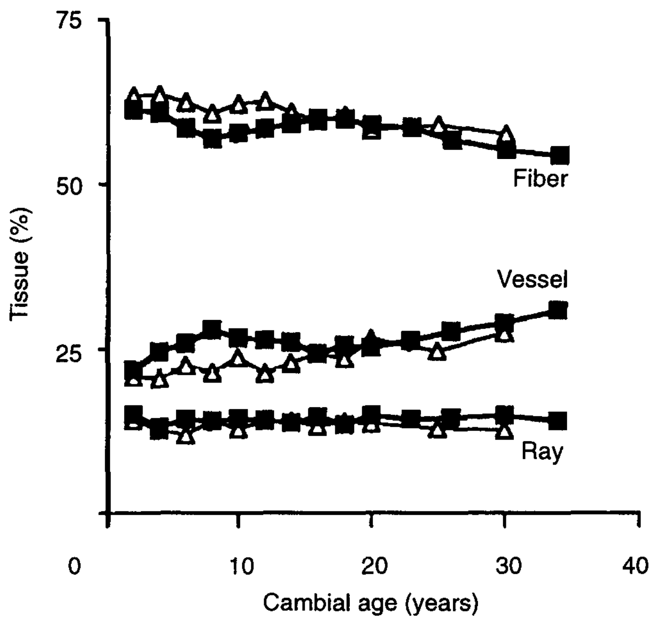

Figure 1—Tissue proportions in red alder; open triangles are upper height and closed boxes are breast height. The middle of the tree (pith) is at cambial age 0 and the bark is out to the right.

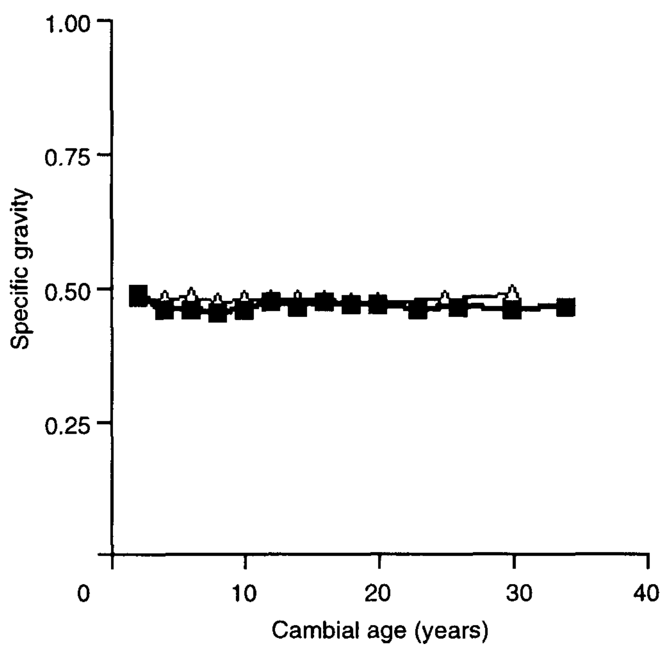

Figure 2—Specific gravity in red alder.

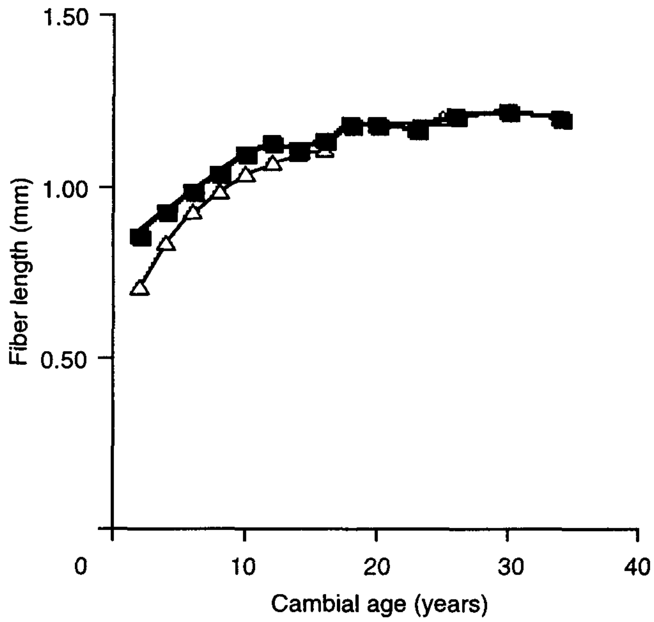

Figure 3—Fiber length in red alder.

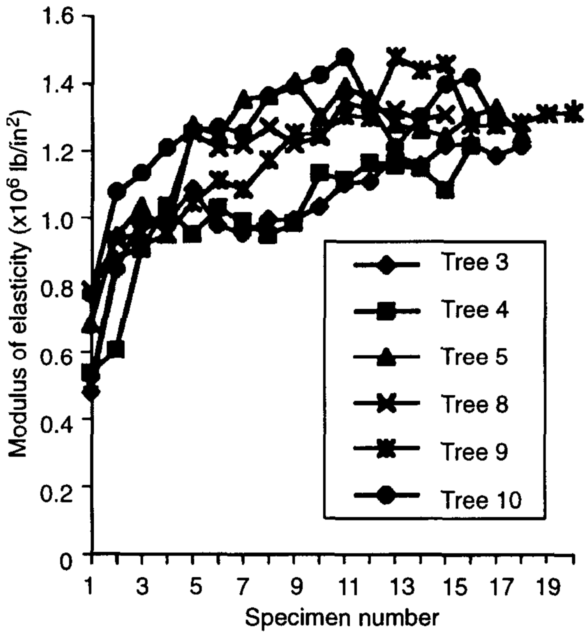

Figure 4—Red alder modulus of elasticity at breast height. The specimen numbers begin at the pith and increase toward the bark from left to right.

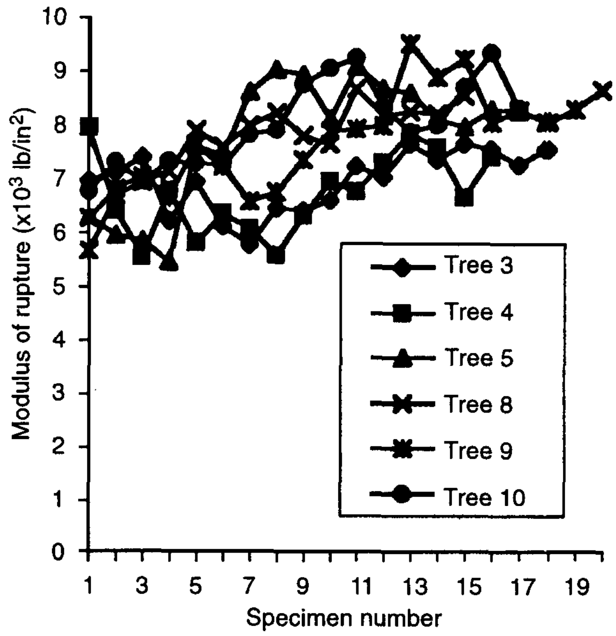

Figure 5—Red alder modulus of rupture at breast height. The specimen numbers begin at the pith and increase toward the bark from left to right.

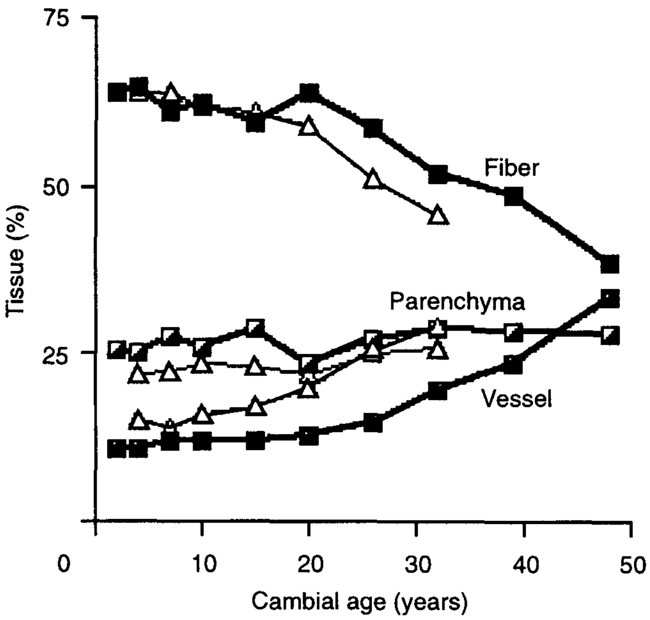

Figure 6—Tissue proportions in Oregon white oak. Parenchyma is the sum of ray tissue and axially oriented parenchyma.

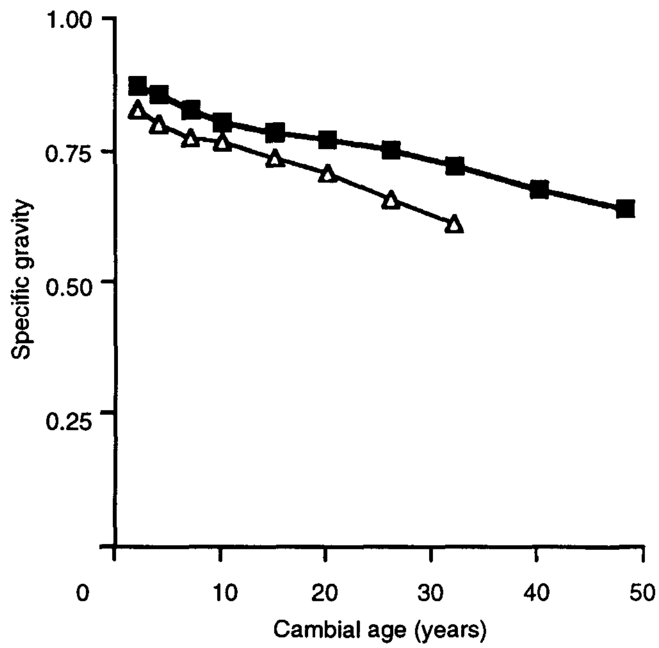

Figure 7—Specific gravity in Oregon white oak.

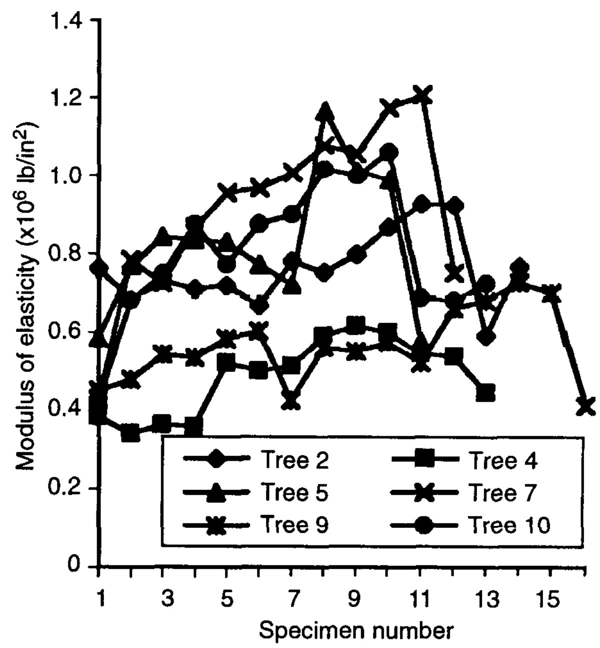

Figure 9—Oregon white oak modulus of elasticity at breast height. The specimen numbers begin at the pith and increase toward the bark from left to right.

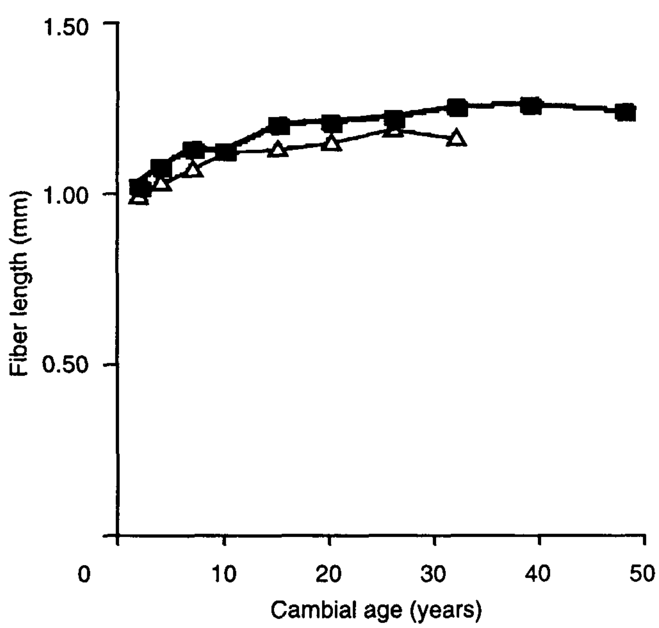

Figure 8—Fiber length in Oregon white oak.

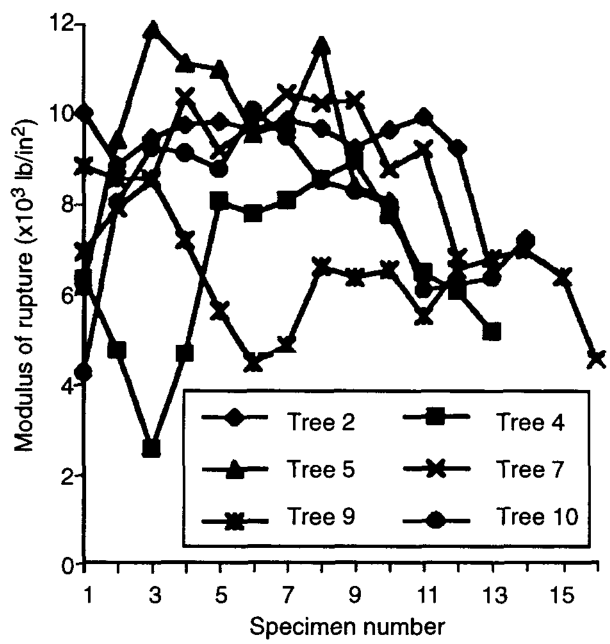

Figure 10—Oregon white oak modulus of rupture at breast height. The specimen numbers begin at the pith and increase toward the bark from left to right.

Hardwoods of the Pacific Northwest

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The history of hardwoods in the Pacific Northwest is sometimes characterized by contradictions. Hardwoods have been valued as useful trees. They have been a raw material resource for homes, furniture, and implements; a source of food for people and game animals; and a source of beauty in a largely evergreen landscape. Hardwoods have also been considered weeds, undesirable competitors with regenerative conifers. This contradiction continues today.

The current economic condition of the forest products industry and the increased emphasis on diversity and ecosystem processes continue to stress the importance of Pacific Northwest hardwoods. More people than ever are seeking a variety of information on hardwoods. This information is scattered among many, sometimes obscure, publications or found in the experience of many individuals.

To make this diverse information more readily available, our final publication brings together information on the biology, management, and processing of the Pacific Northwest (western Washington and Oregon, and northwestern California) hardwood species. The comprehensive publication covers a wide range of subjects and provides detailed information on the 10 species listed below.

Common Name	Scientific Name
Bigleaf maple	*Acer macrophyllum* Pursh
Black cottonwood	*Populus trichocarpa* Torr. & Gray
California black oak	*Quercus keloggii* Newb.
California-laurel	*Umbellularia californica* (Hook. & Arn.) Nutt.
Giant chinkapin	*Castanopsis chrysophylla* (Dougl.) A. DC.
Oregon ash	*Fraxinus latifolia* Benth.
Oregon white oak	*Quercus garryana* Dougl. ex Hook.
Pacific madrone	*Arbutus menziesii* Pursh
Red alder	*Alnus rubra* Bong.
Tanoak	*Lithocarpus densiflorus* (Hook. & Arn.) Rehd.

Although most of the book is written for people with some background in forestry and wood products, the first chapter reviews basic principles and terminology and discusses characteristics common to all hardwood species. The following chapters detail several aspects of each of the 10 hardwood species. The discussion topics for each species include general characteristics (size, longevity, and form; geographic range; and timber inventory), biology and management (tolerance; crown position; ecological role; associated vegetation; suitability and productivity of sites; climate; elevation; soils; flowering and fruiting; seed; natural regeneration from seed; regeneration from vegetative sprouts; regeneration from planting; site preparation and vegetation management; stand management; mixed-species stands; growth and yield; interactions with wildlife; insects and diseases; and genetics), harvesting and utilization (cruising and harvesting; and product recovery), wood properties (characteristics; weight mechanical properties; drying and shrinkage; machining; adhesives; finishing; and durability), and related literature. Each chapter covers both what is and what is not known about the specific species. In many cases, very little is known.

The purpose of this document is to increase the knowledge of indigenous hardwood species among forest managers and wood product users, and thus promote and maintain ecosystem diversity and sustainable supplies of these species. We also hope to increase utilization options related to the eco-. nomic development of hardwoods.

For Additional Information

Niemiec, S.S.; Ahrens, G.R.; Willits, S.; Hibbs, D.E. 1995. Hardwoods of the Pacific Northwest. Research Contribution 8. Corvallis, OR: Forest Research Laboratory, Oregon State University. 115 p.

Oregon and Washington Hardwood Management Workshops for Foresters Advising Nonindustrial Private Forestland Owners

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The future of hardwood forestlands in the Pacific Northwest depends to a large extent on the management of nonindustrial private forestlands (NIPF). Foresters in the Northwest have traditionally encouraged control or elimination of hardwood species, and therefore expertise regarding hardwood management is lacking. To educate foresters who advise NIPF owners on management practices that favor hard-wood species, two hardwood management workshops were held in the Pacific Northwest region. The workshops updated foresters (state service foresters, county extension foresters, and private forestry consultants) on the most recent information concerning management, harvesting, and marketing options for hardwoods in Oregon and Washington. The foresters were also surveyed to bring together their knowledge and opinions concerning the role of hardwoods on NIPF.

Within this research and demonstration program, hardwood management workshops were part of a group of projects that addressed hardwood availability and supply. With increasing use of hardwoods, both researchers and manufacturers familiar with this resource have serious concerns about its sustainability. For decades, the policies and practices affecting Northwest forests have effectively favored conifers. Thus, the future supply of hardwoods is uncertain.

Management practices by NIPF owners will play an important role in determining future hardwood supplies. Currently, they own about half the hardwood resource in the Northwest and an even greater portion of the future resource because intensive conifer management is effectively reducing the hardwood component on land owned by others. Although the relatively high percentage of hardwoods on NIPF continues to regenerate, foresters advising these owners usually discourage hardwood management because of poor expectations for future economic returns and a lack of knowledge about hardwood management options.

Each Hardwood Management Workshop was a two-day program consisting of a day of indoor presentations and discussion with a second day in the field for viewing and discussing of actual practices. The indoor session was led by researchers and practitioners, with presentations using slides, overhead projections, and product samples. A workbook, provided for each participant included a synthesis of information on hardwood management and specific notes on each hardwood species. Numerous reprints from recent publications, including the most recent papers establishing practical guidelines for seed collection and regeneration of red alder, were distributed. Key topics of the workshop included the following:

- Hardwood Silviculture—site selection; assessment of site quality, hazards and risks; regeneration; site preparation and vegetation management; stand management; management of species mixtures; growth and yield; forest practices and regulations affecting hardwoods; and special opportunities for NIPF
- Harvesting Hardwoods-logger's perspective on harvesting methods, challenges, and opportunities on NIPF; hardwood manufacturing industry's perspective on hardwood logging, systems, operators, and costs
- Marketing Hardwoods-inventory and appraisal; log and lumber prices past, present, and future; types of markets; timing of sales; economics of hardwood management; incentives and opportunities for NIPF
- Discussion and Synthesis (an interactive discussion among presenters and participants)-objectives and interests of NIPF owners concerning hardwoods; perceived obstacles to hardwood management; future potential for hardwoods on NIPF; what foresters need from researchers

A variety of hardwood management, harvesting, and research sites were visited. These field sites provided examples and testing grounds for the theories, practices, and issues covered during the indoor session.

The Oregon Hardwood Management Workshop was held May 4-5, 1993, with the indoor session at the Oregon Department of Forestry office in Salem. Field sites were located in the North Santiam River drainage, including stops at a small hardwood sawmill, an active hardwood harvesting site, hardwood riparian forests, and two hardwood plantations. The participants included 16 state foresters, 8 private consultants, 5 extension foresters, 2 loggers, 1 state forest practices forester, 1 hardwood industry representative, 1 USDA Forest Service researcher, and 1 Soil Conservation Service forester.

The Washington Hardwood Management Workshop was held October 12-13, 1993, with the indoor session at the University of Washington's Pack Forest near Elbe. Field sites included an experimental planting of alder located on Pack Forest, mixed hardwood harvest and regeneration sites on nearby state lands, natural hardwood stands, and an alder test plantation (Weyerhaeuser Co.) near Rainier, Washington. The participants included 14 state foresters, 13 private consultants, 2 hardwood industry representatives, 2 researchers from the University of Washington, 2 researchers from Oregon State University, 2 USDA Forest Service foresters, 1 Washington State University Extension forester, 1 logger, and 1 state wildlife biologist.

The material presented in the workbook and other handouts was well received. Many of the participants were not familiar with recent changes concerning management, harvesting, and marketing of hardwoods. At both workshops, the response and participation was positive. Comments received indicated that many participants thought the information was valuable and that further updates of information on hardwoods, along with additional workshops, were needed.

In addition to the education and training provided, another important product of the workshops was the information we received regarding likely hardwood management practices on NIPF. This information was incorporated in "Hardwoods in the Pacific Northwest: A Policy Perspective" (USDA Forest Service Res. Pap. PNW-RP-478), a related project completed under this same overall research program. Although NIPF management goals and practices are diverse, foresters made several general points based on their experience with NIPF owners. There appears to be increasing interest and some action towards taking advantage of existing hardwood regeneration and hardwood management opportunities on NIPF. Although there is considerable interest in hardwood management, there seems to be little long-term commitment. Much of the interest is stimulated by the hope of achieving short-term economic returns with fast-growing hardwoods. A major factor is the potential for continued increases in hardwood log values. Currently, very few NIPF acres are planted or otherwise intensively managed for hardwood production.

Foresters gave significant input on the kinds of information they need from researchers who study hardwood management. More information, such as that presented at the workshop, is needed to evaluate the potential of existing hardwood stocking of various species. Better growth and yield information is needed for all hardwood species. Fact sheets listing both limitations of and opportunities for exotic hardwood species are needed. Quarterly market surveys and price reports were requested. In particular, a detailed and periodically updated guide to hardwood log buyers was requested. An important outcome was that the Washington Hardwoods Commission prepared the first version of such a guide to log buyers in Washington state.

The major conclusion drawn from the workshops is that foresters who advise NIPF owners need accurate, practical information relating to hardwoods on a continuing basis. Forestry Extension, the Hardwood Silviculture Cooperative, and other research groups should continue or expand efforts to provide updated information and transfer technology. Towards this end, the compendium "Hardwoods in the Pacific Northwest" (produced by a related project in this same overall research program, available from Forestry Publication Office, Oregon State University) provides a new, readily available source of information on hardwoods. Consistent hardwood price reporting and an updated guide to hardwood log buyers should be pursued for both Oregon and Washington. Additional workshops should also be held as we accumulate more experience and information pertaining to management of hardwoods.

Acknowledgments

- Oregon Department of Forestry, Forestry Assistance Program
- University of Washington
- Washington State University, Forestry Extension

Oregon Hardwood Supply Project

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Hardwood species, especially red alder, were once considered a weed in Oregon but now have an economic value to support their management as timber. This project focused on hardwood supply from non-industrial private forest (NIPF) lands in Western Oregon and had three components. They were (1) the mapping of major hardwood species by age grouping and stocking levels for Oregon's two largest NIPF counties; (2) the purchase of computer software and training to enable local service foresters to assist in the matching of log buyers with sellers; and (3) the development of a pamphlet showing the location and description of the major hardwood timber types on Western Oregon NIPF lands.

Maps showing locations and characteristics of NIPF timber resources in Lane and Douglas counties were developed for this project. These maps were plotted from data taken from a digital inventory of NIPF land prepared by Atterbury Consultants, Inc., for the Oregon Department of Forestry (ODF) in 1992. Included in this project are maps that show locations of hardwoods and poorly stocked forest land by species cover type, age class, and volume class. These maps are available for viewing at ODF offices in Salem, Veneta, and Springfield; Lane County Council of Governments; and Douglas County's Oregon State University (OSU) Extension Service.

Computer software and training have been provided to Western Oregon ODF service foresters and OSU forestry extension foresters to enable them to manage the 1992 NIPF forest cover inventory. With this software, they can identify and locate on maps individual forest cover types by size, age, species, and/or stocking level characteristics. Addresses and phone numbers of ODF and extension foresters with these capabilities can be obtained through ODF's Salem Office.

The third component of this project was the development of a pamphlet describing Western Oregon's major hardwoods on NIPF lands by age and volume characteristics, and displaying these characteristics on three maps. Two maps show the location of red alder along the coast and in northwest Oregon, while the other shows the location of Oregon White Oak/ Pacific Madrone in southwest Oregon. These pamphlets are available at all ODF and OSU Extension offices in Western Oregon.

Hardwood Price Reporting

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and Environmental Studies
Richard W. Haynes
Pacific Northwest Research Station

Since 1985, the hardwood lumber industry in the Pacific Northwest has grown considerably. Despite this growth, accurate information concerning the value of hardwood stumpage, particularly red alder *(Alnus Rubra* Bong.), is not available to forest managers. One consequence of this is that forest managers and landowners have not have realized the economic value of hardwoods, such as red alder, and they have continued to eradicate, rather than manage, hardwoods.

This research was motivated by concerns about whether timberland managers and owners have the necessary information to make rational decisions regarding hardwoods. Small quantities of red alder are sold as stumpage and the prices we found relate to the domestic delivered log market. Although we did not examine it in this study, a vigorous export market for high quality red alder logs exists in the Pacific Northwest. In this study, we attempted to develop an accurate price series on domestic delivered red alder logs in the Pacific Northwest region. Efforts to include other species failed because industry-level information was limited.

Methods

Utilizing statistical methods, we showed that data obtained from the Washington Department of Natural Resources (DNR) and the Oregon Department of Forestry (ODF) are the closest available representations of actual market conditions. This conclusion is based on testing different time series against one another to satisfy the conditions of reliability, consistency, and robustness. We also looked for indications of seasonality and long-term trend. The goal was to find a reliable price series that could be published regularly.

Results

All data sets reveal that Oregon prices are statistically higher than Washington prices. In the Washington DNR data, we also found a significant difference between prices from each of the surveyed regions. We compared the average, variance, standard deviation, and proportion of months with a change to the different sources of price information. While the average for some series is closer to the actual data than the average for all of the data, the variance, the coefficient of variation, and the proportion for the data are all closest to data from actual producers. Based on simple comparisons and this test of significance, we found the DNR data to be the closest proxy for actual producer data.

The data from Washington mills indicate that seasonality exists. Prices are higher in the winter and spring than in the summer and fall. In contrast to Washington, prices from mills in Oregon do not show seasonality. However, the quarterly data from the ODF suggest some seasonal variation. Prices are higher in quarters one and two than in quarters three and four. Finally, we found a positive trend in the price of red alder in Washington for the period of January 1986 to April 1992.

Conclusion

Until recently, red alder prices in Washington have been lower than those in Oregon. This situation seems counterintuitive as the export market is stronger in Washington, and there are more competitive mills there. If prices are driven by supply side issues, however, it may be easier for Washington mills to tap their hardwood supply than it is for Oregon mills. For example, most hardwood is on private timberland, which there is more of in Washington.

We concluded from the results above that the Washington DNR data will serve as an adequate proxy of the population of prices in Washington. Looking at the data from Oregon, the ODF series does not match up to actual producer prices as well as the DNR prices in Washington do. Nevertheless, it is the best available alternative for use in systematic price reporting.

The assumption that hardwood markets are freely competitive has allowed us to test the time series against one another by suggesting that all price series come from the same population. Although many industry observers suggest that the markets are not competitive, we found no evidence contrary to our assumption. Prices are robust, especially when looking at the average value of logs obtained from the mills themselves. One trait of imperfect price setting is that prices do not move for months at a time. We found the opposite here; while mills may not change their list prices for a few months, their average log price changes frequently. Hence, we feel confident that our assertion of competitive markets holds in the hardwood industry of the Pacific Northwest.

Implementation

Implementation of these results in terms of price reporting has not been carried out; we are waiting for an assessment of the availability of price statistics from state agencies.

For Additional Information

Sohngen, Brent L.; Haynes, Richard W. 1994. Hardwood price reporting. Res. Pap. PNW-RP-470. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 16 p.

Hardwood Policy Evaluation

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The forest products industry in the Pacific Northwest has traditionally been a softwood industry, with hardwoods playing a minor role. The declining availability of old growth softwoods and rapidly increasing inventories of hardwoods on cut-over lands have changed that picture. Today the hardwood industry, based on formerly underutilized species like red alder *(Alnus rubra* Bong.) and bigleaf maple *(Acer macrophyllum* Pursh), is an important part of the forest products industry. Concern in the industry is now focused on future supplies and the impact that changing forest management policies has on those supplies. This project addressed those concerns by evaluating current hardwood policy issues including resource conditions, regulatory and nonregulatory institutions, forest management, harvesting trends, the industry, and markets. The goal was to provide an overview of the hardwood resource in the Pacific Northwest; to evaluate regulatory and nonregulatory policy institutions and their impact on hardwood supplies; to synthesize forest management impacts on supplies; and to determine the status and prospects for the hardwood industry. These critical issues directly impact the success of the Value-Added Research and Demonstration Program for western hardwoods in the Pacific Northwest.

The first section of our evaluation contained an overview of the hardwood resource, which was assembled from the most current inventory data available in Western Oregon and Westem Washington. Hardwood area, volume, resource characteristics, and harvest data illustrated the current resource status. A systematic assessment of policy issues that directly impact short-term supply was conducted. These issues included forest practice regulations, other regulatory influences, and landowner harvesting behavior.

The second section of the evaluation focused on resource management issues that are long-term determinants of supply. An assessment of management plans and policies of major public and private owners of forest land in the Pacific Northwest was conducted to determine hardwood management strategies. Changes in hardwood management and its effect on long-term supply were summarized. Economic and ecological benefits of hardwoods were also addressed.

The final section of the evaluation examined the hardwood industry in the Pacific Northwest. Markets and economic values were summarized. Estimates of employment and income impacts of the hardwood industry, both regionally and nationally, were made, and the potential for increased use of hardwood species other than red alder was examined.

The evaluation provided a comprehensive picture of the status of hardwoods in the Pacific Northwest and the regulatory environment and forest management policies that determine short-term and long-term supply. Among the significant findings were the following:

- Existing hardwood resources are at the highest level in history (Fig. 1). Private lands account for 70 percent of the hardwood inventory and contribute 90 percent of the harvest.

- Short-term supply appears to be adequate for existing processing capacity in many areas. Environmental regulations, forest practice rules, and urbanization, however, have disproportionate impacts on hardwoods and may make significant amounts of the inventory unavailable for harvest.

- The long-term supply of hardwoods in the Pacific Northwest is uncertain, and forest management policies on many ownerships indicate that current inventory levels will not be sustained.

- Pacific Northwest hardwoods have world-wide market acceptance, and demand is strong in both domestic and foreign markets. The hardwood processing industry is a significant part of the forest products industry in the Pacific Northwest (Table 1).

The evaluation included policy recommendations that were based on our findings and conclusions. These called for improved measurement and accounting of hardwood resources, continued silvicultural research, research to determine how the resource can be used in the regulatory environment, and promotion of secondary and high value-added manufacturing using Pacific Northwest hardwoods.

It is essential that accurate information on the hardwood resources on federal lands be determined. In addition, there is a critical need for increased recognition of the potential of the hardwood resource on public lands in general.

For Additional Information

Raettig, Terry L.; Connaughton, Kent P.; Ahrens, Glenn R. 1995. Hardwood supply in the Pacific Northwest: A policy perspective. Res. Pap. PNW-RP-478. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 80 p,

Table I-Estimated average annual employment from the Pacific Northwest hardwood resource

	Oregon		Washington	
Industrial sector	1990	1991	1990	1991
Lumber and wood products	1,309	1,327	1,696	1,718
Logging	320	350	674	692
Sawmills	790	741	845	847
Veneer and plywood	199	241	177	179
Secondary	1,677	1,677	725	725
Pulp and paper	863	875	643	758
Forestry	197	234	184	196
Total	4,046	4,113	3,248	3,397

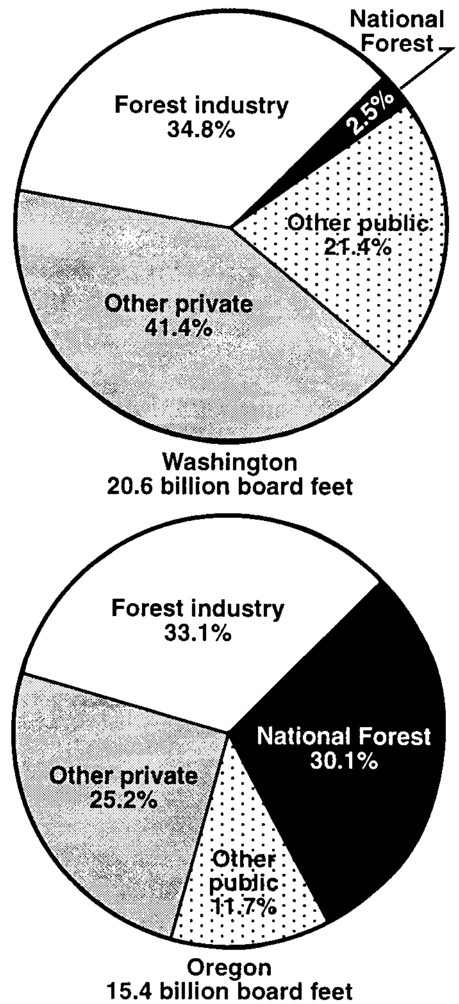

Figure 1—Hardwood sawtimber inventory by state and owner.

Perceptions of Red Alder Harvesting Limitations

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Interest in harvesting and utilization of red alder *(Alnus rubra* Bong.) has increased dramatically with the diminishing supply of softwoods from federal and state timberlands. Both small landowners and large corporations are seeking opportunities and information on how to begin or increase the harvesting of their red alder stands. To identify the specific barriers and/or myths that may be preventing this harvesting, informal interviews were conducted in 1992 with a variety of interested parties including forestry consultants, small mill owners, large corporations, federal, state, and county agencies, loggers, and private landowners.

Forty-three issues were raised by those interviewed. The responses were reviewed to determine if they were a barrier or a myth (in the three years since the interviews, circumstances have changed the status of several of the issues). We evaluated each barrier to determine which were technical in nature and could thereby be overcome with research or education, and which were in place for policy, ecological, or economic reasons. There is considerable overlap between categories (for example, timber sales that are too large for the small hardwood industry to purchase may be too large because of the timber sale economics, the landowners policies, or a lack of understanding of the hardwood industry). Several themes were consistent throughout the responses. These included long-term steady supply, riparian zone issues and restrictions, the economics of using hardwoods, which can be marginal, and lack of information regarding the value of the hardwood resource. In addition, there remains a prevalent mindset that the conifer resource is the most important, and the hardwood resource by itself is not important.

Within the issues that were identified as research, most addressed logging concerns such as costs, equipment, and riparian zone impacts. An attempt was made to set up a small timber sale in cooperation with a small private landowner to develop cost information for two types of logging systems. Unfortunately, the logistics of finding a willing landowner with enough land to test more than one logging system, logging companies with flexible equipment, and finally, weather that would permit logging during the time of year that researchers were available proved to be too difficult in the time frame that was set aside for this study.

Following is the compiled list of barriers and myths.

Barriers

Policy

- Federal agencies do not emphasize “secondary products” such as alder.
- No funds are allocated towards projects involving alder.
- Clearcuts in predominately hardwood stands are not appropriate under the special forest products program.
- Alder mills are usually at the mercy of the softwood buyers for their supply of logs. Alder mills want more control over the supply of logs.
- There is no effort on the part of the State to offer any alder sales to industry.
- Small landowners are worried that new legislation regarding wetlands may lock up their timber resource for the future, and therefore are harvesting stands now to liquidate their assets. This puts more alder on the market now, but depletes the future supply.
- State agencies are allowed to log 100 million board feet of alder, but only 40 million board feet as a come along with the fir.
- Incentives, such as tax credits or preferential tax rates, are needed for private landowners who manage red alder.

Economic

- Alder is removed in pre-commercial thinnings and is slashed.
- Alder mills are usually at the mercy of the softwood buyers for their supply of logs. Alder mills want more control over the supply of logs.

- Most of the alder comes off private lands. Thus, in the winter, supply is limited because many of these private roads are not plowed.
- Mills that do their own logging of alder find that most of the stands are 50% conifer, then they have the problem of reselling the conifers.
- Future supply is a problem-many alder stands that are being cut are being converted to conifers.
- Portable chippers on logging sites are viewed as a problem because they can reduce the volume available for lumber and veneer processing.
- When the chip market is up, there is an overcut of alder.
- Better sorting of alder is needed—some loggers will not spend the time to sort even when they know that extra income is available to them when this is done.
- The value of alder will have to be in the same range as Douglas-fir to ensure a continuing supply of alder for the future.

Ecological

- In many thinnings, all hardwoods are reserved for wildlife trees.
- As biodiversity evolves, alder will become a more important component of the stand structure.
- The better alder is found in the riparian areas that are unavailable for harvesting.
- Wetlands issue could eliminate hardwoods as a product,

Technical

Educational

- Alder is viewed as an inferior species, value is not there.
- In some areas the cruisers felt that there was not enough volume to bother with or that the trees were too crooked to be marketable.
- Accurate volume tables for alder are needed. No studies have been done for form class.
- Many alder sales that are offered are not what the alder processors consider to be worthwhile sales. Stems are too small and crooked and sites are poor.
- Agencies should put up alder sales that smaller companies can compete for.
- Some cutters are not as careful with falling alder as they would be with falling a conifer. A mental adjustment has to take place in moving from an old-growth stand to an alder stand.
- Future supply will be a problem. Many alder stands are being cut and converted to conifers.
- Training on scaling of alder is needed.
- The value of alder will have to be in the same range as Douglas-fir to ensure a continuing supply of alder for the future.
- Small landowners are not actively managing the hardwoods on their property.
- Better information about what type of site is suited to alder is needed.
- Better inventory and volume tables on alder are needed.

Research

- As biodiversity evolves, alder will become a more important component of the stand structure.
- Alder is expensive to log-smaller logs and more turns. Loading a truck with small logs can take 45 minutes.
- Smaller yarders are needed with less horsepower to reduce the amount of breakage in yarding.
- Smaller logging shows with various entries are needed.
- Better inventory and volume tables for alder are needed.
- Information on two-stage logging, one for alder and a separate one for the conifers, is needed. Is this feasible or is it more effective to log both at same time?
- Scientific information on riparian areas is needed.
- The growth and rotation length of alder must be improved. Alternative rotations with Douglas-fir should be considered. Improved alder genetics are needed.
- There is a lack of creativity in riparian areas; all the timberland in the riparian areas is needed. Manageable units could be laid out while still protecting the riparian area.

Myths

- People who want to use alder have not been aggressive enough in requesting alder sales and working with the agencies.
- Hardwoods are not part of the allowable cut base.
- There will be a lack of supply in the late 1990s; people will be out of business.
- Land base for forestry is dwindling because it is being diverted into developments. Low elevation lands are not being used for forestry, some are being sold as housing areas and the owners are not managing the forest resource.

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