MECHANICAL GRADING OF LUMBER SAWN FROM SMALL-DIAMETER LODGEPOLE PINE, PONDEROSA PINE, AND GRAND FIR TREES FROM NORTHERN IDAHO

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ABSTRACT

Forest lands of the Inland Northwest have many timber stands consisting of overgrown, densely stocked trees that create a fire hazard and are prone to disease. These stands need to be thinned, but the cost of harvesting often exceeds the value of the timber produced. However, because of the dense stocking and the resulting slow growth these trees may produce lumber with desirable mechanical properties. One method for sawmills to more fully utilize the potential grade yield and realize greater economic return from such lumber may be to produce machine-stress-rated (MSR) lumber instead of visually graded dimension lumber. The purpose of this study was to determine the mechanical properties, and corresponding economic value, of lodgepole pine, grand fir, and Ponderosa pine dimension lumber produced from typical overstocked forest stands in northern Idaho. The lumber was visually graded and tested for modulus of elasticity and modulus of rupture, and each piece was sorted into two types of grade categories: 1) visual Structural Light Framing; and 2) MSR. This study indicated that two of the three species we tested had good visual and mechanical characteristics. MSR grading of the lodgepole pine group produced a $27/MBF increase in value above visual grading, and MSR grading the grand fir group produced a $15/MBF increase in value above visual grading. The Ponderosa pine samples were from poor quality trees "thinned from below." Because of the poor yield in the higher visual grades, Ponderosa pine thinnings in this study were judged not to be a good candidate for production of MSR lumber. This study points out the potential value of lumber sawn from overstocked stands of timber, but demonstrates the need for an assessment process to estimate local resource capability.

The Inland Northwest has many dense forest consisting of predominately small-diameter, same-age trees. These stagnated forests were created by large stand replacement fires followed by natural regeneration and several decades of fire suppression and minimal self-thinning. A survey of the Colville National Forest (21) provides a good example of typical stagnated forests. The stands are characterized by high densities of trees less than 9 inches diameter at breast height (DBH). The species mix consists of lodgepole pine (*Pinus contorta*), Ponderosa pine (*Pinus ponderosa*), western larch (be *occidentals*) and Douglas-fir (*Pseudotsuga menziesii*), often with a thick under study of grand fir (*Abies grandis*).

Thinning of dense, stagnated timber stands can increase the quality of future harvests and improve forest health (15). However, thinning these stands produces mostly small-diameter (4 to 10 in. DBH) logs that do not have a high economic value, and may actually have negative value at the mill (19). Traditionally, the logs from such thinnings have not been utilized for solid-sawn

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lumber because of their low value. These logs have low volume and a high cost of removal. However, as the average size of logs being harvested has declined, technology has been developed to process small-diameter logs more efficiently. Alternative mill strategies, such as producing mechanically graded lumber, may increase mill profits (17). Although these logs are of small diameter, they may have slow growth rates that produce logs with less juvenile wood, higher density wood, and greater mechanical properties. A study of an even-age lodgepole pine forest in British Columbia demonstrated that lumber strength increased as tree DBH decreased (16).

Two methods of structural grading were considered to evaluate the potential value of small-diameter timber from northern Idaho. The first, and most common, was structural grading by visual assessment. Visual grading employs the concept that pieces of lumber with small knots are usually stronger than lumber with larger knots. Procedures for visual grading of 2-inch-thick "dimension" lumber are governed by the National Grading Rule, and are the same across species (14,20). While visual grading rules for dimension lumber are species independent, property assignment procedures depend upon species. Further, visually graded lumber is often marketed in species groupings, the assigned properties of which may be controlled by the weaker species in the grouping (5). A producer having available a stronger species in the grouping, or trees having superior growth characteristics, may have to settle for assigned properties that are less than might be possible through more precise grading methods.

The second grading method used was for machine-stress-rated (MSR) lumber. Commercially produced since the early 1960s, MSR grading combines visual assessment of knots, and other defects, with nondestructive measurement of bending stiffness to more precisely estimate properties (7). The most popular method for producing MSR lumber is to segregate lumber into grades by means of mechanical evaluation of bending stiffness combined with visual limitations. Because of the more precise grading methods used, yield of MSR lumber grades tend to be more dependent upon the local resource than are those of visually graded lumber. MSR grading procedures produce lumber having a lower coefficient of variation in modulus of elasticity (MOE) than does visual grading, and uses destructive quality control testing to verify property assignment. The reduced variability in MOE is of particular importance in engineered structural components such as metal-plated wood trusses, structural glue-laminated beams, and fabricated I-joists (22). The MSR process may also allow a producer to take advantage of a superior local resource and achieve design values not possible through visual grading (13).

MSR lumber currently constitutes a small portion of the dimension lumber market, but it may have the greatest potential for growth of sawmill products (7). MSR lumber production in the United States continues to grow; production increased by nearly 60 percent over the past 5 years (18). The production of MSR lumber from smaller-diameter logs may offer a higher value alternative to the production of visually graded lumber. However, before lumber manufacturers will invest in the equipment necessary for MSR grading, the mechanical properties of lumber from logs harvested from timber-stand thinnings must be determined. Grand fir and lodgepole pine were identified as two species that are likely to be produced from timber-stand thinnings and have high potential for increased value through MSR grading. Ponderosa pine was also selected for study because of its prevalence in stagnated forests in the intermountain west.

The first objective of this study was to determine the mechanical properties of grand fir, Ponderosa pine, and lodgepole pine 2 by 4's manufactured from logs harvested from one site in northern Idaho. The second objective was to sort the sample into both visual and MSR grade categories and to compare the grade yield and economic value for the two grading methods.

METHODS

The trees for this study were obtained from two locations in the Inland Northwest. Grand fir and lodgepole pine logs were harvested from a second-growth, even-age, forest stand in the Idaho Panhandle National Forest north of Priest River, Idaho. There was no documented stand history, but the district forester was able to provide the following information based on a current inspection.[1] The stand was regenerated by a catastrophic fire, or a combination of logging and residual burning, approximately 45 years ago. The forester estimated a species mix of 30 percent grand fir, 30 percent lodgepole pine, 20 percent western redcedar, and 20 percent western hemlock. The stand had an approximate basal area of 180 square feet per acre, an average height of 65 feet with a range of 47 to 85 feet, and an average DBH of 8.5 inches with a range of 7 to 11 inches. The Ponderosa pine was harvested from a second-growth site planted in 1952 in the Nez Perce National Forest southeast of Grangeville, Idaho. The site consisted of 99 percent Ponderosa pine and 1 percent Douglas-fir. The logs for this study were obtained by "thinning from below," which removed the poorer quality trees.

A cooperating sawmill produced a maximum number of 12-foot 2 by 4's from each log. The 12-foot length was chosen because it is a commonly marketed length of MSR lumber and could be easily handled in the laboratory. The rough 2 by 4 lumber was dried in a commercial kiln to a moisture content (MC) no greater than 19 percent, planed to dimension size, and shipped to the University of Idaho for analysis. At the University, all 2 by 4's were assigned a visual grade by a Western Wood Products Association (WWPA) grader. To improve grade, a small quantity of lumber was "pencil trimmed" to a shorter length. The goal of this study was to evaluate approximately 300 12-foot 2 by 4's of each species for their potential as MSR lumber. To assist with assignment of MSR grades to the remaining 12-foot 2 by 4's, the WWPA inspector assigned a visual limitation class per WWPA rules (20).

The dynamic modulus of elasticity (MOE) for each 2 by 4 was then determined using a Metriguard Model 340 Transverse Vibration E-Computer. The E-Computer determines MOE based on resonant vibration frequency and density. A IO-foot-long aluminum bar, of known stiffness, was used in vibration to calibrate the E-computer, Each 2 by 4 was simply supported flatwise as a beam spanning the entire length of the board (12 ft. for this analysis), and the

[1] D. Cobb. 1997. District forester, Idaho Panhandle National Forest. Personal communication.

specimen was then set into vibration by gently tapping it near the center of the span. A load cell measured the frequency of vibration and board weight, and the E-Computer calculated MOE for each piece.

An Instron Model 1137 Universal Testing Machine was used to perform the static mechanical strength and stiffness tests; no tension tests were included in this study. Data were collected via a National Instruments model PC-LPM-16 data-acquisition board and Measure software. The testing was performed per ASTM Standard D 198 (2) with the 2 by 4's loaded on edge. Third-point loading was used to create constant moment in the center third of the span. Span length was 73.5 inches to achieve a span-to-depth ratio of 21:1. Pieces were tested such that maximum strength-reducing characteristics were randomly located. Each piece was loaded at a 2-in./min. rate of deflection and loading proceeded until ultimate failure. The time to failure averaged approximately 1 minute. Deflection was measured using a linear voltage differential transducer (LVDT), and force was measured with the load cell on the Instron machine.

Immediately after breaking, a small sample (1 in. by 1-1/2 in. by 3-1/2 in.) was removed from each 2 by 4 near the point of failure to determine MC and specific gravity. The MC of each sample was measured using the ovendry method specified by ASTM Standard D 4442 (4). Specific gravity, based on ovendry weight and volume at time of test was determined according to ASTM Standard D 2395 (6).

The MOE, modulus of rupture (MOR), and visual grade data for each piece were used to sort the lumber into MSR categories. WWPA rules allow sorting into any design bending strength (Fb) and modulus of elasticity (E) combination. However, there are a limited number of categories that are commonly marketed in the western United States, and for the species considered in this study they include 2400Fb - 2.0E, 2100Fb - 1.8E, 1800Fb - 1.6E, 1650Fb - 1.5E, and 1450Fb - 1.3E (18). For this study, only 2400Fb - 2.0E, 2100Fb-1.8E, and 1650Fb - 1.5E categories were considered. The 1450Fb - 1.3E category was not considered because there is less of this grade produced. The MSR categories were compiled according to American Lumber Standards (ALS) Committee rules (1), which include the following requirements:

1) Average MOE for a grade group must be equal or greater than assigned E.

TABLE 1. - Lumber yield for visual grades.

	Piece count			
	2 by 4 by 12 ft.	2 by 4 by 10 ft.	2 by 4 by 8 ft.	Volume
Grand fir				(BF)
Select Structural	29	3	1	257
No. 1	246	32	18	2,277
No. 2	83	21	22	921
No. 3	14	4	6	171
Economy	15	2	19	235
Total	387	62	66	3,861
Lodgepole pine				
Select Structural	35	10	9	395
No. 1	186	17	7	1,639
No. 2	59	19	17	689
No. 3	13	5	2	148
Economy	4	2	10	99
Total	297	53	4.5	2,969
Ponerosa pine				
Select Structural	1	0	0	8
No. 1	70	12	0	640
No. 2	173	20	0	1,517
No. 3	16	3	0	148
Economy	128	0	10	2,256
Total	388	35	0	4,569

2) 95 percent of the pieces must have an MOE greater than 82 percent of assigned E value:

For 2.0E grade: 2.0×10^6 psi × 0.82 = 1.64×10^6psi.

For 1.8E grade: 1.8×10^6 psi × 0.82 = 1.48×10^6psi

For 1.5E grade: 1.5×10^6 psi × 0.82 = 1.23×10^6 psi

3) 95 percent of pieces must have an MOR greater than 2.1 times the assigned Fb:

For 2400Fb grade: 2,400 psi × 2.1 = 5,040 psi

For 2100Fb grade: 2,100 psi × 2.1 = 4,410 psi

For 1650Fb grade: 1,650 psi × 2.1 = 3,465 psi

The results of the static bending tests for each species group were sorted by static MOE to determine the highest-strength mix of MSR categories that could be produced for each species. Table 2 of ASTM D 2915 (3) provides the acceptable number of failed pieces as a function of sample size. A 75 percent confidence level was used to determine grade levels.

ALS rules also stipulate that after removing MSR boards there shall be no visual grades produced that have a design bending strength greater than the design bending strength of the lowest MSR category produced (1,650 psi for this study). A Select Structural grand fir (hem-fir species grouping) 2 by 4 has a size adjusted Fb of 2,100 psi. Therefore, this is not an acceptable visual grade after 1650 Fb material has been removed. However, the adjusted Fb for a No.1 hem-fir is 1,425 psi, which is less than the lowest MSR category of 1,650 psi; therefore, a No.1 visual grade can be produced. The same logic is also valid for lodgepole pine (spruce-pine-fir(s) species grouping); therefore one could produce a No. 1 visual grade lodgepole pine but not a Select Structural grade.

After the lumber was sorted into visual and MSR grades, the economic value was determined for each species group. The value comparison of visual grades versus machine grades was based on approximate current, random-length lumber prices as of November 14, 1997, as reported by a local mill.

TABLE 2. — *Summary of mechanical properties of 2 by 4's from small-diameter trees.*

Species	Grade	No.	MC	Specific gravity	$MOE_{dynamic}$ Mean	$MOE_{dynamic}$ SD	MOE_{static} Mean	MOE_{static} SD	MOR Mean	MOR SD	MOR 5th
			(%)	(OD/MC)	(× 10^6 psi)				(x 10^3 psi)		
Grand fir	Sel.Str.	29	11.6	0.34	1.613	0.17	1.549	0.15	8.268	0.96	6.465
	No. 1	246	11.5	0.34	1.407	0.23	1.394	0.19	4.723	1.43	3.410
	No.2	83	11.6	0.35	1.400	0.25	1.385	0.23	6.514	1.66	- -
	No.3	14	11.2	0.34	1.384	0.28	1.381	0.27	6.251	1.60	2.734
Lodgepole pine	Sel.Str.	35	13.4	0.43	1.781	0.27	1.756	0.24	8.898	1.57	6.190
	No. 1	186	13.4	0.40	1.460	0.22	1.477	0.21	6.575	1.47	4.068
	No.2	59	13.5	0.41	1.584	0.26	1.511	0.24	7.439	1.76	4.586
	No.3	13	13.7	0.41	1.530	0.26	1.500	0.23	7.011	1.83	- -
Ponderosa pine	Sel.Str.	1	- -	- -	- -	- -	- -	—	- -	- -	- -
	No.1	70	11.1	0.36	0.959	0.20	0.927	0.20	4.451	1.37	2.700
	No.2	173	10.9	0.35	0.877	0.19	0.855	0.18	3.884	1.41	2.051
	No.3	16	11.4	0.36	0.854	0.22	0.820	0.21	3.430	1.263	- -

TABLE 3. — *Comparison between the results* **of** *this study and the in-grade data at 12 precent MC.*

Species	Grade	N. Idaho MOE 50th	N. Idaho MOR 5th	In-Grade MOE 50th	In-Grade MOE .75LL	In-Grade MOE .75UL	In-Grade MOR 5th	In-Grade MOR .75LL	In-Grade MOR .75UL
				(× 10^6 psi)			(× 10^3 psi)		
Lodgepole pine	Sel.Str.	1.73	6.211	1.334	1.301	1.366	4.610	3.390	5.521
	No.2	1.54	4.533	1.157	1.108	1.186	2.820	2.625	3.109
Ponderosa pine	No.2	0.84	2.091	0.962	0.936	0.975	2.647	1.866	2.747

RESULTS AND DISCUSSION

RESULTS BY VISUAL GRADING

The grand fir and lodgepole pine logs had an average small-end diameter of 5 to 6 inches, while that of the Ponderosa pine was about 7 inches. The gross output of lumber from the sawmill green chain was 4,317 board feet (BF) of grand fir and 3,444 BF of lodgepole pine. The Ponderosa pine logs were slightly larger, averaging 9 inches on the small-end. Complete gross output data were not obtained for Ponderosa pine. After planing and removal of boards (1 by 4's), the remaining 2 by 4's were visually graded prior to further sorting. The results of visual grading are shown in **Table 1.**

As **Table 1** demonstrates, the logs produced over 65 percent of the 2 by 4's in a visual grade of No. 1 or Select Structural, based on board foot volume, and less than 7 percent Economy for both grand fir and lodgepole pine. This high yield is attributed to the small knot size of the lumber. However, the ponderosa pine thinnings, with larger knots, yielded approximately 50 percent Economy grade lumber. A low yield of higher grade lumber is typical of kiln-dried Ponderosa pine from "young-growth" trees (9). One of the initial goals of the study was to produce approximately 300 12-foot 2 by 4's of each species, and since this goal was met, all of the 8-foot and 10-foot 2 by 4's were removed from further study. Since the Economy lumber would generally not make MSR lumber, it was also removed. In addition, a small number of grand fir pieces were used for pre-testing and therefore not included in the final analysis.

TABLE 4. — *Minimum MOE* **for each** *MSR category.*

Species	MSR grade	Minimum MOE Actual	Minimum MOE Allowable
		(× 10^6 psi)	
Grand fir	2000 Fb-1.8E	1.73	1.48
	1650 Fb-1.5E	1.34	1.23
Lodgepole pine	2400 Fb-2.0E	1.87	1.53
	2000 Fb-1.8E	1.72	1.48

In the 1960s, a *Western Wood Density Survey* was conducted to determine the distribution of specific gravity for 15 western species (10,11). The specific gravity values for Idaho reported in the *Survey* were converted from a green basis to the approximate MCs of our test samples (6). The average specific gravity for grand fir from northern Idaho was converted to 0.36 at 11.5 percent MC according to the *Survey*, and it was 0.34 in our study **(Table 2).** For lodgepole pine, the *Survey* value for northern Idaho converted to 13.5 percent MC was 0.40, and the **Table 2** value is 0.38. The *Survey* value for Ponderosa pine from northern Idaho is 0.39 at 11 percent MC versus the value of 0.35 that we found. Thus, the values in our study are slightly lower than those of grand fir and lodgepole pine from the *Western Density Survey*. Our values for Ponderosa pine are 0.04 lower than those from the *Survey*, but

TABLE 5. — Mechanical properties for visual and MSR grading.

Visual grade	Select Structural	No.1	No.2	No.3	Total		
Grand fir							
2 by 4 by 12 ft. (qty.)	29	242	81	14	366		
Volume (BF)	232	1936	648	112	2928		
Avg. MOE ($\times 10^6$ psi)	1.54	1.39	1.39	1.38	1.40		
Avg. MOR (psi)	8240	6720	6570	6250	6790		
Avg. SG	0.342	0.345	.348	.341	0.345		
MSR grade	2100Fb-1.8E	1650Fb-l.5E	No.1	No.2	No.3	Total	
2 by 4 by 12 ft. (qty.)	14	228	90	29	5	366	
Volume (BF)	112	1824	720	232	40	2928	
Avg. MOE ($\times 10^6$ psi)	1.80	1.50	1.20	1.13	111	1.40	
Avg. MOR (psi)	8530	7240	5930	5460	4610	6790	
Avg. SG	0.370	0.347	0.337	0.344	0.319	0.345	
Visual grade	Select Structural	No.1	No.2	No.3	Total		
Lodgepole pine							
2 by 4 by 12 ft. (qty.)	35	186	59	13	293		
Volume (BF)	280	1488	472	104	2344		
Avg. MOE ($\times 10^6$ psi)	1.75	1.47	1.55	1.50	1.52		
Avg. MOR (psi)	8890	6530	7420	7010	7010		
Avg. SG	0.428	0.400	0.413	0.411	0.406		
MSR grade	2400Fb-2.0E	2100Fb-l.8E	1650Fb-1.5E	No.1	No.2	No.3	Total
2 by 4 by 12 ft. (qty.)	24	33	187	38	8	3	293
Volume (BF)	192	264	1496	304	64	24	2344
Avg. MOE ($\times 10^6$ psi)	2.00	1.80	1.50	1.18	115	1.51	1.52
Avg. MOR (psi)	760	8880	6750	5240	4950	8130	7010
Avg. SG	0.471	0.436	0.400	0.381	0.364	0.404	0.406

this would seem logical because our material came from a Ponderosa pine plantation.

The mechanical properties, by visual grade, of the 2 by 4's tested are summarized in **Table 2.** It is of interest to compare these results against values from a more representative sample. The properties for the northern Idaho data were adjusted to an MC of 12 percent (8) and compared against the data collected on about 80 2 by 4's collected during the In-Grade Testing Program (12) **(Table 3).** Grand fir was sampled as part of the hem-fir species grouping in the In-Grade Program, and not as an individual species. Therefore, grand fir is not included in this comparison. For MOE, the median value (50th percentile) of the lodgepole pine data from northern Idaho was above the upper 75 percent confidence interval of the median In-Grade data for both Select Structural and No. 2 grades. The same is true for the 5th percentile value for lodgepole pine. For No. 2 Ponderosa pine thinnings, the median MOE value of the northern Idaho data is slightly less than the 75 percent lower confidence limit of the In-Grade value. For MOR, the 5th percentile of the northern Idaho data is within the confidence interval of the In-Grade data. Although of a limited sample size, it would appear that the mechanical properties of the 45-year-old, small-diameter lodgepole pine sample is higher than might be expected. For the Ponderosa pine thinnings, the MOR is within the confidence interval and therefore appears to be typical, but the MOE is low. This would be expected for trees that probably contain a higher percentage of juvenile wood.

MECHANICAL GRADING OPTIONS

Because of the low yield of visually graded lumber obtained from the ponderosa pine thinnings, no MSR yield simulations were conducted with this lumber. Of all the combined grand fir and lodgepole pine pieces tested, only three lodgepole pine 2 by 4's were removed from MSR grade due to visual characteristics and no pieces in either species were removed due to low MOR. Although three pieces of grand fir in the 1650Fb - 1.5E grade had an MOR less than 2.1 times design Fb, this amounted to less than 5 percent of that category. Therefore, none were reduced in grade. As shown in **Table 4** all categories in both species had an actual minimum MOE greater than the minimum allowable MOE.

A considerable portion of both grand fir and lodgepole pine had mechanical properties high enough to be graded as MSR lumber **Table 5.** Sixty-six percent of the grand fir 12-foot 2 by 4's made MSR grade and 83 percent of the lodgepole pine 12-foot 2 by 4's qualified for an MSR grade. **Figure 1** shows that an almost equal proportion of No. 1, No. 2, and No. 3 visual grades made MSR grade. ALS rules required that no Select Structural 2 by 4's could be produced as MSR grade residuals for this case. However, all visually graded Select Structural grand fir and lodgepole pine pieces made MSR grade, therefore, the ALS rule had no effect on this study sample.

Table 6 shows the comparison of economic value for the grand fir and lodgepole pine groups when graded visually and graded with MSR with visual grade residuals. There was a $15/MBF increase in the value of grand fir when MSR grading was added to the value of random-length hem-fir lumber, and a value increase for MSR lodgepole pine over random-length SPF(s) lumber was $27/MBF. The increase in value was largely due to the high percentage of No. 3 visual grades that moved into MSR categories. Sixty-four percent of the No. 3 grand fir 2 by 4's and 77 percent of the No. 3 lodgepole pine 2 by 4's moved into an MSR category. Producing MSR lumber in categories below the 1650Fb - 1.5E level had diminishing economic return. As shown in **Table 4** there was a large quantity of No. 1 and No. 2 visual grades remaining after removal of MSR grades. The value of No. 1 and No. 2 is greater than that of the 1450Fb - 1.3E. Therefore, grades of MSR lower than 1650Fb - 1.5E produced lower values than the visual grades.

Using portable equipment, such as the transverse vibration tester used in this study, provides an economical method of evaluating a local resource at a particular mill. However, allowable MOE values are based on static tests of lumber tested on edge. Therefore, equations are needed to estimate static MOE from the MOE determined using portable equipment. This information, coupled with visual grade requirements, will allow a mill to evaluate the potential for MSR lumber yields from their resource. The linear relationship obtained in this study between static edgewise MOE and long-span, flatwise MOE determined in transverse vibration is shown in **Figures 2** and **3.** The coefficient of determination of the two species is greater than 0.85.

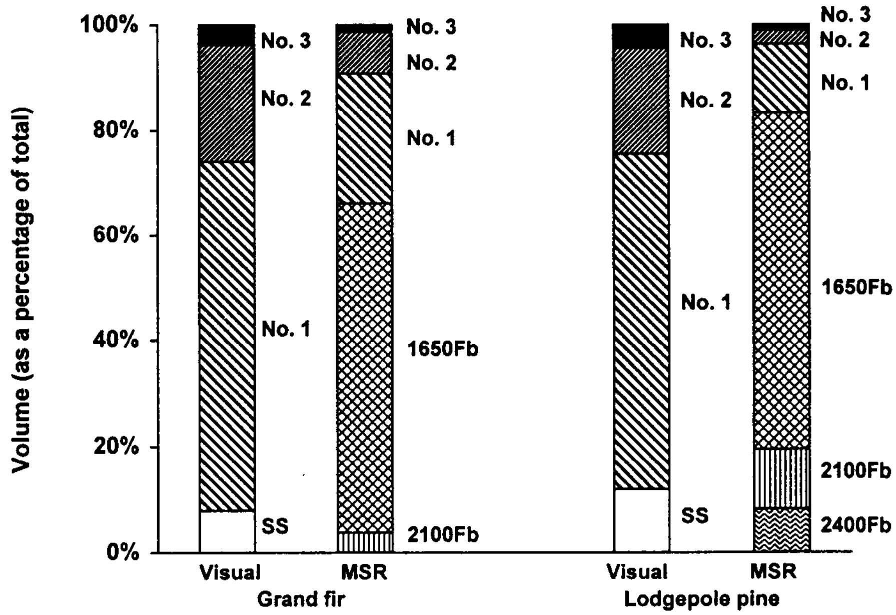

Figure 1. —Yield comparison for visual and machine grading.

TABLE 6. — Value increase for machine stress-rating.

Grade	Price	Visual grade Volume	Visual grade Value	Machine stress-rated Volume	Machine stress-rated Value
	($/MBF)	(BF)	($)	(BF)	($)
Grand fir					
2100Fb-1.8E	425			112	48
Select Structural	425	232	99	0	0
1650Fb-l.5E	395			1824	720
No. 1	380	1,936	736	720	274
No. 2	350	648	227	232	81
No. 3	240	112	27	40	10
Total		2,928	1,088	2,928	1,132
Increase in value			$15/MBF		
Lodgepole pine					
2400Fb-2.0E	475			192	91
2100Fb-l.8E	425			264	112
Select Structural	425	280	119	0	0
1650Fb-l.5E	395			1,496	591
No. 1	380	1,488	565	304	116
No. 2	350	472	165	64	22
No. 3	240	104	25	24	6
Total		2,344	875	2,344	938
Increase in value			$27/MBF		

CONCLUSIONS

The small-diameter grand fir and lodgepole pine trees harvested on an overstocked site in northern Idaho produced high quality visual grade lumber with good mechanical properties. This study illustrates that, in addition to favorable visual characteristics, this lumber is also a good candidate for machine stress rating. At current prices, MSR grading could increase lumber value $27/MBF for lodgepole pine 2 by 4's and $15/MBF for grand fir 2 by 4's. However, the results of this study indicated that the Ponderosa pine thinnings were not good candidates for production of mechanically graded lumber. This study points out the potential value of lumber sawn from overstocked stands of timber, but demonstrates the need for an assessment process to estimate local resource capability.

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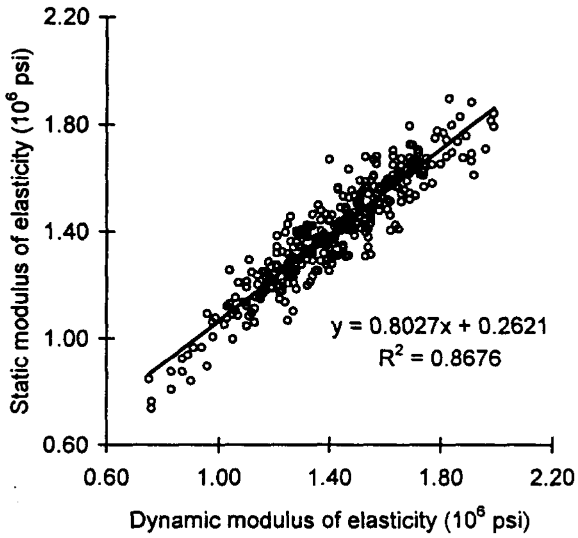

Figure 2. — Static edgewise MOE vs. dynamic flatwise MOE for grand fir.

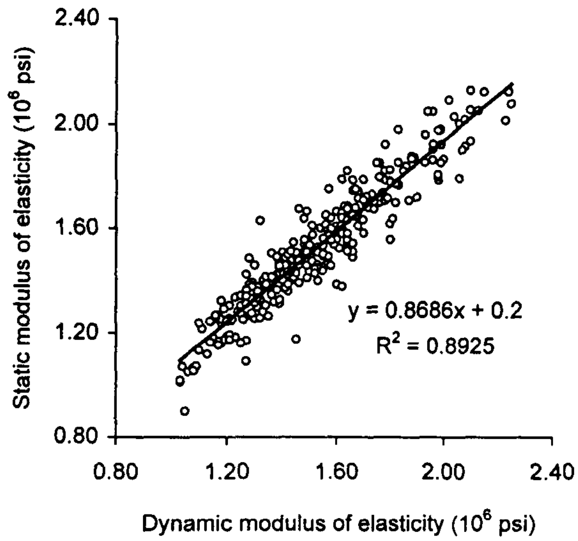

Figure 3. — Static edgewise MOE vs. dynamic flatwise MOE for lodgepole pine.

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