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CORE LIST

an improved system for estimating the value of western white pine

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ABSTRACT

This report describes an improved system for estimating the lumber selling value or volume of western white pine sawtimber.

Of 298 trees selected to represent the full range in size and quality of commercial sawtimber available in northern Idaho, 192 were used to develop a prediction model for estimating the value and lumber tally volume of individual western white pine trees. Of the remaining 106 trees, seven were culls and 99 were used to test the prediction equation.

The model developed contains six tree characteristics:

1. Tree diameter
2. Tree height
3. Height to the first live limb
4. The number of limb-free and defect-free faces in the butt 16-foot log
5. Diameter of the largest limb in the butt 16-foot log
6. Total tree defect percent.

The prediction equation, using those six characteristics, accounts for 94 percent of the variation in tree value and 95 percent of the variation in lumber tally volume as measured by the regression R^2 values.

A test of the system indicated that the prediction underestimated the value of all trees by 6.5 percent and underestimated the lumber tally volume by 2.7 percent.

The system is faster and more objective than log grading and has the additional advantage of eliminating grouping error by being a continuous predictor.

Keywords: Western white pine, tree value estimates, tree volume estimates, grading system.

INTRODUCTION

This paper, written primarily for timber appraisers, describes an improved system for estimating the lumber selling value or volume of individual tracts of western white pine (*Pinus monticola* Dougl.) sawtimber. It is similar to one described earlier by Lane, Plank, and Henley.¹

Conventional systems for appraising the value of western white pine sawtimber incorporate volume and quality estimates of the resource. The estimate of quality has generally been in the form of discrete log grades. These log grades have often proven to be inadequate for a number of reasons:

1. *Application is slow and thus expensive.* The timber cruiser is required to scrutinize each 16-foot log throughout the merchantable stem.
2. *Application is difficult, subjective, and thus inconsistent.* To determine the grade for each 16-foot unit, the cruiser must categorize limbs as to size and whether they are live or dead. He must then determine the number in each category along with such information as the amount of clear area in these 16-foot units to determine the "grade." It is difficult for a cruiser to be consistent in application with such subjective inputs.
3. *Grouping error in estimating value is introduced.* When placing logs into discrete value classes (log grades), there will generally be a range of values within each class. Also, there is no distinct difference in value between the poorest logs of one grade and the best logs of the next lower grade.

The new system differs from the conventional log grading procedure in two principal ways: (1) It provides a selling value estimate for each cruise tree as a unit--therefore, it is more appropriately designated a tree grading system than a log grading system, and (2) the system does not group trees into restricted or discrete quality classes--it is a continuous system where the estimated value of each tree is in itself a "grade."

In comparison with a log grading system, this system has the advantage of being faster, and thus more economical; more objective and thus more consistent. It also eliminates grouping error by being a continuous predictor.

The following describes the development, performance, and application of the new system.

¹Paul H. Lane, Marlin E. Plank, and John W. Henley. A new and easier way to estimate the quality of inland Douglas-fir sawtimber. USDA For. Serv. Res. Pap. PNW-101, 9 p., illus. Pac. Northwest For. & Range Exp. Stn., Portland, Oreg. 1970.

STUDY PROCEDURES

Sample

A sample of 298 trees was selected to represent the full range in diameter and quality of commercial western white pine sawtimber available in northern Idaho. The trees were from eight areas on the Kaniksu, St. Joe, and Coeur d'Alene National Forests as shown in figure 1. The eight areas were chosen to represent differences in tree size, stem quality, and site characteristics. Within each area, individual sample trees were selected on the basis of d.b.h. Some average characteristics of the sample trees by area are shown in table 1.

The study trees were felled and bucked into saw logs according to normal industry practice. The visible surface characteristics of each log were recorded immediately after the trees were felled.

Figure 1.--Range of western white pine in the "Inland Empire" and general locations of the eight areas from which study trees were cut.

Table 1.--Some average characteristics of study trees by sample area

Characteristic	Sample area								Total or average
	1	2	3	4	5	6	7	8	
D.b.h. range (inches)	9.9-33.1	11.0-29.6	10.4-45.0	10.9-21.9	9.1-22.3	26.5-54.0	10.5-34.1	9.3-24.3	9.1-54.0
Average d.b.h. (inches)	14.4	23.5	20.9	17.1	13.3	38.4	21.9	15.2	19.2
Total height range (feet)	60-125	83-173	71-200	80-144	81-125	144-215	71-179	84-137	60-215
Average height (feet)	94	142	126	114	102	184	142	109	120
Defect range (percent)	0-66	0-51	0-91	0-19	0-29	10-98	0-56	0-39	0-98
Average defect (percent)	9.2	10.9	18.6	7.8	4.0	40.5	13.8	4.4	12.8
Age range (years)	49-134	107-211	60-170	58-111	53-88	237-336	123-290	58-77	49-336
Average age (years)	74	176	93	84	66	299	213	66	117
Number of trees	70	25	54	20	40	26	27	36	298

The sample trees were processed at what was considered a typical western white pine sawmill. The study logs were sawn under normal production conditions to obtain the highest value from each log. The usual white pine lumber items were produced, and the lumber tally values and volumes were based on kiln-dried, surfaced lumber tally according to general industry practice.

Developing the Prediction Model

Before data analysis, 99 of the 298 sample trees were drawn at random to test the prediction equations that would be developed. Of the remaining trees, 192 were used for model building and estimating the coefficients.²

The "stepwise regression" procedure and the "all possible regressions" procedure³ were used to identify the tree characteristics that were most important in determining tree values and lumber tally volumes.

The general procedure used in building the model was to identify the factors that would affect the dependent variables of tree dollar value and lumber tally volume. These factors in the form of a general model are as follows:

$$\begin{array}{l} \text{tree value (dollars)} \\ \text{or} \\ \text{lumber tally volume} \end{array} = \text{tree volume} - \text{tree defect} + \text{tree quality}.$$

Each factor in the general model can be partially quantified by one or several individual tree characteristics (independent variables). A list of the independent variables that were examined can be found in appendix I. The stepwise regression procedure was used to identify those individual tree characteristics that best represented each factor in the general model. For example, the number of limb-free

²Seven of the 199 trees selected for model building and estimating coefficients were omitted because they were cull trees, i.e., less than 25 percent of the gross volume of the tree was in sound wood. Consequently, the system is designed for sound trees only.

³Terminology taken from Norman Draper and H. Smith. Applied regression analysis. New York: John Wiley & Sons, Inc., 407 p., 1966.

faces on the butt log of the tree might best represent the factor tree quality. The independent variables that either had little or no effect on tree value or volume or were too difficult or impossible to quantify in cruising were omitted after screening. The remaining variables, along with alternative forms of the same variable, were screened by means of the all possible regressions procedure to choose the final variables for the model. The final variables selected for the model were those that were most practical for application in timber appraisals and those that statistically accounted for the most variation in lumber volume and value.

Six measurable characteristics survived as the most important and practical criteria for grading trees:

1. Tree diameter,
2. Tree height,
3. Height to the first live limb,
4. Diameter of the largest limb in the butt 16-foot log,
5. The number of limb-free and defect-free faces in the butt 16-foot log, and
6. Total tree defect (percent).

These six characteristics along with several transformations of the same characteristics were selected as the best independent variables for the model. These variables along with lumber yield information were used to develop the regression equations for predicting total lumber tally volume (board feet) and total value (dollars) on a tree basis. The equation for predicting tree value and/or volume is:

$$\begin{array}{lcl}
 \text{tree value} & & \\
 \text{or} & = & b_0 + b_1 DEF (D^2H) + b_2 D + b_3 H + b_4 HTFL \\
 \text{tree volume} & & + b_5 LRLB16 (D^2H) + b_6 NLFF16 (D^2H) \\
 & & + b_7 DEFSQR (D^2H) + b_8 D^2 + b_9 (H/D)^2 + b_{10} D^2 H
 \end{array}$$

where:

b_0 is Y intercept constant.

b_i , $i = 1-10$ are the regression coefficients.

DEF is estimated percent defect of gross cruise volume.

DEFSQR is DEF squared.

D is tree diameter in inches at 4.5 feet above ground.

H is the total tree height in feet.

HTFL is the height to the first limb with green needles on the tree.

LRLB16 is the diameter of the largest limb in inches in the butt 16-foot log.

NLFF16 is the number of limb-free and defect-free faces in the butt 16-foot log.

The equations developed account for about 94 percent of the variation in tree value and 95 percent of the variation of the tree lumber tally volume as measured by the regression R^2 values.

HOW THE SYSTEM PERFORMS

Of the 298 sample trees, 99 were selected at random to test the performance of the prediction equations. The six quality criteria measurements were recorded for each of the 99 trees. Predictions of the lumber selling value and volume were then calculated, using the procedures described in the next section of this paper.

Table 2 shows comparisons of estimated and actual values totaled for the 99 test trees. Plots of the estimated versus actual tree values and volumes of individual trees are shown in figures 2 and 3. As shown in figures 2 and 3, the value or volume of individual trees may not be estimated accurately by the equation; but there are approximately equal numbers of high and low estimates. Table 2 shows that there is little difference between the estimated and actual; i.e., a 6.5-percent difference for value and a 2.7-percent difference for volume.

Table 2.--*A comparison of actual and predicted lumber selling value and volume for 99 western white pine trees*

Unit	Estimated	Actual	Percent difference
Total value ^{1/} (dollars)	8,376.00	8,964.24	-6.5
Total lumber tally volume (board feet)	72,695.00	74,745.00	-2.7

^{1/} Value based on 1968 lumber prices developed for western white pine by U.S. Forest Service, Region 1.

HOW TO USE THE SYSTEM

Computer facilities for making regression analyses and solving equations are essential for efficient use of the system.

It is also necessary to have, in a form suitable for computer use, the tree characteristic data (the six grading criteria) and lumber grade yield data for each of the 192 trees from the mill study used to develop the system. A listing of the 192 cards containing the necessary information and the card format are illustrated in appendix II.

Figure 2.--Plot of estimated over actual tree value.

Figure 3.--Plot of estimated over actual tree lumber tally volume.

A step-by-step procedure for estimating the selling value of a group of trees or tract of timber is as follows:

1. Select sample trees.
2. Measure and record for each sample tree the six characteristics: (1) tree diameter, (2) tree height, (3) tree defect, (4) height to the first live limb, (5) size of the largest limb in the butt 16-foot log, and (6) the number of limb-free and defect-free tree faces on the butt 16-foot log. More complete information on how to measure and record these characteristics is shown in appendix III.
3. Assign desired lumber prices to each of the lumber grades (or combinations) recorded in the base study.
4. Using these assigned lumber prices, compute a dollar value for each of the 192 trees from the base study.
5. Use an appropriate multiple regression program to develop the value equation coefficients for the 192 trees. Use the assigned lumber prices (step 4) and the six tree characteristic variables and transformations as follows:

Dependent variable:

Total dollars/ D^2H

Independent variables:

DEF

$DEFSQR$

$LRLB16$

$NLFF16$

D/D^2H

H/D^2H

D^2/D^2H

$(H/D)^2/D^2H$

$HTFLL/D^2H$

$1/D^2H$

6. Solve the value equation for the selected sample trees in step 1 using coefficients developed in step 5.

To estimate the lumber volume of a sample tree or group of trees, simply solve the following equation using the coefficients shown:

$$\begin{aligned} \text{Total lumber tally volume (bd. ft.)} = & -393 - (.00005126) (DEF) (D^2H) \\ & + (88.9538) (D) - (5.61835) (H) \\ & + (.40147) (HTFLL) - (.000131608) (LRLB16) (D^2H) \\ & - (.000323497) (NLFF16) (D^2H) \\ & - (.0000008985) (DEFSQR) (D^2H) \\ & + (2.27154) (H/D)^2 - (3.14853) (D^2) \\ & + (.0234706) (D^2H) \end{aligned}$$

CONCLUSIONS

Field application tests of the system indicate that the tree-valuation system reported has several advantages over valuation systems based on the discrete log grades currently being used.

It is faster to apply and thus more economical. Other than measuring total tree height and the height to the first live limb, the characteristics to be measured are confined to the butt 16-foot log. It is not necessary to look at each 16-foot segment as is the case with a discrete log grade system. It requires less experience and judgment by the timber cruiser; thus, training and checking of cruisers is easier. Selling price is computed easily and more directly than by procedures that involve adjusting yield by log overrun estimates. The user should remember that, as with any statistical procedure of this nature, the equations may not show the value of an *individual* tree accurately; they should be used to estimate the total value of a group of trees.

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Western Wood Products Association--for providing a grading supervisor.

APPENDIX I. LIST OF INDEPENDENT VARIABLES

Defect Related

1. Defect percent
2. Defect percent squared

Presence or absence of:

3. Scars and/or seams
4. Basal scars and/or seams
5. Nonbasal scars and/or seams
6. All scars
7. Basal scars
8. Nonbasal scars
9. All seams
10. Basal seams
11. Nonbasal seams

Length of:

12. All scars and seams
13. Basal scars and seams
14. Nonbasal scars and seams
15. All scars
16. Basal scars
17. Nonbasal scars
18. All seams
19. Basal seams
20. Nonbasal seams

Presence or absence of:

21. Sucker limbs
22. Live sucker limbs
23. Dead sucker limbs
24. Bulges and/or bumps
25. Burls over 4 inches
26. Rotten knots
27. Conks
28. Broken top
29. Snow break
30. Blister rust cankers
31. Total number of burls
32. Total number of rotten knots on tree
33. Total number of rotten knots on butt 32-foot log
34. Total number of conks
35. Total number of knot clusters
36. Total diameter of burls
37. Total diameter of knot clusters
38. Sweep deviation
39. Crook deviation
40. Count of defects

Quality Related

41. Height to the first dead limb
42. Height to the first live limb
43. Size of the first dead limb
44. Size of the first live limb
45. Size of the largest limb (live or dead) on the butt 16-foot log
46. Size of the largest limb (live or dead) on the butt 32-foot log
47. Height to the start of the crown
48. Crown length
49. Crown length per height to the start of the crown
50. Height of clear bole allowing no defect
51. Height of clear bole allowing defect
52. Height of limb-free bole allowing no defect
53. Height of limb-free bole allowing defect
54. Total length of clear face in 4-foot minimum units in the butt 16-foot log
55. Total length of clear face in 4-foot minimum units in the butt 32-foot log
56. Total length of clear face in 8-foot minimum units in the butt 16-foot log
57. Total length of clear face in 8-foot minimum units in the butt 32-foot log
58. Total length of clear bole in 4-foot minimum units on the tree
59. Number of 4-foot clear panels on the tree
60. Number of 4-foot clear panels on the butt 16-foot log
61. Number of 4-foot clear panels on the butt 32-foot log
62. Number of 8-foot clear panels on the butt 16-foot log
63. Number of 8-foot clear panels on the butt 32-foot log
64. Number of 8-foot limb-free panels on the butt 16-foot log allowing defect
65. Number of 8-foot limb-free panels on the butt 16-foot log not allowing defect
66. Number of clear panels on the butt 16-foot log allowing defect
67. Number of clear panels on the butt 16-foot log not allowing defect
68. Number of limb-free faces on the butt 16-foot log allowing defect
69. Number of limb-free faces on the butt 16-foot log not allowing defect
70. Number of limb-free faces on the butt 32-foot log allowing defect
71. Number of limb-free faces on the butt 32-foot log not allowing defect
72. Number of 1-inch and less knots on the butt 16-foot log
73. Number of 2-inch and less knots on the butt 16-foot log
74. Number of 3-inch and less knots on the butt 16-foot log
75. Number of knots greater than 3 inches on the butt 16-foot log
76. Number of 1-inch and less knots on the butt 32-foot log
77. Number of 2-inch and less knots on the butt 32-foot log
78. Number of 3-inch and less knots on the butt 32-foot log
79. Number of knots greater than 3 inches on the butt 32-foot log

Volume Related

- 80. $DBH = D$
- 81. Total height = H
- 82. 16-foot form class
- 83. 32-foot form class
- 84. (D/H)
- 85. $(D/H)^2$
- 86. (H/D)
- 87. $(H/D)^2$
- 88. D^2
- 89. H^2
- 90. D^2H

Miscellaneous

- 91. Age
- 92. Amount of lean

APPENDIX II. TREE QUALITY CHARACTERISTICS AND LUMBER YIELD DATA

The tree quality characteristics and lumber yield data for each of the 192 western white pine trees from the base study are shown in the following list according to the card format shown below.

List of Characteristics

<i>Columns</i>	<i>Data</i>
1- 3	Tree Number
4- 6	Defect Percent
7- 9	DBH
10-12	Total Height
13-15	Height to First Live Limb
16	Largest Limb in Butt 16-foot Log
17	Number of Limb-free and Defect-free Faces in the Butt 16-foot Log
18-21	Volume B Select Lumber
22-25	Volume C Select Lumber
26-29	Volume D Select Lumber
30-33	Volume Molding
34-37	Volume 3 Clear
38-41	Volume 1 Shop
42-45	Volume 2 Shop
46-49	Volume 3 Shop
50-53	Volume 1 Common
54-57	Volume 2 Common
58-61	Volume 3 Common
62-65	Volume 4 Common
66-69	Volume 5 Common
70-73	Total Lumber Tally Volume

[illegible]

[illegible]

APPENDIX III. INSTRUCTIONS FOR APPLYING THE SYSTEM

Instructions for measuring and recording the western white pine tree characteristics used in the equations are shown below.

1. *Tree diameter (D)*.-- Measured and recorded to the nearest 0.1 inch at 4-1/2 feet above ground on the uphill side on the tree.
2. *Tree height (H)*.-- Total tree height measured from the ground on the uphill side of the tree and recorded to the nearest foot. This height includes a dead top if one exists and the projected height if the tree has a broken top.
3. *Height to the first live limb (HTFLL)*.-- Measured and recorded as the height (to the nearest foot) to the first branch⁴ which has live needles.
4. *Largest limb in the butt 16-foot log (LRLB16)*.-- Measured and recorded as the size of the largest limb (see footnote 4) in the butt 16-foot log.⁵ Limb size is recorded inside bark but outside the limb collar. Limb size is rounded as follows:

$0.25 - 1.0 = 1 \text{ inch}$
 $1.1 - 2.0 = 2 \text{ inches}$
 $2.1 - 3.0 = 3 \text{ inches}$
etc.
5. *Number of limb-free and defect-free faces in the butt 16-foot log (NLFF16)*.-- A face is one-fourth the circumference of the tree for the full 16-foot length of the butt 16-foot log (see footnote 5). Any limb or limb stub other than epicormic limbs removes a face. Any scalable defect removes the face in which the defect occurs.⁶ All size knot indicators are allowed. The variable is coded as 0-4 faces.
6. *Scalable defect (DEF)*.-- Expressed as a percent of the gross cruise volume. The estimate includes deductions made from the gross cruise volume for visible abnormalities such as crook, conks, cankers, burls, and bumps. It also includes the estimated volume loss from unknown sources such as logging breakage and hidden or internal defects such as rot or pitch rings.

⁴Epicormic branches are not recorded.

⁵Butt 16-foot log defined as the first 16.5 feet of the tree above normal stump height.

⁶If crook and/or sweep occurs in the butt 16-foot log, one face is removed.

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