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Estimating Value and Volume of Ponderosa Pine Trees by Equations

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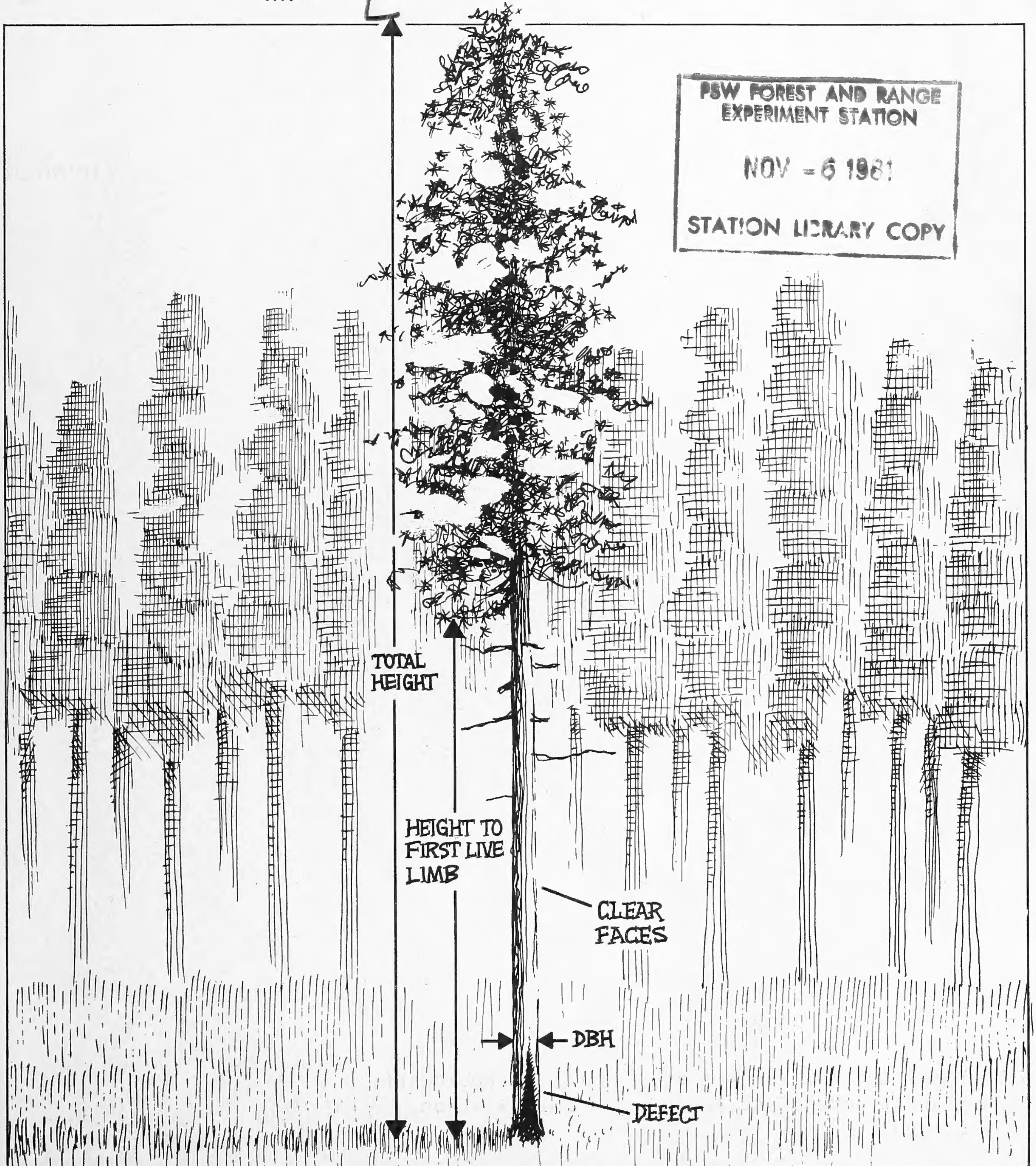

Author

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Abstract

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Equations for estimating the selling value and tally volume for ponderosa pine lumber from the standing trees are described. Only five characteristics are required for the equations. Development and application of the system are described.

Keywords: Lumber value, volume estimation, grading systems, ponderosa pine, *Pinus ponderosa*.

Summary

This paper describes a system for estimating the selling value and lumber volume of ponderosa pine (*Pinus ponderosa* Dougl. ex Laws.) trees. Similar systems have proved easier and more practical than the conventional method of listing logs by discrete classes.

From a sample of 189 trees selected in western Montana, 154 were used to develop two prediction model equations, one for estimating selling value and one for estimating tally volume of lumber. A subsample of 34 trees was withheld from the analysis to test the equation.

Measurement of five characteristics will enable the user to apply the prediction equations to other samples. The tree characteristics are:

1. Diameter
2. Height
3. Height to the first live limb
4. The number of limb-free and defect-free faces on a butt 32-foot log
5. Total defect

The prediction equations account for 91 percent of the variation in value and 97 percent of the variation in lumber volume as measured by the R^2 values.

When the system was applied to the 34 trees withheld from the original data, the prediction of total dollar value was 7.3 percent more than the actual value and the prediction of volume 7.0 percent higher than the actual volume of lumber recovered.

Contents

Introduction

The State of Montana contains an estimated 11 billion board feet (International 1/4 inch rule) of ponderosa pine (Pinus ponderosa Dougl. ex Laws.) sawtimber (USDA Forest Service 1973). Much of this resource is growing on lands administered by the USDA Forest Service. When offered for sale, stumpage value is determined by a system of five log grades. Although this grading system is reliable, an easier and less costly method has been developed that will work equally well.

The Northern Region (Region 1) of the USDA Forest Service is using equations that estimate the lumber tally volume and value of standing trees for several species. Cruisers have found the method fast and simple to use, and the estimates obtained from the equations are being accepted by timber purchasers. The equations in this paper were developed for ponderosa pine because it is the only major species log-graded in Region 1, and the goal is to get all major species in the Region on the same system.

This paper presents, for timber managers, sellers, and buyers, equations for estimating total value and lumber volume of ponderosa pine trees. It documents the steps in developing the equations, demonstrates their use, and shows how well these equations estimate value and lumber volume for a group of trees.

Study Procedures

Sample and Field Procedures

A sample of 189 trees was selected to represent the range in size and quality of old-growth commercial ponderosa pine sawtimber being used by sawmills in western Montana. The trees were from four areas on the west side of the Lolo National Forest. Diameters ranged from 7 to 37 inches and heights from 42 to 165 feet.[1/] The mean diameter was 22 inches and mean height 100 feet.

The surface characteristics of the butt 32-foot portion were recorded for each standing tree. All logs were identified with a tag showing tree and log numbers before they were removed from the woods. In the millyard, they were scaled for board-foot content in the woods length and after they were bucked on the mill deck, they were again scaled. Scaling was done according to procedures in the National Forest Log Scaling Handbook (2409.11, Sept. 1973).

[1/] To convert inches to centimeters, multiply by 2.54; to convert feet to meters, multiply by 0.304 8.

The logs were then processed at a mill considered representative of mills processing ponderosa pine in the northern Rocky Mountain area. The logs were sawn under normal conditions, with the intent of obtaining the highest value from each log. Lumber produced was either 4/4-inch or 5/4-inch shop or 1-inch boards. The values and volumes were based on kiln-dried, surfaced lumber tally according to general industry practice. All lumber was identified throughout the milling phase so that each piece could be related to the log and tree from which it originated.

Developing the Prediction Model

Before data analysis, 34 of the 189 sample trees were randomly selected as a subsample for testing the prediction equations that would be developed. Of the remaining trees, one was inadequately measured, leaving 154 trees as a base for developing the equations.

Twenty-nine variables were screened with a multiple regression program (Dixon 1964) to determine tree characteristics that would be most highly correlated with value and volume of lumber. The independent variables that were examined are listed in appendix 1. Previous studies (Lane et al. 1970, Plank and Snellgrove 1978, Snellgrove et al. 1973) of other species have indicated that many characteristics are poorly correlated with value or volume, so they were not measured. The forward stepwise regression procedure was used to select the subset of independent variables to be included in the regression model for predicting value or lumber tally volume of the trees.

The screening process indicated that six tree characteristics should be observed and recorded.

These characteristics, described in the next paragraph, together with several transformations of the same characteristics, were selected as the best independent variables to be used in the two models.[2/] These variables were used with lumber yield information to develop the regression equations for predicting total value (dollars) and lumber volume (board feet) per tree. The same set of independent variables did not survive as the best estimator of both value and volume; consequently, separate equations were chosen to estimate the dependent variables. The final variables selected for the models were the ones that were most practical for application in timber appraisals and that statistically accounted for the most variation in volume and value.

[2/]Transformations are used not only for constructing interaction variables but also for changing the form of the individual variables so that more of the variation can be explained.

The following model equations are used for predicting total dollar value and total lumber volume of a tree:

$$\text{Total value} = b_0+b_1(\text{LDFF32})+b_2(\text{PADEFT})(D^2H)$$
$$+b_3(\text{DEFPER})(D^2H)+b_4(D^2)$$
$$+b_5(DH)+b_6(D^2H).$$

$$\text{Total lumber volume} = b_0+b_1(H)+b_2(\text{HTFLL})$$
$$+b_3(\text{DEFPER})(D^2H)$$
$$+b_4(\text{DEFSQR})(D^2H)+b_5(D^2H);$$

where:
b_0 is Y intercept constant,
b_1, $b_2 \ldots b_6$ are regression coefficients,
LDFF32 is the number of limb-free and defect-free faces on the butt 32-foot log,
PADEFT is the presence or absence of any defect (1 if present, 0 if absent),
DEFPER is estimated defect expressed as a percentage of gross cruise volume,
D is diameter at breast height (inches),
DEFSQR is estimated defect percent squared,
H is total tree height (feet),
HTFLL is the height to the first live limb.

Coefficients for the volume equation are as follows:

b_0	= -3.00685
b_1	= -0.826482
b_2	= 0.422030
b_3	= -0.0000843925
b_4	= 0.000000829797
b_5	= 0.0155223

Coefficients for the value equation vary as lumber prices vary and can be determined by the steps in the section, "How To Use the System."

The equations account for 91 percent of the variation in dollar value and 97 percent of the variation in lumber volume. The standard error of estimates are $51.89 and 139 board feet.

How the System Performs

From the sample of 189 trees, a subsample of 34 trees was randomly selected to test the performance of the estimating equations. The general characteristics (d.b.h., total height, criteria for the faces, height to first live limb, and defect) were recorded for each of the 34 trees in the subsample. Predictions of selling value and volume of lumber were then calculated using the equations.

Table 1 shows comparisons of estimated and actual values for the 34 subsample trees. Figures 1 and 2 show that the estimates of value and volume are about equally split by the 45-degree line.

Table 1--Comparison of estimated and actual selling value and volume of lumber from 34 ponderosa pine trees

Item	Total value	Difference	Total lumber volume	Difference
	Dollars	Percent	Board feet	Percent
Estimated	6,221.58	+7.3	29,865	+7.0
Actual	5,796.14		27,904	
Mean deviation	+12.51		+58	
Mean absolute deviation	37.13		93	

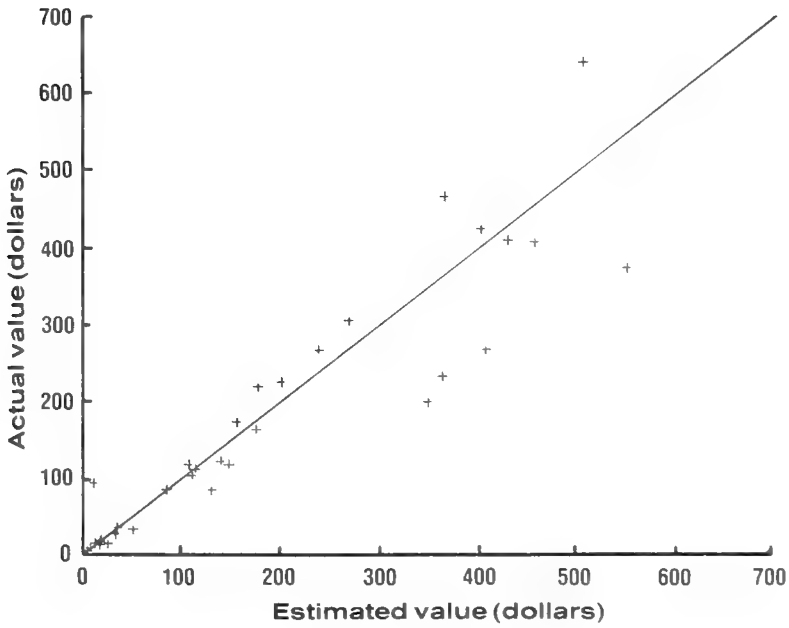

Figure 1.--Actual value versus estimated value of ponderosa pine trees.

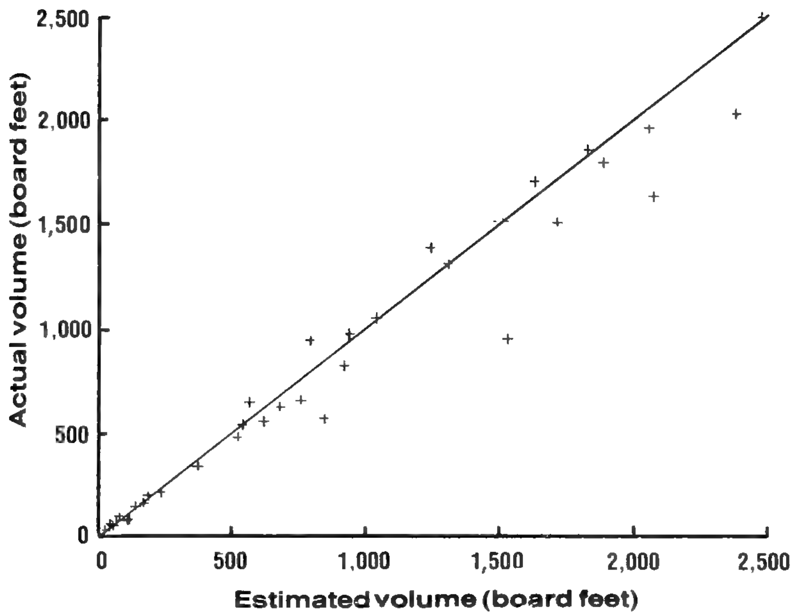

Figure 2.--Actual volume versus estimated volume of ponderosa pine trees.

How To Use the System

Computer facilities for making regression analyses are essential for efficient use of this system. Regression coefficients for tree values are derived from the tree characteristic data, the lumber grade yield data for each tree in the base study, and appropriate lumber prices. These data and the card format for the 154 trees are shown in appendix 2.

The total lumber tally volume of a tree or group of trees may be estimated by solving the following equation using the coefficients shown:[3/]

Total lumber tally volume (board feet) = 3.00685-0.826482(H)+0.422030(HTFLL) -0.0000843925(DEFPER)(D^2H) +0.000000829797(DEFSQR)(D^2H) +0.0155223(D^2H).

A procedure for developing a value equation for the 154 tree data set and current prices is as follows:

1. Assign current or desired lumber prices to each lumber grade recorded in the base study.

[3/]Note that this system was developed to predict values and volumes of 4/4- and 5/4-inch lumber. Using this system to predict values and volumes in areas where relatively large amounts of dimension lumber are obtained may not give accurate results.

2. Multiply these prices by the appropriate lumber yield information shown in appendix 2 to obtain a dollar value for each of the 154 trees in the base study.

3. Use an appropriate multiple regression program to develop the value equation coefficients for the 154 trees. Use the computed total dollar value (step 2) and five of the six tree characteristics in the following transformations:

   Dependent variable:
   Total dollars/D^2H

   Independent variables:
   LDFF32/D^2H
   PADEFT
   DEFPER
   D^2/D^2H
   DH/D^2H
   $1/D^2H$

4. Select sample trees.

5. Measure and record for each sample tree the five characteristics: (1) diameter, (2) height, (3) defect, (4) presence or absence of defect, and (5) number of limb- and defect-free faces in the butt 32-foot log.

6. Now apply this equation to a new group of trees using the following steps: Use coefficients developed in step 3 to solve the value equations for the sample trees selected in step 4.

Conclusions

Field tests of this system and similar systems have demonstrated that they have a number of advantages over the conventional log grading method. It is faster to apply in the field and thus more economical. Fewer judgment factors are required than with the log grading system presently used for ponderosa pine. Selling price is calculated easily and more directly than by methods that involve adjusting yield by log overrun estimates. In addition, training and checking of cruisers are easier.

This system is similar to others that have been used successfully by the USDA Forest Service in the northern Rocky Mountains. The performance of these systems and their acceptance by both timber buyers and sellers indicate that they are simple, workable methods of estimating the quality of standing sawtimber.

This system was developed where the major portion of lumber was manufactured into 4/4-inch and 5/4-inch items. Inferences as to the applicability of the system in areas where dimension lumber is a sizable portion of the cut may give misleading results.

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Appendix 1. Independent Variables

Defect related variables:

1. Defect percent.
2. Defect percent squared.
3. Presence or absence of defect.

Quality related variables:

4. Number of limb- and defect-free 8-foot panels on the butt 16-foot log.
5. Number of limb-free 8-foot panels on the butt 16-foot log.
6. Number of limb- and defect-free 8-foot panels on the butt 32-foot log.
7. Number of limb-free 8-foot panels on the butt 32-foot log.
8. Number of limb- and defect-free 16-foot faces on the butt 32-foot log.
9. Number of limb-free 16-foot faces on the butt 32-foot log.
10. Number of limb-free faces with no defect on the butt 16-foot log.
11. Number of limb-free faces on the butt 16-foot log.
12. Number of limb-free faces with no defect on the butt 32-foot log.
13. Number of limb-free faces on the butt 32-foot log.
14. Length of scar.
15. Presence or absence of scar on butt log.
16. Presence or absence of conks.
17. Size of the largest limb on the butt 16-foot log.
18. Size of the largest limb on the butt 32-foot log.
19. Height to the first live limb.

Volume related variables:

20. d.b.h. = D
21. Total height = H
22. D^2
23. DH
24. H^2
25. D/H
26. H/D
27. (H/D^2)
28. D^2H
29. $1/D^2H$

Appendix 2. Tree Quality Characteristics and Lumber Yield Data

The tree quality characteristics and lumber yield data for each of the 154 trees in the base study are listed according to the card format shown below.

Columns	Data
1-3	Tree number
4-6	d.b.h.
7-9	Total height
10	Number of limb- and defect-free (clear) faces on the butt 32-foot log
11-12	Height to the first live limb
13	Presence or absence of defect
14-16	Defect percent
17-20	Volume of B Select lumber
21-24	Volume of C Select lumber
25-28	Volume of D Select lumber
29-32	Volume of Moulding lumber
33-36	Volume of 3 Clear lumber
37-40	Volume of 1 Shop lumber
41-44	Volume of 2 Shop lumber
45-48	Volume of 3 Shop lumber
49-52	Volume of Shop-out lumber
53-56	Volume of 2 Common & Btr lumber
57-60	Volume of 3 Common lumber
61-64	Volume of 4 Common lumber
65-68	Volume of 5 Common lumber
69-72	Volume of Pitch Select lumber

TREE	DBH	TOT HT	CL FA	HT LMB	P-A DEF	PCT DEF	B-SEL	C-SEL	D-SEL	MLDG	3-CL	1-SHP	2-SHP	3-SHP	SHP-O	2-COM	3-COM	4-COM	5-COM	P-SEL
							V O L U M E													
1	357	132	3	40		1	28	82	198	419		138	645	208	15	230	252	76	5	144
2	263	123	1	66		2	34	46	64	91		69	214	78		159	348	83		
3	209	90	3	34			13	31	122	32		26	52	17	10	185	210	19	4	
4	266	109	3	41	1	2	20	96	63	231		47	198	79	13	189	241	29		14
6	200	96	3	48		5		53	81	41		8	18			92	111	35	26	7
7	254	133	3	47		3	7	113	120	112		41	212	30		173	174	55	2	
9	195	108	4	44		7	17	73	41	16		16	13			259	69	17		
11	221	98		37				42	69	4		16		27		185	250	18	3	
12	290	118	1	24		2	74	76	114	171		165	390	40		165	243	14	5	
14	243	119	3	35		2		70	75	173		89	254	42		235	86			
15	243	118	1	22				37	98	111		138	275	110	13	163	78	48	17	
16	327	124		47		4		30	66	170		107	562	248	23	105	408	48	10	
22	296	124		28		1	27	44	63	96		67	357	180	77	145	340	30	3	47
23	316	118		30	1	9	19	56	105	124		123	343	168		201	143	29	17	5
25	267	110	1	31	1	4		47	84	103		55	168	93	12	165	139	17	5	24
26	264	118	3	41		1		49	50	178		188	235	185		140	182	30		
27	318	125		36		6		14	131	214		34	405	390	93	176	345	21	3	25
28	307	130	1	36	1	3		29	49	198		91	461	165	19	283	194	20	6	10
29	286	113	3	47	1	12	74	105	96	160		26	157	181	20	139	148	44	27	
31	202	107	4	40		6		109	58	142		9				200	106	23	4	
32	367	151	3	50		27	202	249	116	338		65	586	495	47	25	345	387	185	48
33	330	125	3	40	1	28	163	193	138	354	38	250	182	157	19	20	63	112	45	
34	282	106	1	36	1	7	3	27	193	224		87	183	141		161	107	34	13	
37	349	126	2	22		11	26	80	152	315	38	205	691	262		81	292	138	41	
38	317	131	2	65		34		61	91	365	40	241	672	150	38	14	247	200	8	
40	258	105		25					7	13		13	106	142	78	77	144	206	28	
41	296	125		24		1		18	9	58	17	211	436	168	32	102	183	78	119	
42	180	88		30		80			6	3		16				176	169	15		
43	160	86		30		8				3		6				119	171	7		
44	201	96		34					2	5			90	122		131	241	41	13	
45	126	65		28												75	58	7		
46	111	54		28						3			8			24	41	3		
47	135	88		30					3							60	92	15		
48	99	65		34	1											29	27	7		
51	262	95		39		1		6	4	25		74	307	221	23	97	239	22	17	
52	268	109		27		2		18	10	86		44	538	95	15	53	270	50	11	
53	124	77		19						6						46	47	16		
54	92	69		20												10	13	6		
55	298	110		24		1		13		5	15	193	481	193		66	332	71	9	
57	222	121	1	52	1	4	12	48	64	115		77	116	60	8	79	265	10	9	

		TOT	CL	HT	P-A	PCT	VOLUME													
TREE	DBH	HT	FA	LMB	DEF	DEF	B-SEL	C-SEL	D-SEL	MLDG	3-CL	1-SHP	2-SHP	3-SHP	SHP-0	2-COM	3-COM	4-COM	5-COM	P-SEL
58	308	139	1	37	1	4		22	26	177	22	259	565	269	17	245	292	126	4	
59	372	116	4	44		16			15	104		26	119	195	250		324	997	150	
60	312	112		45		13		18	19	53		130	618	397	66	19	257	66	8	
62	291	125	2	39		10	3	47	100	83		60	410	374	12	190	329	129	17	
64	333	127	1	40				55	167	131		55	432	671	143	120	484	52	25	
65	344	119		30		2		17	51	208		164	516	244	75	119	364	46		
66	230	120	2	37		1		32	21	87		136	338	36		254	210	15	5	
67	187	108	2	35				10	24	80		21	10	96		262	70	28	5	
69	240	120	1	38	1	7			16	67		117	289	121		169	114	81	8	
70	154	93		17	1	5		3	5	8						150	40	24		
71	74	64		36												12		3		
72	166	81		27		12										74	100	25	7	
73	140	89	1	29					25							71	47	8		
74	347	128		41		6		22	51	130		95	887	551	132	32	335	161	14	
76	327	117		25	1	3			18	55		116	657	526	53	44	415	212	41	
77	240	108		25	1	6	14	27	46	119		74	97	69		104	189	26	4	
78	287	124	2	21	1	6	8	66	111	100		20	383	182		45	319	237	13	
79	365	128		47	1	27		17	25	80		30	492	569	58	29	287	331	31	55
84	89	60		33					6	3						26	6	4		
85	295	116	4	52		13	24	35	20	154		47	382	318	57	5	273	110	34	
87	195	103	4	55		12		42	56	55		13	8	16	17	135	159	40	7	
89	280	120		60		2		28	43	118		86	360	173	8	104	276	210	6	2
90	328	110	1	36	1	19		63	72	93		70	522	219		44	239	173	26	
91	297	117	3	54		3	14	48	63	197		17	268	252	43	44	210	343	40	
92	307	124	1	39		4			23	85		202	606	242	4	172	284	60	29	
93	302	135	1	33	1	8		5	14	72		30	309	459	45	87	546	243	15	4
95	200	88		42		24			10	37		33	105	42		94	150	16	5	
96	169	92	1	50		3			16	26		27	21	59		57	153	35		
97	250	99		52		2		3		69		51	231	140		135	265	123	3	
98	267	104	3	27		2	136	84	59	161		53	123	20	10	240	102	3		51
99	226	122	1	28		3	3		65	46		11	81	102		148	285	13		10
100	351	113		42		2		15	14	129		254	557	416	123	99	315	50	6	
101	355	110	4	43		4	160	228	92	358		163	427	232		185	241	63	38	48
102	340	128	2	32	1	5	11	94	73	267		186	453	518	46	64	438	41	7	
103	163	53		22		13	5	6	15	3						8	67	29	5	
106	290	109	3	45	1	17		29	62	128		15	63	390		51	171	214	16	118
107	282	106	1	29	1	24	4	5	29	11		65	197	123	39	69	165	186	30	
108	363	109		28	1	4		7	21	202		143	592	598	213	106	227	99	14	27
109	131	44		21		14			8							12	45	22		
110	216	90		24	1	28		14	31	44		19	23	8		78	189	73	26	
111	139	58	1	40	1	22		3	4	12						7	59	4		

TREE	DBH	TOT HT	CL FA	HT LMB	P-A DEF	PCT DEF	B-SEL	C-SEL	D-SEL	MLDG	3-CL	1-SHP	2-SHP	3-SHP	SHP-O	2-COM	3-COM	4-COM	5-COM	P-SEL
							VOLUME													
115	172	111	2	33					15	4		27				154	281	23	8	
116	148	101		44					4				8			87	177	79	5	
118	208	105		43		2			13	5		19				137	349	66		
119	169	110		57					5	5		39	36	10		155	153	45	5	
120	130	101		44					7							75	59	29		
121	103	65		44		14										44	31	17		
123	157	106		37		8			13	2		8				146	115	12		
124	330	152	2	32		8	3	60	33	221		273	680	260	22	153	226	52	16	
125	162	91		38	1					2			6			106	132	53		
127	199	106	1	33	1	2			3	34		27	56	69		216	248	43	3	8
128	180	120		74	1	7		3		8		13				222	143	61		
130	130	103	2	45												159	53	21		
132	92	80		48		14										31	29	6		
133	149	106		40	1	4			7			8				142	147	27		
134	111	101		66						5						64	66	32		
136	145	117	1	53		5			6	3						117	149	15		
137	145	97		46					8							125	100	21	3	
139	119	105	3	65	1	8		3		3						66	55	20	15	
140	299	163		52		3	7	30	87	218	37	466	808	214		167	286	153	69	
142	109	80		20					5							55	12	26		
143	75	77		50												7	6		2	
144	103	84		47	1											34	44	19		
145	79	76		45												5	8	5		
146	136	78		44	1											80	70	27		
147	372	162	3	72	1	7		44	69	389		222	784	444	55		161	385	78	55
148	248	120		64	1	7		18	3	46		41	206	206		81	111	160	49	
149	312	140	3	83	1	40		85	9	156		158	314	310	13	38	200	24		
152	102	42		20												20	23			
153	134	30		10					5							5	39	9		
154	193	66		22		27		3				8				38	178	30	15	
155	199	89		29	1							39	24			167	184	43		
156	280	94		29		4	21	78	71	73		53	220	58		107	260	52	9	
157	270	85	1	28	1	12		79	62	50		34	95	87	17	96	143	120		
158	165	61		22	1	33			19	27						20	132	18	4	
159	245	104	1	56	1	9	31	46	50	227		40	117	54	10	35	110	77	5	
160	275	114		42	1	12		34	53	126		123	437	93	9	46	157	136	28	
162	338	96	2	42		20	113	196	63	206		237	413	95	4	26	201	109	53	
164	226	66		20	1	4			7	6		19	11			23	253	79		
165	289	99		19	1	14	5	70	60	54		94	227	33		78	441	175	8	
166	159	86		34	1	21		3	27	19		14				77	64	24		
167	260	91	2	45	1	13		11	46	28		50	100	22		57	124	195	5	

		TOT	CL	HT	P-A	PCT						V O L U M E								
TREE	DBH	HT	FA	LMB	DEF	DEF	B-SEL	C-SEL	D-SEL	MLDG	3-CL	1-SHP	2-SHP	3-SHP	SHP-O	2-COM	3-COM	4-COM	5-COM	P-SEL
168	311	93	2	40		20		7	81	78		8	53	45	105	4	101	223	235	57
169	180	83		13	1	17		3		3		21	8	15		72	132	53	10	
171	115	79		26	1	29	7		12							22	33	7		
173	90	68		20	1	33										5	11	5		
175	160	77		19		6			16			18				85	73	11		
179	304	83	4	36		18	101	112	133	268		56	120	72	31	79	228	95	14	
180	300	130	1	24	1	2		101	268	217		69	198	132	30	90	150	117	16	38
181	85	68		10		50											14	3	8	
182	124	86		49					5	3						123	11	8	2	
183	145	81		22					9							99	70	26	4	
184	250	76		35	1	4		35	33	26		40	84	111	17	9	271	21	28	
187	224	83		37	1	4			14	13			8			43	227	287	18	8
188	199	74		28	1	10			10	24			17	30	10	70	257	29	13	
189	256	85		24	1	5		12	5	66		93	208	122	35	43	266	45	8	
190	208	64		13					2			8	13			55	193	14		
191	80	64		37												7		3	4	
192	90	68		35												9	8	2	3	
195	110	67		15						3						52	12			
196	189	89		36				2	11			6	8			118	187	36		
197	119	83		51		14										24	25	34	8	
198	116	89		22		30										35	46			
250	170	64	1	29		5	4	30	49	39						3	29	38	7	
253	180	77		27	1				12	14			34	43	9	51	109	13	3	
254	310	153	3	85		7	103	156	152	274		86	471	125	15	338	199	29	5	14
255	130	82		18					3							82	62	3	9	
256	150	82		35		5			14	12		6				127	44	6		
257	110	69		31												35	27	5	5	
258	160	77		36		86		3								41	124	26		
259	194	109		35				3	12	22		17	75	26		242	59	9	10	
261	250	130		50		2	2	4	34	29		107	186	55		434	183	25		
262	210	99		31				18	78	12						215	139	12	7	
309	268	110	1	65	1	10		18	20			8	192	250	53	59	304	135	19	

Plank, Marlin E. Estimating value and volume of ponderosa pine trees by equations. USDA For. Serv. Res. Pap. PNW-283, 13 p. Portland, OR: Pac. Northwest For. and Range Exp. Stn.; 1981.

Equations for estimating the selling value and tally volume for ponderosa pine lumber from the standing trees are described. Only five characteristics are required for the equations.
Development and application of the system are described.

Keywords: Lumber value, volume estimation, grading systems, ponderosa pine, *Pinus ponderosa*.

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