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Estimation of Diameter at Breast Height from Stump Diameter for Lodgepole Pine

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ABSTRACT

Equations to estimate diameter at breast height outside bark from the stump diameter outside bark are presented for 13 lodgepole pine sites. The data came from three National Forests in Montana. General equations are also given for two varieties of lodgepole pine from data collected across the range of the species in North America. Simple linear regression methods were used. As an application, a procedure for obtaining tree volume is described.

KEYWORDS: diameter at breast height, d.b.h., stump diameter, volume

INTRODUCTION

Utilization researchers needed to predict diameter at breast height (d.b.h.) from stump diameter to reconstruct pretreatment stand tables. This reconstruction was necessary to correct for inadequate plot size in the original sampling scheme. The dominant species was lodgepole pine (*Pinus contorta* var. *latifolia*).

Estimating d.b.h. from stump measurements has other applications, including estimating volume, verifying harvesting practices following tree removal, determining the history of cutover lands, and assessing damage that results from adverse environmental conditions. In all cases, only the stump diameter is known.

Ziegler (1907) and Alemdag and Honer (1977) presented tabulations of the relationship between breast height and stump diameters for variety *latifolia*. The data were from Wyoming and Canada, respectively. Faurot (1977) gave an equation relating stump diameter to d.b.h. for lodgepole pine in the Northwest. These studies were neither site specific nor limited to small-diameter stems.

This paper presents equations to estimate d.b.h. from stump diameter for 13 small, overstocked lodgepole pine sites in Montana. General equations for *latifolia* and *murrayana* representing the range of these lodgepole pine varieties in North America are also given.

DATA COLLECTION

For the first study, data were collected from 15 stands on the Deerlodge, Gallatin, and Lewis and Clark National Forests in Montana. Some pretreatment characteristics of the stands are detailed in table 1. These stands are used to evaluate harvesting technology alternatives and to identify those that will result in financially feasible treatment for the existing economically submarginal conditions. This group of stands will also allow long-term evaluations of growth response and regeneration as well as other biological responses.

Original pretreatment stand tables were based on circular fixed plots of 1/300 acre. After harvesting, some stands had few trees remaining, so the plot size was expanded to 1/100 acre in order to obtain an adequate post-treatment sample. This enlargement of plot size created statistical problems that could be corrected only by enlarging the pretreatment plot size. Consequently, all stands were reinventoried using either a 1/50-acre or a 1/100-acre plot size.

By the time the reinventory need became apparent, harvesting had been completed on most stands. This required a reinventory procedure that would include both standing residual trees and stumps, and at the same time acquire the data base needed to estimate the d.b.h. of the cut trees. To do this, original 1/300-acre plot centers were located and an enlarged circumference established. Within the plot, both d.b.h. and stump diameter were measured on standing trees to the nearest 0.1 inch at heights of 4.5 feet and 4 inches. For cut trees, stump diameters were taken at 4 inches above the ground or at the highest point on stumps less than 4 inches. These measurements were made outside the bark. Small trees (<3.0 inches d.b.h.) were not well represented in the residual stand because most had been cut. The sample of smaller trees was therefore augmented on five units by adding approximately 40 trees from each control area.

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Table 1—Stand characteristics of 15 lodgepole pine stands in Montana

Stand	National Forest	Age	Elevation	Density	Basal area	Habitat type[1]
		Years	*Feet*	*Stems/acre*	*Ft²/acre*	
Spring Emery	Deerlodge	99	6,800	3,168	211	ABLA/LIBO
Ballard North	Deerlodge	80	6,300	2,997	281	ABLA/LIBO
Ballard South	Deerlodge	80	6,300	2,249	285	ABLA/LIBO
Corduroy East	Deerlodge	85	5,900	2,318	206	ABLA/VACA
Corduroy West	Deerlodge	88	5,900	3,191	196	ABLA/VACA
Corduroy North	Deerlodge	81	5,900	7,046	202	ABLA/VACA
Rattling Gulch	Deerlodge	59	5,600	997	139	PSME/VACA
Echo Lake	Deerlodge	88	6,700	6,159	241	PSME/LIBO
South Flat[2]	Gallatin	86	6,800	2,381	171	ABLA/VASC
Getcho[2]	Gallatin	96	6,800	1,870	178	ABLA/CARU
Reas Pass[2]	Gallatin	88	7,200	1,272	155	ABLA/VASC
Dry Fork East	Lewis and Clark	57	5,400	4,799	153	PSME/LIBO
Dry Fork West	Lewis and Clark	50	5,400	5,318	145	PSME/LIBO
Currie North	Lewis and Clark	54	5,000	2,490	147	PIEN/LIBO
Wet Park	Lewis and Clark	88	6,800	4,195	247	ABLA/CACA

[1]Habitat types from Pfister and others (1977).
[2]These three stands were combined in this study.

Table 2—Coefficients and descriptive statistics of equations $y = a + bx$, where y is d.b.h. in inches outside bark and x is stump diameter in inches outside bark; for 13 lodgepole pine sites in Montana

Site	Stand	*a*	*b*	Sample size	Range of *x*	se	R^2
					Inches		
1	Spring Emery	0.171	0.806	171	2-8	0.210	0.95
2	Ballard North	.428	.728	194	4-12	.247	.96
3	Ballard South	.493	.720	255	3-13	.259	.96
4	Corduroy East	.155	.793	241	1-11	.210	.98
5	Corduroy West	.319	.766	185	2-9	.223	.96
6	Corduroy North	.212	.773	341	1-8	.159	.96
7	Rattling Gulch	.237	.758	181	1-13	.319	.98
8	Echo Lake	.149	.774	185	1-8	.197	.97
9	South Flat, Getcho, Reas Pass	.325	.778	236	2-10	.221	.95
10	Dry Fork East	.125	.809	155	2-7	.138	.97
11	Dry Fork West	−.027	.842	234	1-7	.151	.98
12	Currie North	−.079	.853	128	2-9	.151	.97
13	Wet Park	.246	.777	71	2-8	.171	.97

For the second study on general characteristics, the data were collected as part of a major study on the lodgepole pine resource across the range of the species in North America (Koch 1986). This research involved sampling 243 *latifolia* trees from latitudes 40 through 60 degrees at 2.5-degree intervals across 10 degrees of longitude. The area sampled reached from central Utah and Colorado north to the Yukon Territory. Trees with d.b.h. of 3, 6, and 9 inches were sampled at low, medium, and high elevations within each latitudinal zone; elevational zone averaged much higher in the south (8,000 to 10,000 feet) than in the north (2,000 to 3,000 feet). In addition, 36 *murrayana* trees in the same diameter classes were sampled at medium elevation at four latitudes (37.5, 40, 42.5, and 45 degrees) in California and Oregon. Elevations sampled for this variety averaged lowest at 45 degrees (3,765 feet) and highest at 37.5 degrees (7,879 feet), with only one longitude per latitude.

Both d.b.h. and stump diameter were recorded in millimeters but were converted to inches for this report. The stump diameter was measured at 6 inches above the ground. Measurements were made outside the bark.

EQUATIONS

Simple linear regression methods were used to develop stump-d.b.h. equations for the two studies described above. For estimating d.b.h. from stump diameter, these simple models have been shown to be as reliable as more complicated models (Bylin 1982). The form of the equation is $y = a + bx$, where y is the estimated d.b.h. in inches outside bark and x is the stump diameter in inches outside bark. The equation coefficients for the Montana study

Table 3—Coefficients, descriptive statistics, and general information for estimating d.b.h. from stump diameter for two lodgepole pine varieties. The equation form is $y = a + bx$, where y is d.b.h. in inches outside bark and x is stump diameter in inches outside bark

Factor	*latifolia*	*murrayana*
a	0.338	0.378
b	.790	.802
Sample size	243	36
Range of *x* (inches)	3-13	3-12
se	.402	.344
R^2	.97	.98
Average age (years)	90	81

sites are given in table 2. More general equations for varieties *latifolia* and *murrayana* are shown in table 3.

Statistics given in the tables for each equation are "se" and "R^2". The "se" stands for the standard error of the estimate and is calculated as the square root of the residual mean square. The "R^2" is the percentage of the variation explained by the regression.

For comparison purposes, the equation developed by Faurot (1977) for lodgepole pine is $y = -0.292 + 0.874\ x$ ($R^2 = 0.98$ and se = 0.546). In Faurot's equation y is the estimated d.b.h. in inches outside bark and x is the stump diameter in inches inside bark. The sample of 227 trees was taken from unmanaged second-growth stands in western Montana. Trees were less than 80 years old. Stump diameters were measured at a 1-foot stump height and ranged from 1.4 to 20.7 inches.

USING THE EQUATIONS

The equations, as given in table 2, have most application to small lodgepole pine in western Montana with stump diameters falling within the ranges shown. The specific equation can be chosen by matching site conditions to a stand in table 1. In the absence of this site information, the general equations in table 3 could be used.

Stump heights for all equations were less than the Forest Service standard of 1 foot, which is more common in sawtimber than in post-pole utilization practices. These equations represent relationships between stump diameter and d.b.h. for a 4-inch stump height (6 inches for the general equations). This must be remembered when applying the equations.

A useful application of these results is determining the cubic foot tree volume when only the stump diameter is known. This can be done with the following procedure:

Step 1: estimate d.b.h. from stump diameter

Step 2: estimate tree height from d.b.h.

Step 3: estimate tree volume using height and d.b.h.

Step 1 is the main topic of this paper; steps 2 and 3 are detailed here.

In addition to the fixed plots described above, variable plot data were collected for the Montana study. The variable plot measurements included tree height and d.b.h. so that equations to predict height for each site could be developed. The form of the relationship is $y = c + d \log_{10} x$, where y is tree height in feet and x is d.b.h. in inches outside bark. The equation coefficients for the Montana study sites are given in table 4. Similar equations

Table 4—Coefficients and descriptive statistics of equations $y = c + d \log_{10} x$, where y is tree height in feet and x is d.b.h. in inches outside bark; for 13 lodgepole pine sites in Montana

Site	Stand	*c*	*d*	Sample size	Range of *x*	se	R^2
					Inches		
1	Spring Emery	12.41	45.82	185	1.6-7.7	3.52	0.76
2	Ballard North	12.51	57.21	263	1.6-9.6	4.07	.82
3	Ballard South	7.83	64.49	143	1.8-9.6	4.88	.76
4	Corduroy East	17.43	47.61	204	1.9-8.2	3.03	.81
5	Corduroy West	16.20	44.01	214	1.0-7.6	3.54	.80
6	Corduroy North	14.34	37.00	92	1.0-5.6	3.47	.73
7	Rattling Gulch	14.95	44.10	243	2.1-9.8	4.36	.61
8	Echo Lake	16.50	41.56	104	1.0-6.3	3.34	.79
9	South Flat, Getcho, Reas Pass	11.74	48.19	496	1.4-8.5	3.28	.80
10	Dry Fork East	14.38	36.35	160	1.1-5.5	3.18	.75
11	Dry Fork West	12.46	36.14	175	1.0-5.6	3.17	.79
12	Currie North	11.65	45.04	117	1.5-7.3	3.41	.71
13	Wet Park	8.62	48.70	133	1.3-9.3	3.59	.83

Table 5—Coefficients and descriptive statistics for estimating tree height from d.b.h. for two lodgepole pine varieties. The equation form is $y = c + d \log_{10} x$, where y is tree height in feet and x is d.b.h. in inches outside bark

Variety	*c*	*d*	Sample size	Range of *x*	se	R^2
				Inches		
1 = *latifolia*	−1.60	68.04	241	2.87-9.41	7.88	0.74
2 = *murrayana*	−12.60	76.96	36	2.87-9.41	11.41	.65

were developed for varieties *latifolia* and *murrayana* using data collected for the general characterization study. These are shown in table 5.

Once the height is estimated from the d.b.h., tree volume can be calculated using an equation derived by James Brickell, formerly with the Intermountain Research Station (Cole 1971):

$$V = 0.002782\ D^2H\ (H^{0.0488}/D^{0.0959})$$

where V is tree volume in cubic feet, D is the d.b.h. in inches outside bark, and H is tree height in feet.

CONCLUSION

The equations here provide a method by which tree diameter, height, and volume can be estimated after harvesting using stump diameter. The equations developed predict quite well and give reasonable estimates across the range of stump diameters in these data bases. They provide new information about the smaller lodgepole pine in the Northern Rocky Mountains specifically, and in general across the North American range of the species.

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