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STUMP DIAMETER - D.B.H. RELATIONSHIPS FOR YOUNG-GROWTH MIXED CONIFER SPECIES[1]

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Foresters sometimes must estimate the timber volume that recently existed on cutover forest land. This may be necessary, for example, if a stand killed by fire was salvage-logged before an inventory of killed timber could be made; or in cases where the timber was cut and removed by a trespasser. Usual procedure in these situations is to cruise the tract, taking diameter inside-bark (d.i.b.) measurements on stumps. Then tree diameter breast high (d.b.h.) is estimated using the rule-of-thumb that "d.b.h. equals stump d.i.b." Finally, given an estimate of d.b.h., tree volume is obtained from a volume table.

This paper presents regression equations which can be used to predict tree d.b.h. from stump d.i.b. measurements for young growth ponderosa pine, sugar pine, white fir, Douglas fir, and incense cedar.[2] They show that the timber cruiser's old rule-of-thumb -- "d.b.h. equals stump d.i.b." -- will produce erroneous tree volume estimates for these species of young-growth timber. The rule is accurate for ponderosa pine with stump d.i.b. of 33.0 inches and larger. But, if applied to smaller ponderosa pine or to other species, it will either under- or overestimate d.b.h. and thus result in an under- or overestimate of tree volume. For example, the volume of a Douglas fir tree with a stump d.i.b. of 36 inches is underestimated by about 10 per cent if the rule is used. In contrast, the volume of a sugar pine tree of equivalent diameter is overestimated by 10 per cent. Our findings show that estimating tree volume by the "d.b.h. equals stump d.i.b." rule results in the following:

Species	Rule yields volumes which are:
Ponderosa pine	Overestimates for stump d.i.b. 32.0 inches or less; accurate estimates for 33.0 inches and larger.
Sugar pine	Overestimates.
Douglas fir	Overestimates for stump d.i.b. 14.0 inches or less; accurate estimates for 15.0-16.0 inches; underestimates for 17.0 inches or larger.
Incense cedar	Overestimates for stump d.i.b. 15.0 inches or less; underestimates for 17.0 inches and larger.
White fir	Underestimates.

The d.b.h.-stump d.i.b. relationships reported below can be used to obtain unbiased estimates of tree d.b.h. based on stump d.i.b. They may be used in deriving timber volume estimates on cutover areas by first measuring stump d.i.b., converting this measurement to d.b.h. with the appropriate equation or table, and then obtaining tree volume from local volume tables; or, if tree height-d.b.h. relationships are available, from stand volume tables. Table 1 shows the regression equation and sample basis for each species. Table 2 gives the estimated arithmetical mean d.b.h. associated with a stump of 12 to 50 inches.

BASIS FOR THE REGRESSION EQUATIONS

Data used in developing the regression equations are stump d.i.b. and tree d.b.h. measurements from

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[2]Pinus ponderosa Laws., Pinus lambertiana Dougl., Abies concolor (Gord. & Glend.) Lindl., Pseudotsuga menziesii (Mirb.) Franco, and Libocedrus decurrens Torrey.

374 trees cut on the Challenge Experimental Forest, Yuba County, California, in cooperation with the Soper-Wheeler Company. The trees ranged from 40 to 90 years in age and were from young-growth stands typed as Pacific ponderosa pine and Pacific ponderosa pine -- Douglas fir (2). Site index at Challenge is high, from 140 to 170 feet (average total height of dominant ponderosa pine trees at a base age of 100 years measured at breast height) based on site index curves for even-aged young-growth ponderosa pine (1). Basal area stocking is 80-220 sq ft per acre, averaging about 160 sq ft, and stocking averages 45,000 bd ft per acre.

All tree and stump measurements were made on the uphill side. D.b.h. was taken as the average of two calipered measurements at right angles to each other 4.5 feet above ground level. Stump d.i.b. was measured one foot above ground. On stumps one foot high, two caliper measurements inside-bark -- one across the axis of greatest diameter and the second at right angle to the first -- were averaged to obtain stump d.i.b. On higher stumps, two caliper measurements were made outside-bark at the one foot level and averaged to obtain d.o.b. Bark thickness measurements were taken on four sides and averaged. Stump d.i.b. was then computed by subtracting twice the average bark thickness from measured stump d.o.b. If the stump was less than one foot high, measurements were made on the tree at the one foot level. All caliper measurements were made to the nearest tenth inch.

A linear regression model of the following form was used to estimate the relationship between d.b.h. and stump diameter:

$$\text{d.b.h.} = A + B\,(\text{Stump d.i.b.})$$

where

Stump d.i.b. = average diameter of stump measured inside-bark one foot above ground on the uphill side.

A high degree of correlation was found to exist between d.b.h. and stump d.i.b. for each species investigated. Correlation coefficients exceeded 0.97 for all species. Regression coefficients are highly significant, the "t" values exceeding 37.5 for all species.

To provide a measure of possible error in predicting d.b.h. with the regression equations, 95 per cent confidence intervals are shown for the mean d.b.h. associated with each stump diameter. (These confidence intervals are based on the assumption that the Y_i distributions are normal and have equal variances.) The intervals represent for a given stump diameter the limits within which the true population mean d.b.h. is expected to fall at a 95 per cent probability level. These intervals, within the bounds of the sample, range from 0.5 to 2.4 inches and become smaller as estimated d.b.h. approaches the mean diameter of the sample trees. The intervals were computed with the following equation (3, p. 170):

$$CI(Y) = \hat{Y} \pm t_{.05} S_y \sqrt{\frac{1}{n} + \frac{x^2}{\sum_{i=1}^{n} x_i^2}}$$

where

$CI(Y)$ = a confidence interval for Y.

Y = the true population mean diameter associated with a stump diameter, X.

$\hat{Y}$ = the estimated mean diameter associated with a stump diameter, X.

$t_{.05}$ = student's t for n-2 degrees of freedom at 95 per cent confidence level.

S_y = the estimated standard error of estimate.

$$= \sqrt{\frac{\sum_{i=1}^{n} (Y_i - \hat{Y}_i)^2}{(n-2)}}$$

Y_i = the actual measured d.b.h. of the ith tree in the regression sample.

n = the number of sample trees used to calculate the regression equation.

x = the deviation of a stump diameter, X, from the mean stump diameter of the regression sample, $\bar{X}$.

= $(X - \bar{X})$.

$\bar{X}$ = the average stump diameter of the regression sample.

x_i = the difference of the ith actual regression sample stump diameter, X_i, and the regression sample mean, $\bar{X}$.

= $(X_i - \bar{X})$.

APPLICATION OF RESULTS

The d.b.h.-stump d.i.b. equations or tables can be used in estimating timber volume on cutover tracts following the procedures outlined on page 1. However, it is not possible with the data given to attach confidence statements to the volume estimates produced. It is recommended that the use of the regression equations be limited to stands similar to those which were the basis for this work. If it is desired to use equations in other forest types or on different sites, tests should first be made to determine if the regression equations produce acceptably accurate predictions of mean d.b.h. Finally, it is important that stump d.i.b. be measured one foot above ground; if measured at different heights, biased estimates will be obtained. Stump d.i.b. at one foot on taller stumps can be estimated by taking d.o.b. measurements at one foot and then subtracting double bark thickness.

TABLE 1

D.b.h. and stump diameter relationships for young-growth conifers, Challenge Experimental Forest

SPECIES	CONSTANTS OF THE D.B.H.-STUMP DIA. REGRESSION EQUATIONS[a]		COLUMN C[b]	COLUMN D[c]	STD. ERROR OF ESTIMATE	SAMPLE BASIS			
	A	B				No. of Trees	Avg. d.b.h.	Range of d.b.h.	Range of Stump d.i.b.
Ponderosa pine	-0.30625	1.00784	63.4	.9927	1.402	61	27.7	11.9-47.4	12.3-49.8
Sugar pine	0.50682	0.94638	71.5	.9923	1.218	82	28.0	12.0-48.4	12.0-52.3
Douglas fir	-0.92870	1.06029	37.5	.9773	2.127	68	30.5	12.0-48.6	11.4-49.0
Incense cedar	-1.80074	1.11149	38.3	.9726	1.562	86	21.1	12.1-40.0	12.0-34.6
White fir	-0.07417	1.01448	50.1	.9854	1.475	77	22.6	11.7-50.7	11.4-51.2

[a]Where:

$$\text{D.b.h.} = A + B\ (\text{Stump d.i.b.})$$

[b]Column C - Calculated "t" value for regression coefficient.
[c]Column D - Correlation coefficient.

TABLE 2

Estimated d.b.h. for given stump d.i.b., mixed conifers[a]

PONDEROSA PINE

STUMP DIB	DBH	95% CONFIDENCE INTERVAL	STUMP DIB[b]	DBH	95% CONFIDENCE INTERVAL
in.	in.		in.	in.	
12.0	11.8	11.2 - 12.4	32.0	31.9	31.6 - 32.3
13.0	12.8	12.2 - 13.4	33.0	33.0	32.6 - 33.3
14.0	13.8	13.2 - 14.4	34.0	34.0	33.6 - 34.4
15.0	14.8	14.3 - 15.4	35.0	35.0	34.5 - 35.4
16.0	15.8	15.3 - 16.3	36.0	36.0	35.5 - 36.4
17.0	16.8	16.3 - 17.3	37.0	37.0	36.5 - 37.4
18.0	17.8	17.4 - 18.3	38.0	38.0	37.5 - 38.5
19.0	18.8	18.4 - 19.3	39.0	39.0	38.5 - 39.5
20.0	19.9	19.4 - 20.3	40.0	40.0	39.5 - 40.5
21.0	20.9	20.4 - 21.3	41.0	41.0	40.5 - 41.6
22.0	21.9	21.5 - 22.3	42.0	42.0	41.4 - 42.6
23.0	22.9	22.5 - 23.3	43.0	43.0	42.4 - 43.6
24.0	23.9	23.5 - 24.3	44.0	44.0	43.4 - 44.7
25.0	24.9	24.5 - 25.3	45.0	45.0	44.4 - 45.7
26.0	25.9	25.5 - 26.3	46.0	46.1	45.4 - 46.7
27.0	26.9	26.5 - 27.3	47.0	47.1	46.4 - 47.8
28.0	27.9	27.6 - 28.3	48.0*	48.1*	47.3 - 48.8
29.0	28.9	28.6 - 29.3	49.0*	49.1*	48.3 - 49.8
30.0	29.9	29.6 - 30.3	50.0*	50.1*	49.3 - 50.9
31.0	30.9	30.6 - 31.3			

TABLE 2

(continued)

SUGAR PINE

STUMP DIB	DBH	95% CONFIDENCE INTERVAL	STUMP DIB	DBH	95% CONFIDENCE INTERVAL
in.	in.		in.	in.	
12.0	11.9	11.3 - 12.4	32.0	30.8	30.5 - 31.1
13.0	12.8	12.3 - 13.3	33.0	31.7	31.4 - 32.0
14.0	13.8	13.3 - 14.2	34.0	32.7	32.4 - 33.0
15.0	14.7	14.2 - 15.2	35.0	33.6	33.3 - 33.9
16.0	15.7	15.2 - 16.1	36.0	34.6	34.3 - 34.9
17.0	16.6	16.2 - 17.0	37.0	35.5	35.2 - 35.9
18.0	17.5	17.1 - 17.9	38.0	36.5	36.1 - 36.8
19.0	18.5	18.1 - 18.9	39.0	37.4	37.0 - 37.8
20.0	19.4	19.1 - 19.8	40.0	38.4	38.0 - 38.8
21.0	20.4	20.0 - 20.7	41.0	39.3	38.9 - 39.7
22.0	21.3	21.0 - 21.7	42.0	40.2	39.8 - 40.7
23.0	22.3	22.0 - 22.6	43.0	41.2	40.7 - 41.7
24.0	23.2	22.9 - 23.5	44.0	42.1	41.7 - 42.6
25.0	24.2	23.9 - 24.5	45.0	43.1	42.6 - 43.6
26.0	25.1	24.8 - 25.4	46.0	44.0	43.5 - 44.6
27.0	26.1	25.8 - 26.3	47.0	45.0	44.4 - 45.5
28.0	27.0	26.7 - 27.3	48.0	45.9	45.4 - 46.5
29.0	28.0	27.7 - 28.2	49.0*	46.9*	46.3 - 47.5
30.0	28.9	28.6 - 29.2	50.0*	47.8*	47.2 - 48.4
31.0	29.8	29.6 - 30.1			

DOUGLAS FIR

STUMP DIB	DBH	95% CONFIDENCE INTERVAL	STUMP DIB	DBH	95% CONFIDENCE INTERVAL
in.	in.		in.	in.	
12.0	11.8	10.7 - 12.9	32.0	33.0	32.5 - 33.5
13.0	12.9	11.8 - 13.9	33.0	34.1	33.5 - 34.6
14.0	13.9	12.9 - 14.9	34.0	35.1	34.5 - 35.7
15.0	15.0	14.0 - 15.9	35.0	36.2	35.6 - 36.8
16.0	16.0	15.1 - 17.0	36.0	37.2	36.6 - 37.9
17.0	17.1	16.2 - 18.0	37.0	38.3	37.6 - 39.0
18.0	18.2	17.3 - 19.0	38.0	39.4	38.7 - 40.1
19.0	19.2	18.4 - 20.0	39.0	40.4	39.7 - 41.2
20.0	20.3	19.5 - 21.0	40.0	41.5	40.7 - 42.3
21.0	21.3	20.6 - 22.0	41.0	42.5	41.7 - 43.4
22.0	22.4	21.7 - 23.1	42.0	43.6	42.7 - 44.5
23.0	23.5	22.8 - 24.1	43.0	44.7	43.7 - 45.6
24.0	24.5	23.9 - 25.1	44.0	45.7	44.8 - 46.7
25.0	25.6	25.0 - 26.2	45.0	46.8	45.8 - 47.8
26.0	26.6	26.1 - 27.2	46.0	47.8	46.8 - 48.9
27.0	27.7	27.2 - 28.2	47.0	48.9	47.8 - 50.0
28.0	28.8	28.2 - 29.3	48.0	50.0	48.8 - 51.1
29.0	29.8	29.3 - 30.3	49.0	51.0	49.8 - 52.2
30.0	30.9	30.4 - 31.4	50.0*	52.1*	50.8 - 53.3
31.0	31.9	31.4 - 32.5			

TABLE 2
(continued)

WHITE FIR

STUMP DIB	DBH	95% CONFIDENCE INTERVAL	STUMP DIB	DBH	95% CONFIDENCE INTERVAL
in.	in.		in.	in.	
12.0	12.1	11.6 - 12.6	32.0	32.4	31.9 - 32.9
13.0	13.1	12.6 - 13.6	33.0	33.4	32.9 - 34.0
14.0	14.1	13.7 - 14.6	34.0	34.4	33.8 - 35.0
15.0	15.1	14.7 - 15.6	35.0	35.4	34.8 - 36.0
16.0	16.2	15.7 - 16.6	36.0	36.4	35.8 - 37.1
17.0	17.2	16.8 - 17.6	37.0	37.5	36.8 - 38.1
18.0	18.2	17.8 - 18.6	38.0	38.5	37.8 - 39.2
19.0	19.2	18.8 - 19.6	39.0	39.5	38.7 - 40.2
20.0	20.2	19.9 - 20.6	40.0	40.5	39.7 - 41.3
21.0	21.2	20.9 - 21.6	41.0	41.5	40.7 - 42.3
22.0	22.2	21.9 - 22.6	42.0	42.5	41.7 - 43.4
23.0	23.3	22.9 - 23.6	43.0	43.5	42.6 - 44.4
24.0	24.3	23.9 - 24.6	44.0	44.6	43.6 - 45.5
25.0	25.3	24.9 - 25.6	45.0	45.6	44.6 - 46.6
26.0	26.3	25.9 - 26.7	46.0	46.6	45.6 - 47.6
27.0	27.3	26.9 - 27.7	47.0	47.6	46.6 - 48.7
28.0	28.3	27.9 - 28.7	48.0	48.6	47.5 - 49.7
29.0	29.3	28.9 - 29.8	49.0	49.6	48.5 - 50.8
30.0	30.4	29.9 - 30.8	50.0	50.6	49.5 - 51.8
31.0	31.4	30.9 - 31.9			

INCENSE CEDAR

STUMP DIB	DBH	95% CONFIDENCE INTERVAL	STUMP DIB	DBH	95% CONFIDENCE INTERVAL
in.	in.		in.	in.	
12.0	11.5	10.9 - 12.1	32.0	33.8	33.0 - 34.5
13.0	12.6	12.1 - 13.2	33.0	34.9	34.1 - 35.7
14.0	13.8	13.3 - 14.3	34.0	36.0	35.1 - 36.8
15.0	14.9	14.4 - 15.3	35.0*	37.1*	36.2 - 38.0
16.0	16.0	15.6 - 16.4	36.0*	38.2*	37.3 - 39.2
17.0	17.1	16.7 - 17.5	37.0*	39.3*	38.3 - 40.3
18.0	18.2	17.8 - 18.6	38.0*	40.4*	39.4 - 41.5
19.0	19.3	19.0 - 19.7	39.0*	41.5*	40.4 - 42.7
20.0	20.4	20.1 - 20.8	40.0*	42.7*	41.5 - 43.8
21.0	21.5	21.2 - 21.9	41.0*	43.8*	42.5 - 45.0
22.0	22.7	22.3 - 23.0	42.0*	44.9*	43.6 - 46.2
23.0	23.8	23.4 - 24.1	43.0*	46.0*	44.7 - 47.3
24.0	24.9	24.5 - 25.3	44.0*	47.1*	45.7 - 48.5
25.0	26.0	25.6 - 26.4	45.0*	48.2*	46.8 - 49.7
26.0	27.1	26.6 - 27.6	46.0*	49.3*	47.8 - 50.8
27.0	28.2	27.7 - 28.7	47.0*	50.4*	48.8 - 52.0
28.0	29.3	28.8 - 29.9	48.0*	51.6*	49.9 - 53.2
29.0	30.4	29.8 - 31.0	49.0*	52.7*	51.0 - 54.3
30.0	31.5	30.9 - 32.2	50.0*	53.8*	52.0 - 55.5
31.0	32.7	32.0 - 33.3			

[a]D.b.h. and confidence intervals are rounded to nearest tenth inch. Confidence intervals apply to predicted d.b.h. of means of populations associated with a particular stump diameter.

[b]Diameters with an asterisk are outside the range of the sample.

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