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Predicting Diameter at Breast Height from Stump Diameters for Northeastern Tree Species

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Abstract

Presents equations to predict diameter at breast height from stump diameter measurements for 17 northeastern tree species. Simple linear regression was used to develop the equations. Application of the equations is discussed.

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Either standard or local volume tables are used to assess volume loss of trees. Standard tables provide an estimate of volume usually based on d.b.h. (diameter at breast height) measurements and some measure of height. Local volume tables provide an estimate of volume based on d.b.h. measurements alone. Use of either table requires some measure of d.b.h.

However, many situations arise today where the volume, and ultimately the value of trees, must be assessed from stump measurements. These situations include assessing timber sales based on stump diameters, checking harvesting practices following tree removals, tracing the history of cutover lands, assessing damage resulting from adverse environmental conditions, and determining volume loss due to timber trespass (Hampf 1954). In all of these situations, only the stump diameter is known. Therefore, in order to use volume tables, d.b.h. must be estimated from stump measurements. The relationship between stump diameter and d.b.h. is usually highly correlated since the variable to be estimated is only 4½ feet up the tree bole from the known variable, stump diameter. Once d.b.h. is estimated, the tree volume can be estimated.

Previous studies relating stump diameter to d.b.h. have been made. McClure (1968) and Raile (1978) made two of the most recent studies in the Southeastern and North-central regions of the United States, respectively. In the Northeast, Hampf (1954; 1955a, b, c, d, e; 1957a, b) published stump diameter/d.b.h. relationships for white pine, American beech, northern red oak, sugar maple, yellow birch, yellow-poplar, pitch pine, and white oak. Since the 1950's, additional research in the Northeast has been limited to a single estimator of several northern hardwood species grouped together (Nyland 1977).

The relationships between stump diameter and d.b.h. should not change much over time, but there has been some recent interest in using them for a wider range of species, especially the high-value species. For this reason, I have developed equations that predict d.b.h. based on stump diameter for 17 of the major northeastern tree species.

Data Collection

The data were taken from utilization plots in 14 northeastern states (Connecticut, Delaware, Kentucky, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Ohio, Pennsylvania, Rhode Island, Vermont, and West Virginia). The plots are used to relate timber volume output to timber inventory at private logging operations. Between 1969 and 1979, more than 7,000 trees were measured.

Tree species, stump diameter, and d.b.h. measurements were obtained for all trees on the utilization plots. Diameter at breast height was taken 4½ feet above the ground on the uphill side with a diameter tape, and measured to the nearest 0.1 inch. After the tree was harvested, stump diameter inside the bark was taken across the axis of the butt log on cylindrical logs, or averaged across the largest and smallest diameters on irregularly shaped logs. Stump diameter was measured to the nearest 0.1 inch and ranged from 2.1 inches to 48.5 inches (Table 1). No stump heights were measured.

Table 1.—Range of stump diameters, in inches, for 17 northeastern tree species

Species	Range of stump diameters
Spruce and fir	4.7-22.8
Southern hard pines[a]	3.8-26.0
Northern hard pines[b]	2.4-18.8
Eastern white pine	5.1-33.0
Eastern hemlock	5.9-26.5
Other softwoods	2.1-24.1
Red maple	3.5-38.5
Sugar maple	4.5-42.7
Birch and elm	4.6-34.0
Hickory	4.9-35.7
Beech	6.2-42.8
Ash, aspen, and basswood	5.3-38.8
Yellow-poplar	6.4-45.5
Black cherry	6.1-34.0
White oak	4.0-43.0
Red oak	5.6-48.5
Other hardwoods	2.7-36.8

[a]Includes loblolly, shortleaf, pond, and virginia pine.
[b]Includes pitch and red pine.

Equation Development

The equations were developed by using simple linear regression because the simple linear models are as reliable as the more complex models in predicting d.b.h. from stump diameter (Bylin 1982). The form of the equation used is $y = a + bx$; where y is the predicted d.b.h. in inches and x is the stump diameter (inside the bark) in inches.

The trees were initially grouped to represent species most commonly harvested throughout the Northeast. Some of the species with small sample sizes were combined with species with similar equations (not significantly different at the 0.05 level of significance). The result was a group of 17 northeastern species (Table 2).

Sometimes it is difficult to identify the species from only the stump. In these instances, a general softwood or hardwood equation can be useful. Therefore, I developed a second set of equations that grouped all of the softwood species together and all of the hardwood species together (Table 3).

Application and Reliability

To use these equations, the species or species group must be identified (softwood or hardwood if species is unknown), and stump diameter must be measured to the nearest 0.1 inch inside the bark. On irregularly shaped stumps, it is sometimes necessary to take more than one diameter measurement. Where the stump is fluted or flared, measurements should be taken across the widest and narrowest diameters, and then averaged. It is not necessary to measure the height of the stumps. Once the stump diameter is measured, d.b.h. can be predicted. For example, the predicted d.b.h. for a spruce tree with a 14-inch stump diameter measured in the future would be:

$$y^\circ = 0.96596 + (0.79667)(14.0)$$
$$= 12.1 \text{ inches}$$

Knowing the prediction interval is as important as being able to predict the d.b.h. based on the stump diameter, especially where there is a legal question. The variance of the predicted d.b.h. gives a range to judge the value of timber loss. With the values from Tables 2 and 3, the prediction interval can be calculated by:

$$v(y^\circ) = s^2\left(1 + \frac{1}{n} + \frac{(x^\circ - \bar{x})^2}{CSS}\right)$$

where s^2 = mean square error of the sample
n = number of observations in the sample
x° = stump diameter to be measured in the future
$\bar{x}$ = mean stump diameter of the sample
CSS = corrected sum of squares of $x = ns^2(x)$

For a 14-inch stump diameter, the variance around the expected d.b.h. would be:

$$v(y^\circ) = 1.03742 \times \left(1 + \frac{1}{337} + \frac{(14.0 - 11.8)^2}{3{,}445.6}\right) = 1.04$$

Table 2.—Equation coefficients and descriptive statistics for predicting d.b.h. from stump diameters for northeastern tree species

General form of the equation: y = a + bx; where y = d.b.h. in inches and x = stump diameter in inches (inside bark)

Species group	Species	Coefficients a	Coefficients b	Number of observations n	Mean square error s^2	Mean stump diameter $\bar{x}$	Corrected sum of squares CSS	Coefficient of determination r^2
1	Spruce and fir	0.96596	0.79667	337	1.03742	11.8	3,445.6	0.863
2	Southern hard pines[a]	.28124	.91555	771	.79494	12.0	10,629.3	.936
3	Northern hard pines[b]	−.80166	1.00648	262	.88401	9.6	2,468.6	.916
4	Eastern white pine	.31469	.89376	593	1.48222	15.8	14,545.9	.930
5	Eastern hemlock	.11001	.93799	166	.93607	14.6	3,415.0	.951
6	Other softwoods	.28116	.82265	244	.83069	8.6	2,579.0	.897
7	Red maple	.14487	.93115	317	1.80608	13.5	7,950.8	.924
8	Sugar maple	.80040	.88053	681	1.74577	15.5	15,622.7	.911
9	Birch and elm	−.46354	.93169	306	2.38329	14.4	6,017.7	.878
10	Hickory	−.12857	.89882	211	1.38766	16.3	5,419.9	.938
11	Beech	.90346	.83463	418	1.95408	15.3	14,076.3	.923
12	Ash, aspen, and basswood	2.31037	.79467	286	2.23919	17.2	6,598.2	.868
13	Yellow-poplar	.73063	.88267	365	2.69833	18.1	10,420.8	.892
14	Black cherry	.59477	.92565	141	3.32100	16.3	5,067.5	.904
15	White oak	1.44718	.78919	735	2.88608	17.8	25,951.7	.884
16	Red oak	.97470	.82015	1,061	2.65736	19.5	38,690.2	.902
17	Other hardwoods	.45665	.88839	159	2.12453	17.2	7,327.0	.945

[a]Includes loblolly, shortleaf, pond, and virginia pine.
[b]Includes pitch and red pine.

Table 3.—Equation coefficients and descriptive statistics for predicting d.b.h. from stump diameters for general species groups based on northeastern tree species

General form of the equation: y = a + bx; where y = d.b.h. in inches and x = stump diameter in inches (inside bark)

Species group	General Species	Coefficients a	Coefficients b	Number of observations n	Mean square error s^2	Mean stump diameter $\bar{x}$	Corrected sum of squares CSS	Coefficient of determination r^2
1	Softwoods	0.03796	0.91308	2,373	1.15667	12.5	50,668.8	0.939
2	Hardwoods	1.08806	.83487	4,680	2.58726	17.0	159,664.0	.902

The 95-percent confidence interval for a predicted d.b.h. value would be approximately $y^{\circ} \pm 2v(y^{\circ})^{1/2}$. Therefore, the spruce stump measuring 14.0 inches in diameter would be expected to have a d.b.h. of 12.1 inches, but its d.b.h. could be as high as 14.1 inches or as low as 10.1 inches at two standard deviations $(12.1 \pm 2(1.04)^{1/2})$.

Once d.b.h. is estimated, tree volume likewise can be estimated. Local volume tables can be used to determine volume from d.b.h. measurements, but such tables may be unavailable. Standard volume tables should then be used, but average heights must be taken from trees left standing in the surrounding area because standard volume tables usually require that both d.b.h. and height be known.

Limitations

No stump heights were measured, so the equations represent the stump diameter/d.b.h. relationships for average stump heights in the Northeast. USDA Forest Service standards normally assume a 1-foot stump height, but this may vary in actual practice. The equations presented here should be used where trees were harvested by conventional methods close to a 1-foot stump height, or where equations for the desired species are unavailable. In other situations, equations or tables that include stump height may be more appropriate.

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