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Estimating Northern Red Oak Site-Index Class from Total Height and Diameter of Dominant and Codominant Trees in Central Appalachian Hardwood Stands

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Abstract

Northern red oak site-index (SI) class is estimated using height and diameter of dominant and codominant trees for five Appalachian hardwood species. Methods for predicting total height as a function of diameter are presented. Because the total height of 4- and 6-inch trees varies less than 5 feet for the three northern red oak SI classes, use trees that are at least 8 inches in d.b.h. when estimating site class.

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Introduction

Determining site quality is one of the first steps in managing forest land. Once site quality is known, growth of wood products can be estimated and various forest management practices evaluated. For eastern hardwoods, the generally accepted method for estimating site quality is site index (SI) based on the 50-year height growth of dominant and codominant trees (Carmean 1975; Schnur 1937). Yield tables for managed and unmanaged stands have been developed for most of the hardwood forest types (Gingrich 1971; Leak and Filip 1970). Northern red oak (*Quercus rubra* L.) is one of the most widely used eastern hardwood SI species because it occurs over much of the eastern hardwood region and is found over a relatively wide range of site quality within most forest types (Fowells 1965).

Site index based on height over age has been determined for several upland hardwood species. But difficulties arise in determining the age of trees. Hardwoods are difficult to bore and the pith often is missed because of unsymmetrical radial growth. Also, slow-growing trees are difficult to age without magnification.

To avoid the problem of determining age, Stout and Shumway (1982) and Reinhardt (1983) described methods of estimating SI using height and diameter of dominant and codominant trees. This paper reports height/diameter relationships for five central Appalachian species and explains how to use height and diameter of dominant and codominant trees to estimate northern red oak SI class.

Methods

Fifty-six even-aged stands 20 to 80 years old were selected for study. All stands were located in north-central West Virginia within 25 miles of Parsons. Stand size ranged from 5 to 15 acres. Site index was estimated using height/age relationships of northern red oaks present in each stand (Schnur 1937). Within each stand, 10 to 60 dominant or codominant northern red oak, red maple (*Acer rubrum* L.), sugar maple (*Acer saccharum* Marsh.), yellow-poplar (*Liriodendron tulipifera* L.), or black cherry (*Prunus serotina* Ehrh.) trees that showed no outward signs of suppression or damage from fire, insects, or disease were selected for study.

Total height and diameter at 4.5 feet (d.b.h.) were measured on 2,550 study trees. Height was measured using a telescopic measuring pole or Relaskop. Diameter ranged from 3.0 to 38.1 inches and total height ranged from 15 to 115 feet.

Data on tree height and diameter were grouped by 10-foot-stand northern red oak SI class: 60 for 56 to 65 feet, 70 for 66 to 75 feet, and 80 for 76 to 85 feet.

Following Stout and Shumway (1982), data for each species/site index group were fitted to the equation:

$$\text{Ln}(H) = \text{Ln}(4.5 + a(1 - \text{EXP}(-bD)))$$

where H = total height
D = diameter at breast height (4.5 feet)
a = coefficient for the asymptote
b = slope coefficient
Ln = napierian logarithm

Results and Discussion

Asymptote and slope coefficients are shown in Table 1. Standard errors for the asymptote coefficients ranged from 1.613 to 13.460; for slope coefficients, standard errors ranged from 0.003 to 0.018.

These equations were used to estimate total height of dominant and codominant trees by 2-inch diameter class for each 10-foot SI class and species (Table 2).

Using the measured height and diameter, Table 2 was then used to assign each of the original 2,550 trees an SI class. The proportion of trees classified correctly is shown in Table 3. For simplification, the diameter classes are combined into three groups. About two-thirds of the trees were classified correctly as the classification improved with increasing diameter.

It is common to determine height and age of trees to estimate site index. When standing trees are used, workers commonly use an increment borer to extract a core and then count annual rings to obtain the age. Difficulties arise when the core does not include the pith because the tree is too large or unsymetrical. Also, it is difficult to detect annual rings of species such as sugar maple, or to count annual rings of slow-growing trees. Such difficulties are eliminated when total height and diameter are used to estimate SI class.

The use of height/diameter curves to estimate SI probably is accurate only when only dominant or codominant trees are used and SI is estimated to the nearest 10-foot class. This method should not be used with trees of lower crown classes or used to estimate SI in smaller than 10-foot classes.

When using Table 2, SI should be estimated to the nearest 10-foot class because the data used to compute the regression were grouped by 10-foot SI class. For example, if a codominant red oak tree is 14 inches d.b.h. and 80 feet tall, the estimated northern red oak SI class would be 70 feet.

Table 1.—Number of trees measured, values of asymptote (a) and slope (b) coefficients, and associated standard errors

Species	Site-index class	No. of trees measured	a	SE	b	SE
Red oak	60	203	79.450	1.613	0.137	0.005
	70	394	93.331	1.678	0.109	0.005
	80	212	111.848	2.030	0.098	0.004
Yellow-poplar	70	189	129.736	6.378	0.070	0.004
	80	433	148.125	3.686	0.066	0.003
Black cherry	60	43	76.175	3.986	0.151	0.012
	70	293	109.481	2.756	0.089	0.003
	80	320	128.483	3.739	0.077	0.003
Sugar maple	70	73	98.498	4.533	0.010	0.008
	80	145	112.150	3.651	0.087	0.005
Red maple	60	160	75.454	3.134	0.140	0.009
	70	48	89.130	6.747	0.129	0.018
	80	37	140.296	13.460	0.065	0.008

Table 2.—Estimated total height of dominant and codominant trees by diameter class, species, and northern red oak SI class (coefficients are from Table 1)

D.b.h. class (inches)	Red oak			Yellow-poplar		Black cherry			Sugar maple		Red maple		
	SI 60	SI 70	SI 80	SI 70	SI 80	SI 60	SI 70	SI 80	SI 70	SI 80	SI 60	SI 70	SI 80
	Feet												
4	38	37	41	36	39	39	37	38	37	38	37	40	37
6	49	49	51	49	53	50	50	52	49	50	47	52	50
8	57	59	65	60	66	58	60	63	59	61	55	62	61
10	64	66	74	70	77	64	69	73	67	70	61	69	72
12	69	72	82	79	86	68	76	82	73	77	66	75	80
14	72	77	88	86	94	71	83	89	79	84	69	79	88
16	75	81	93	92	102	74	88	95	83	89	72	82	95
18	77	85	97	98	108	76	92	101	87	93	74	85	101
20	79	87	101	103	114	77	96	105	90	97	75	87	107
22	80	89	103	107	118	78	99	109	92	100	76	88	111
24	81	91	106	110	123	79	101	113	94	103	77	90	115
26	82	92	108	113	126	79	103	115	96	105	78	90	119
28	83	93	109	116	130	80	105	118	97	107	78	91	122
30	83	94	110	119	133	80	106	120	98	109	79	92	125

Table 3.—Proportion of correctly classified trees of five Appalachian hardwood species (values are from Table 2)

Species	D.b.h. group[a]	No. of observations	% of trees classified correctly
Red oak	1	275	55
	2	231	53
	3	303	58
Yellow-poplar	1	267	64
	2	189	67
	3	166	68
Black cherry	1	381	44
	2	191	54
	3	84	73
Sugar maple	1	101	50
	2	52	65
	3	65	68
Red maple	1	164	53
	2	68	49
	3	13	62

[a] 1 = 4 to 8 inches; 2 = 10 to 16 inches; 3 = 18+ inches.

The height/d.b.h. formulae shown in Table 1 will be useful in estimating volume as a function of diameter and total height (Martin 1981). This should aid in the development of growth and yield models for mixed Appalachian hardwood stands where tree species and d.b.h. are observed and total height is estimated.

There is little variation in the estimated height of small trees. For example, the total height of trees 4 inches d.b.h. ranges from 36 to 41 feet for the five species across the three site classes (Table 2). Similarly, total height for 6-inch trees ranges from 47 to 53 feet. Therefore, to estimate site class using these data, use trees at least 8 inches d.b.h. The larger the trees, the more accurate will be the estimated site class.

Dominant and codominant red oak, black cherry, and red maple trees will be about 9 inches d.b.h. at stand age 50 on SI class 60 areas (Table 2). Dominants and codominants at stand age 50 average about 10 inches d.b.h. on SI class 70 areas and about 11 inches d.b.h. on SI class 80 areas. These are reasonable values for stands in the central Appalachian hardwood region.

Literature Cited

Carmean, W. H. 1975. **Forest site quality evaluation in the United States.** Advances in Agronomy. 27: 209–269.

Fowells, H. A., compiler. 1965. **Silvics of forest trees of the United States.** Agric. Handb. 271. Washington, DC: U.S. Department of Agriculture. p. 588–592.

Gingrich, Samuel F. 1971. **Management of young and intermediate stands of upland hardwoods.** Res. Pap. NE–195. Upper Darby, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 26 p.

Leak, William B.; Filip, Stanley M. 1970. **Cutting strategies and timber yields.** Res. Pap. NE–153. Upper Darby, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 19 p.

Martin, A. Jeff. 1981. **Taper and volume equations for selected Appalachian hardwood species.** Res. Pap. NE–490. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 22 p.

Reinhardt, Elizabeth. 1983. **Using height/diameter curves to estimate SI in old-growth western larch stands.** Res. Note 20. Missoula, MT: Montana Forest and Conservation Experiment Station, School of Forestry, University of Montana. 4 p.

Stout, Benjamin B.; Shumway, Durland L. 1982. **Site quality estimation using height and diameter.** Forest Science. 28(3): 639–645.

Schnur, G. Luther. 1937. **Yield, stand, and volume tables for even-aged upland oak forests.** Tech. Bull. 560. Washington, DC: U.S. Department of Agriculture. 87 p.

Lamson, Neil I. 1987. **Estimating northern red oak site-index class** from total height and diameter of dominant and codominant trees in central Appalachian hardwood stands. NE–RP–605. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 3 p.

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