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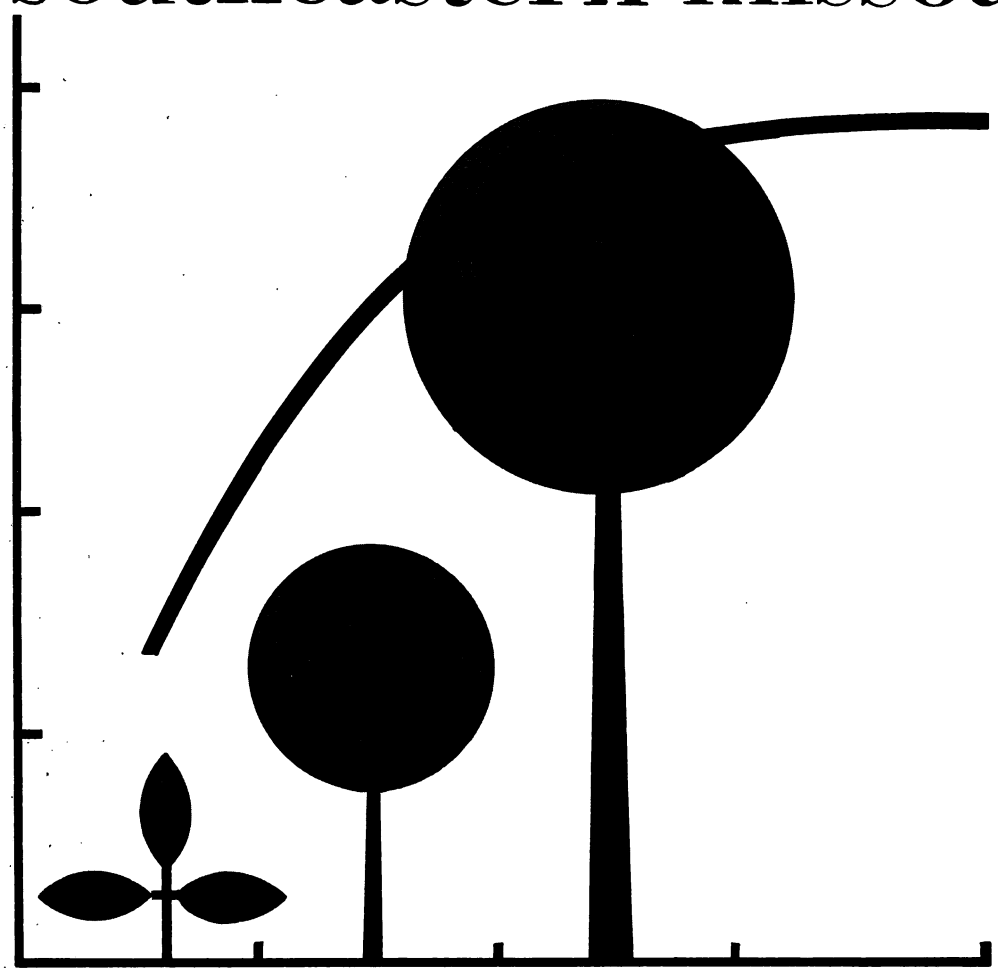
site index prediction table for black, scarlet, & white oaks in southeastern missouri



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SITE INDEX PREDICTION TABLES FOR BLACK, SCARLET, AND WHITE OAKS IN SOUTHEASTERN MISSOURI

Robert A. McQuilkin

APPLICATION

Site index prediction tables were prepared for black, scarlet, and white oak from stem analyses of 741 sectioned trees. These tables were specifically designed to predict site index given tree height and age, and thus differ from conventional site index curves, which show height growth by age and site index.

Confidence intervals, derived from the same data, show the range within which the true mean stand site index is expected to fall for the number of trees measured, the age of the trees, and the probability level.

To estimate the site index of an even-aged oak stand:

1. Delineate a stand that is relatively uniform in site index and tree age.

2. Determine the number of sample trees needed for the desired precision from table 1 or 2.

3. Select as sample trees only straight, undamaged dominant or codominant trees that show no sign of past suppression.

(Sample trees should be similar in age (i.e., differences less than 5 years) to the trees immediately surrounding them. Current research shows that trees older or younger than those around them have different height growth patterns and thus indicate erroneous site indexes. These age differences are sometimes difficult to detect without increment borings because, unless the age differences are large, the trees tend to be similar in size and appearance to the surrounding trees. To ensure that they are similar in age to the trees around them, sample trees should be taken in randomly located groups of 2 or 3. Age differences *between groups* are not important.)

4. Measure tree height and breast-height age; add 2 years to breast-height age to get total age.

5. Keep sample trees separate by the three species; if all sample trees are of one species, calculate the average height and age and read the site index from table 3 or 4. If the sample trees are of more than one species, conversions should be made and all site indexes expressed as equivalent site index of one species before averaging. For most areas, black oak is the best standard site index species to use. Conversions between species may be made as follows:

Black oak SI = Scarlet oak SI - 3.
Scarlet oak SI = Black oak SI + 3.
Black oak SI = White oak SI + 4.
White oak SI = Black oak SI - 4.

Table 1.--*Confidence intervals for stand site index estimates from 3-, 5-, 10-, and 20-tree measurements at the 90 and 95 percent probability levels for black and scarlet oak at ages 10 to 80 years*

n	Age (years) 10	20	30	40	50	60	70	80
90 PERCENT PROBABILITY								
3	±12	±10	±8	±6	±4	±5	±7	±7
5	±7	±5	±4	±3	±3	±3	±4	±4
10	±4	±3	±3	±2	±2	±2	±2	±2
20	±3	±2	±2	±1	±1	±1	±2	±2
95 PERCENT PROBABILITY								
3	±17	±14	±12	±8	±7	±8	±10	±11
5	±9	±7	±6	±4	±3	±4	±5	±5
10	±5	±4	±3	±2	±2	±2	±3	±3
20	±3	±3	±2	±2	±1	±1	±2	±2

Table 2.--*Confidence intervals for stand site index estimates from 3-, 5-, 10-, and 20-tree measurements at the 90 and 95 percent probability levels for white oak at ages 10 to 80 years*

n	Age (years) 10	20	30	40	50	60	70	80
90 PERCENT PROBABILITY								
3	±9	±8	±7	±5	±4	±5	±6	±5
5	±5	±5	±4	±3	±2	±3	±3	±3
10	±3	±3	±2	±2	±1	±2	±2	±2
20	±2	±2	±2	±1	±1	±1	±1	±1
95 PERCENT PROBABILITY								
3	±14	±12	±10	±8	±6	±7	±9	±8
5	±7	±6	±5	±4	±3	±4	±4	±4
10	±4	±4	±3	±2	±2	±2	±2	±2
20	±3	±2	±2	±1	±1	±1	±2	±1

The confidence intervals (tables 1 and 2) show the range within which the true (but unknown) mean stand site index is expected to fall at the given probability level. For example, if the average height of five 30-year-old white oak trees is 38 feet, the estimated site index is 55 feet (table 4), and the 90 percent confidence interval is ± 4 feet (table 2). Thus the true mean stand site index is expected (with a 90 percent probability) to fall within the range 55 ± 4 feet, but may (with a 10 percent probability) fall above or below this range.

Caution must be exercised in predicting site indexes based on very young trees because of the great variation in tree heights at young ages. This variability is shown in the confidence intervals of tables 1 and 2.

Table 3.--*Black and scarlet oak site index estimates by 2-foot height and 2-year age intervals*[1]

Age	Height (feet)																																									
(years)	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50	52	54	56	58	60	62	64	66	68	70	72	74	76	78	80	82	84	86	88	90	92
10		55	57	59	61	63	64	66	68	70	72																																
12			54	56	58	60	62	63	65	67	69	71																															
14				53	55	57	59	61	62	64	66	68	70	72	74																												
16					52	54	56	58	60	62	63	65	67	69	71	73	75																										
18						51	53	55	57	59	60	62	64	66	68	70	72	74	76	78																							
20							50	52	54	56	58	60	61	63	65	67	69	71	73	75	77	79																					
22								49	51	53	55	57	59	61	63	65	67	69	71	73	75	77																					
24									48	50	52	54	56	58	60	62	64	66	68	70	72	74	76	78																			
26										48	50	52	54	56	58	60	62	64	66	68	70	72	74	76	78																		
28										45	47	49	51	53	55	57	59	61	63	65	67	69	71	73	76																		
30											45	47	49	51	53	55	57	59	61	63	65	67	69	71	73	75	77																
32												45	47	49	51	53	55	57	59	61	63	65	67	69	71	73	75	77															
34													45	47	49	51	53	55	57	59	61	63	65	67	69	71	73	75	77														
36													42	45	47	49	51	53	55	57	59	61	63	65	67	69	71	73	75	78													
38														42	44	47	49	51	53	55	57	59	61	63	65	67	69	71	74	76	78												
40															42	44	47	49	51	53	55	57	59	61	63	65	67	70	72	74	76	78											
42																43	45	47	49	51	54	56	58	60	62	64	66	68	70	72	74	76	78	80									
44																	44	46	48	50	52	54	56	58	60	62	64	67	69	71	73	75	77	79	81								
46																	43	45	47	49	51	53	55	57	59	61	63	65	67	69	71	73	75	77	79	81							
48																		43	45	47	49	51	53	55	57	59	61	64	66	68	70	72	74	76	78	80	82						
50																			44	46	48	50	52	54	56	58	60	62	64	66	68	70	72	74	76	78	80	82					
52																				45	47	49	51	53	55	57	59	61	63	65	67	69	71	73	75	77	79	81					
54																				44	46	48	50	52	54	56	58	60	62	64	66	68	70	72	74	75	77	79	81				
56																				43	45	47	49	51	53	55	57	59	61	63	65	67	68	70	72	74	76	78	80				
58																					44	46	48	50	52	54	56	58	60	62	63	65	67	69	71	73	75	77	79	81			
60																					44	45	47	49	51	53	55	57	59	60	62	64	66	68	70	72	74	75	77	79			
62																					43	45	47	48	50	52	54	56	58	60	61	63	65	67	69	71	73	74	76	78	80		
64																					42	44	46	48	50	51	53	55	57	59	61	62	64	66	68	70	71	73	75	77	79		
66																						43	45	47	49	51	52	54	56	58	60	61	63	65	67	69	70	72	74	76	78	79	
68																						43	45	46	48	50	52	53	55	57	59	61	62	64	66	68	69	71	73	75	76	78	
70																						42	44	46	47	49	51	53	54	56	58	60	61	63	65	67	68	70	72	74	75	77	78
72																						42	44	46	47	49	51	52	54	56	57	59	61	62	64	66	68	69	71	73	74	76	78
74																							44	45	47	49	50	52	54	55	57	59	60	62	64	65	67	68	70	72	73	75	77
76																							43	45	47	48	50	52	53	55	56	58	60	61	63	64	66	68	69	71	73	74	76
78																								45	46	48	50	51	53	54	56	58	59	61	62	64	65	67	69	70	72	73	75
80																								45	46	48	49	51	52	54	55	57	59	60	62	63	65	66	68	69	71	72	74

1/ All height and age combinations in this table are within the range of the original black oak data; height and age combinations within the lines indicate the range of the original scarlet oak data.

Table 4.--*White oak site index estimates by 2-foot height and 2-year age intervals*[1/]

Age (years)	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50	52	54	56	58	60	62	64	66	68	70	72	74	76	78	80	82	84	86	88	90	92
10	46	49	52	54	57	60	62	65	68																																	
12	44	47	49	52	54	57	60	62	65	68																																
14		44	47	49	52	54	57	59	62	64	67	69																														
16			44	47	49	52	54	56	59	61	64	66	68	71																												
18				44	47	49	51	54	56	58	61	63	65	68	70																											
20					44	46	48	51	53	55	57	60	62	64	66	69																										
22					42	44	46	48	51	53	55	57	60	62	64	66	69	71																								
24						42	44	46	48	51	53	55	57	59	62	64	66	68	71																							
26							42	44	46	48	51	53	55	57	59	62	64	66	68	70																						
28								42	44	46	48	50	53	55	57	59	61	64	66	68	70																					
30									42	44	46	48	50	52	55	57	59	61	63	66	68	70																				
32									40	42	44	46	48	51	53	55	57	59	61	64	66	68	70																			
34										40	42	44	46	49	51	53	55	57	59	62	64	66	68	70																		
36											40	42	45	47	49	51	53	55	57	60	62	64	66	68	70																	
38												40	43	45	47	49	51	53	55	57	60	62	64	66	68	70																
40													41	43	45	47	49	51	53	55	58	60	62	64	66	68	70															
42													39	41	44	46	48	50	52	54	56	58	60	62	64	66	68	71														
44														40	42	44	46	48	50	52	54	57	59	61	63	65	67	69	71													
46														39	41	43	45	47	49	51	53	55	57	59	61	63	65	67	69	71												
48															39	41	43	45	47	49	52	54	56	58	60	62	64	66	68	70												
50															38	40	42	44	46	48	50	52	54	56	58	60	62	64	66	68	70											
52																39	41	43	45	47	49	51	53	55	57	59	61	63	65	67	69	71										
54																	40	42	44	46	48	50	52	54	56	58	60	62	63	65	67	69	71									
56																	39	41	43	45	47	49	51	53	55	56	58	60	62	64	66	68	70									
58																		40	42	44	46	48	50	51	53	55	57	59	61	63	65	67	68	70								
60																		39	41	43	45	47	48	50	52	54	56	58	60	61	63	65	67	69	71							
62																			41	42	44	46	48	49	51	53	55	57	58	60	62	64	66	67	69	71						
64																			40	42	43	45	47	49	50	52	54	56	57	59	61	62	64	66	68	69	71					
66																			39	41	43	44	46	48	49	51	53	54	56	58	59	61	63	64	66	68	70					
68																			39	40	42	44	45	47	49	50	52	54	55	57	58	60	61	63	65	66	68	69				
70																				40	41	43	45	46	48	49	51	52	54	55	57	58	60	62	64	65	66	68	69			
72																				39	41	42	44	46	47	49	50	52	53	55	56	58	59	61	63	64	66	67	69	70		
74																				39	40	42	43	45	47	48	50	51	53	54	56	57	59	61	62	64	65	67	68	70		
76																					40	41	43	45	46	48	49	51	52	54	55	57	58	60	62	63	65	66	68	69	71	
78																					39	41	42	44	46	47	49	50	52	53	55	56	58	59	61	63	64	66	67	69	70	
80																					39	40	42	43	45	47	48	50	51	53	54	56	57	59	60	62	64	65	67	68	70	71

[1/] All height and age combinations to the left of the line are within the range of the original data; combinations to the right of the line are extrapolations.

DOCUMENTATION

Site quality in even-aged oak stands is usually expressed as site index--the height of the dominant and codominant trees at age 50. Unless the trees are exactly 50 years old, making direct measurements of site index on standing trees requires an accurate method of determining past or future 50-year heights from heights at ages other than 50. This determination is normally made with site index curves, which show the height/age patterns of trees of various site indexes. Properly constructed, such curves do accurately show height growth patterns, but the use of these curves is not the most accurate method of determining site index. Because of this, we recently developed "site index prediction tables" for three oak species (black, *Quercus velutina* Lam.; white, *Q. alba* L.; and scarlet, *Q. coccinea* Muenchh.) in southeastern Missouri from measurements of several hundred trees. This is how we did it.

Tree Selection

All study trees were located on the Clark and Mark Twain National Forests. Of the 741 trees used, 399 were black oak, 276 were white oak, and 66 were scarlet oak.

Trees were chosen from well stocked, even-aged, second growth oak-hickory and oak-pine stands. The trees were dominants or codominants at least 50 years old and showed no growth suppression or damage by fire, insects, or disease. All trees were single-stemmed, although trees with acute-angle forks in the tops were accepted. The trees were located on upland sites that differed widely in soil and topographic characteristics.

Stem Analysis

The trees were felled and sectioned at 4- or 8-foot intervals from the stump to the top of the tree. Height above ground and the number of annual rings were determined at each cutting point.

Because tree age for site index determinations is usually measured at breast height, most study trees were also sectioned at 4-1/2 feet so the difference between total age and breast-height age could be determined. As a result, total age was reckoned to be breast-height age plus 2.

Age at each cutting point was determined by subtracting the ring count at that point from the total tree age. Height-age data for each tree were then plotted on a height/age graph from which the heights of the trees at 10-year intervals were determined.

These 10-year heights were then corrected for a slight inherent bias. The ring counts gave age at a specific height; however, the total height at a given age would be slightly greater than that shown because the cut presumably occurred somewhere in the middle of the height growth for that year. So, half the average annual height growth at that age was arbitrarily added to the 10-year heights to obtain corrected heights (Carmean 1972).

Statistical Analysis

Tree height/age/site index data can be analyzed by using height growth functions or site index prediction functions. These two methods produce basically different results, each of which is useful for a different purpose (Strand 1964).

Height growth functions (i.e., conventional site index curves), because of the way they are constructed, are best suited for determining future or past heights of trees of known site index. On the other hand, site index prediction functions are best suited for determining site index of trees of known height and age. Height growth functions have traditionally been used as site index predictors and, at ages near the index age, only small errors are introduced. At young ages, however, the errors introduced can be significant so site index prediction functions were used in this work.[1]

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[1] *Since this publication was prepared, an article has appeared which discusses this concept further: R. O. Curtis, D. J. DeMars, and F. R. Herman. Which dependent variable in site index-height-age regressions? For. Sci. 20: 74-87. 1974.*

Linear regressions of the form:

$$\text{Site Index} = b_0 + b_1 \text{ (height)}$$

were computed for ages 10 through 80 for each of the three species (Johnson and Worthington 1963). The regressions were then compared by covariance analysis; differences between the black and scarlet oak regressions were nonsignificant so the data for these two species were combined. The black-scarlet regressions were significantly different from the white oak regressions, however, so these two species-groups were kept separate (table 5). The results of these regressions (plus interpolations between equations) were then arranged in the site index prediction charts (tables 3 and 4).

Comparison of Site Index Among Species

Although height growth patterns of black and scarlet oaks of equal site index were similar, black and scarlet oaks growing together showed significant differences in their mean site indexes. Regression equations relating site indexes between these two species on 47, 1/5-acre plots were:

Scarlet oak site index = 6.25 + 0.9450 (black oak site index).

Black oak site index = 0.82 + 0.9439 (scarlet oak site index).

The R^2 for these equations was 0.89.

Because of the nature of regression analysis, these two equations are not identical and each one will predict site index only for the species on the left side of the equation from the known site index of the species on the right side. In spite of this seemingly contradictory nature, these equations are the most accurate for such site index conversions. A simplified equation (derived by bisecting the angle between the two regression lines) resulted in one equation (expressed here two ways) that could convert site indexes both ways between species:

Scarlet oak site index = 2.79 + 1.0006 (black oak site index).

Black oak site index = -2.79 + 0.9994 (scarlet oak site index).

Table 5.--*Statistics of the black-scarlet oak and white oak site index/height regressions for ages 10 to 80*

Age (years)	Number of trees	Intercept	Slope	R^2	Standard error
		BLACK-SCARLET OAK			
10	465	44.68	0.990	0.21	0.30
20	465	29.83	.989	.49	.24
30	465	16.75	1.006	.72	.18
40	465	4.76	1.045	.91	.10
60	272	-1.57	.939	.95	.11
70	145	-1.21	.869	.87	.24
80	44	3.24	.768	.75	.50
		WHITE OAK			
10	276	32.98	1.340	0.32	0.29
20	276	23.68	1.124	.48	.25
30	276	12.95	1.099	.74	.18
40	276	4.88	1.052	.92	.10
60	122	-1.61	.928	.93	.14
70	52	2.66	.775	.78	.33
80	34	-.15	.778	.85	.31

Further simplification can be made with little additional error by using the following approximation:

Scarlet oak site index = black oak site index + 3.

Black oak site index = scarlet oak site index - 3.

Similar analysis of black and white oak data from 67 plots showed significant differences in the mean site indexes. Regression equations relating these two species were:

Black oak site index = 12.49 + 0.8412 (white oak site index).

White oak site index = 3.19 + 0.8876 (black oak site index).

The R^2 for these equations was 0.75. Simplification of these two equations similar to that done for the black-scarlet oak data resulted in a single equation for converting black and white oak site indexes both ways:

Black oak site index = 5.02 + 0.9737 (white oak site index).

White oak site index = 5.15 + 1.0270 (black oak site index).

Conversion can be further simplified with little additional error by using the approximation:

Black oak site index = white oak site index + 4.

White oak site index = black oak site index - 4.

Scarlet and white oak occurred together on only three plots, so no comparisons could be made between these two species. The species-site index comparisons agree generally with similar published comparisons from other oak regions (Nelson and Beaufait 1956, Trimble and Weitzman 1956, Doolittle 1958, and Olson and Della-Bianca 1959).

Comparison of Site Index Curves

These Missouri site index prediction tables were compared with the height growth curves of Schnur (1937) and Carmean (1971) over a wide range of heights and ages. As expected, for ages of about 50 years all three curves predicted similar site indexes for given heights and ages. At ages 10 and 20 however, differences in predicted site index were as much as 26 and 11 feet, respectively, between the Missouri site index prediction tables and the two regional height growth curves.

Analyzing the data by Heger's method (1968) (i.e., regressions of height on site index producing conventional height/age site index curves) showed that differences in tree height-growth patterns exist between the southern Missouri trees and those represented by either of the two regional curves, although the Missouri white oak height-growth patterns closely paralleled the regional curves of Schnur (1937). Missouri white oak trees tended to grow somewhat faster than Carmean's trees (1971) up to 50 years of age, but much slower from 50 to 80 years. Missouri black and scarlet oaks tended to grow faster in height at ages less than 50 years and slower at ages more than 50 years than trees represented by both the Schnur (1937) and Carmean (1971) regional curves.

Computation of the Confidence Intervals

The site index confidence intervals (CI) were computed from the equation:

$$CI = \pm t s_{\bar{x}} .$$

The "t" was obtained from standard tables and was based on the chosen probability level and 2, 4, 9, or 19 degrees of freedom for the 3-, 5-, 10-, and 20-tree measurements, respectively. The $s_{\bar{x}}$ was obtained from the formula:

$$s_{\bar{x}} = \left[\frac{s^2_p + s^2_t}{n} \right]^{\frac{1}{2}},$$

in which n = the number of trees measured (3, 5, 10, or 20), s^2_p (plot variance) = the variance of site indexes of trees in relatively homogeneous even-aged stands, and s^2_t (tree variance) = the variance of the site index estimate for the specified height and age.

The s^2_p was obtained from 77 white oak and 48 black oak 1/5-acre plots. Three trees were sectioned on each plot and their site index determined as previously described. The s^2_p for each of the two species was then the average $\Sigma (SI-\overline{SI})^2/n-1$ of all the plots, and represented the variance of the actual site indexes in relatively uniform forest stands.

The s^2_t was the $s^2_{y.x}$ of the site index/height regressions and represented the variance in estimated site index for given heights and ages.

The confidence intervals (tables 1 and 2) should be interpreted as *minimum* intervals that would be encountered in normal field use. The s^2_p values were based on trees from small plots chosen for their apparent uniformity of tree growth and site index. Variation in site index over larger, less homogeneous areas would undoubtedly be greater. The confidence intervals were based on data from felled and sectioned trees from which precise height and age measurements could be made. Comparable measurements on standing trees would probably be less precise. The confidence intervals are strictly applicable only at the mean height of the trees used in each site index/height regression. The intervals increased slightly with increased deviation of height from the mean and were as much as 1/2 foot greater at height extremes for trees less than 20 years old. The increases were negligible, however, over a broad range of medium heights for trees more than 20 years old.

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