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APPLYING SITE-INDEX CURVES TO NORTHERN HARDWOODS IN NEW HAMPSHIRE

Abstract. Describes a new method for testing site-index curves. Study results indicate that Vermont site-index curves for yellow birch, paper birch, white ash, and sugar maple, and New York-Connecticut curves for red maple, can be applied satisfactorily in New Hampshire when used with certain precautions and corrections.

In both forest management and research, site index[1] has proved useful as a measure of site productivity. Site-index curves have been constructed for most of the commercial forest tree species. However, the shapes of these curves for a particular species may vary among geographic regions because of climatic, soil, or genetic differences. Therefore, available curves require testing before they can be applied outside the region where they were developed.

The study reported in this note was designed to determine the applicability of site-index curves developed for even-aged northern hardwood stands in Vermont (*Curtis and Post 1962*) to comparable stands in the White Mountains of New Hampshire. Curves developed by Hampf (*1965*), based on height-over-age data for red maple in New York and Connecticut, were also tested.

Field Methods

Height and age measurements were taken in even-aged northern hardwood stands 60 years or older throughout the White Mountain National Forest. These stands, selected over a range in elevation from 600 to 2,300 feet, showed no evidence of past cutting or any other drastic change that might have appreciably influenced stand development. From

[1] Height of dominant or codominant trees at a specified age—usually 50, 75, or 100 years.

one to three 1-acre plots were randomly located in each of 24 stands, providing a total of 40 plots.

One sample tree was selected for each of five species, as available, on each plot. This provided 34 yellow birch (*Betula alleghaniensis* Britton), 23 paper birch (*B. papyrifera* Marsh), 15 white ash (*Fraxinus americana* L.), 28 sugar maple (*Acer saccharum* Marsh), and 18 red maple (*A. rubrum* L.). The ages of the 118 trees sampled ranged from 60 to 159 years. The samples were restricted to trees that were dominant or codominant, free from injury and disease, and not visibly suppressed in past growth as evidenced by annual ring widths at breast height.

After felling, each stem was cut in cross section at breast height and six other points at roughly equal intervals up the stem. It was assumed that each cut would be made through the middle of the annual height growth; thus age at each section was found by counting the central ring as ½ year and the remaining rings as 1 year (ring count at the tip is zero). The number of years required to grow from breast height to each higher section point was determined by subtracting the age at a given section point from the age at breast height. Height measurements from the ground to each section point and to the top of the tree were taken to the nearest 1/10 foot.

Analysis

For each sample tree, total height (from the ground to the section point) was plotted over age (section age subtracted from breast-height age), and the points were connected by straight lines. This method of fitting a curve considerably reduces the bias associated with free-hand methods, and it also preserves much of the variation existing in the observed values that would have otherwise been lost by fitting a smooth curve with regression.

Observed site index for each sample tree was determined by using total height to the nearest foot at breast-height age 50 for paper birch and red maple, and breast-height age 75 for yellow birch, sugar maple, and white ash. The appropriate Vermont or New York curve (corrected from total age to age at breast height) of the same site index and species was plotted for each tree sampled. Then the observed height-growth curve for each sample tree could be compared with the corresponding established site-index curve.

Several methods of comparing site-index curves have been used in the past. Standard tests of differences between regression coefficients, as

illustrated by Beck (*1962*), may be used, provided both the hypothesized and observed equations are of the same form and have been developed by standard regression techniques. Curtis (*1966*) used repeated measurements on sample plots to determine regression relationships between age and estimated site index. However, in addition to requiring that suitable remeasurement data covering an extended period of time be available, this method assumes that the repeated observations on the same plot are independent and thus amenable to analysis by standard regression techniques. Others have used a ratio of site index to average tree height for a given stand age, although this lacks the objectiveness of a statistical test (*Smith et al. 1960*).

In this study, the height differences between the sample tree height-over-age curve and the corresponding hypothesized Vermont or New York curve were taken at 20, 40, 60, and 80 years of age, and then expressed as a vector observation (D_1, D_2, D_3, D_4)—(more than four differences could have been taken if a closer expression of the form of the height curve were desired). Eighteen of the sample-tree curves had to be extrapolated a short distance to complete the vector observation at 80 years.

If the hypothesized site-index curves were similar to the sample-tree curves, the observed differences could be expected to approach a zero vector of (0, 0, 0, 0). Therefore, an appropriate test is the use of Hotelling's $T^2 = N\ (\overline{X} - \mu_0)'\ S^{-1}\ (\overline{X} - \mu_0)$, distributed as a non-central F with P and N — P degrees of freedom, where $\overline{X}$ is the mean vector of observed differences, μ_0 is the hypothesized (zero) vector, S is the sample covariance matrix, N is the number of samples (trees), and P is the number of measurements (4) per tree (*Anderson 1958*).

A separate comparison was made for each of the five species, including all trees (all site indices) for that species.

Results and Discussion

No significant differences were found between the Vermont curves and the sample-tree height relationships for yellow birch, paper birch, white ash, and sugar maple. However, a significant difference was revealed between the New York-Connecticut curves and the observed red maple heights.

Although all species except red maple showed non-significance, differences between the Vermont curves and observed tree heights were nearly significant for yellow birch. Mean height differences (table 1)

Table 1.—Mean height differences for five species found by subtracting site-index curve heights from the corresponding sample-tree curve heights

Site-index group (feet)	Trees	Mean age, years			
		20	40	60	80
	No.	*Feet*	*Feet*	*Feet*	*Feet*
			YELLOW BIRCH		
41-50	6	—4.57	—4.33	—1.58	0.72
51-60	11	—2.92	—2.12	—0.34	0.09
61-70	11	—2.64	—1.03	—1.19	0.65
71-80	6	—1.12	0.03	0.17	0.03
All	34	—2.80	—1.78	—0.75	0.37
			PAPER BIRCH		
41-60	9	—2.41	—0.84	0.87	2.06
61-80	14	—0.08	—0.06	0.34	0.63
All	23	—0.99	—0.37	0.55	1.19
			WHITE ASH		
61-80	6	—1.82	—1.95	—1.60	0.37
81-100	9	—0.54	—0.63	—0.03	0.26
All	15	—1.05	—1.16	—0.66	0.30
			SUGAR MAPLE		
41-50	5	—1.12	—0.96	—0.56	0.54
51-60	4	1.93	4.18	1.45	—0.58
61-70	6	—2.25	—0.85	—1.18	0.27
71-80	8	—3.67	—0.71	0.21	—0.40
81-90	5	1.40	3.44	1.66	—0.56
All	28	—1.20	0.65	0.21	—0.04
			RED MAPLE		
41-60	9	—4.90	—0.29	—0.99	—0.53
61-80	9	—2.37	1.07	—0.84	—0.51
All	18	—3.63	0.39	—0.92	—0.52

suggest that the Vermont site-index curves might appreciably underestimate site index when applied to young trees on poor sites. However, above 40 years of age on all sites, and above about 20 years of age on the better sites, the yellow birch curves appear to be reasonably accurate.

The major discrepancies between the observed heights of red maple and the corresponding site-index curves occurred at the 20-year age level. Although overall differences were significant for red maple, it appears that the New York-Connecticut curves can be used with acceptable accuracy at ages of 40 years or more.

When it is necessary to apply either the Vermont curves or the New York-Connecticut curves under situations described above where the

accuracy of the curves is in question, table 1 can be used to correct observed tree heights. Subtract the values in table 1 from the observed sample tree heights. Then use this corrected height to estimate site-index from the appropriate site-index curve. For example, if we had an estimate of average sample-tree height for a 20-year-old stand of yellow birch on a poor site (site-index 40-50), we would add (— (—4.57)) about 4.6 feet to the average sample tree height and then use this corrected value to obtain a more precise estimate of site index from the appropriate curve.

The results of this study indicate that the Vermont site-index curves for yellow birch, paper birch, white ash, and sugar maple and the New York-Connecticut curves for red maple can be applied in New Hampshire when used with the precautions and corrections described above.

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