NORTH CENTRAL FOREST EXPERIMENT STATION

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ESTIMATING SITE INDEX IN EVEN-AGED NORTHERN HARDWOOD STANDS

Gayne G. Erdmann, *Research Forester,*
and **Ralph M. Peterson, Jr.,** *Research Technician,*
North Central Forest Experiment Station,
Marquette, Michigan

ABSTRACT. — Describes two methods for improving site index estimates in diffuse porous even-aged northern hardwood stands.

KEY WORDS: Stem analysis, diffuse, porous, *Acer saccharum* Marsh., *Acer rubrum* L., *Betula alleghaniensis* Britton.

Foresters need to know how good their land is for growing trees. They can estimate the quality of a site by measuring the heights and ages of the dominant and codominant trees on it.

Common practice has been to measure a tree's age with an increment core and its height with a hypsometer. This practice has been useful for estimating ages of conifers and ring porous hardwoods, but has often led to misleading or imprecise results in diffuse porous hardwoods because annual growth rings are more difficult to distinguish. Foresters can increase the accuracy of these estimates and eliminate age and height measurement errors by using a different technique, stem analysis.

Here, we explain how to use stem analysis to estimate the site quality for even-aged, second-growth northern hardwood stands. We describe the field and office procedures to use in developing height-age curves for a specific site. These curves provide the best estimates of the site's quality, because they are based on the past growth of trees there.

We also present an easy way to improve site estimates from existing site curves.

DEVELOPING YOUR OWN TREE HEIGHT AGE CURVE

Select a Suitable Stand to Measure

Suitable stands are:

1. Even-aged with less than a 10-year age difference among the overstory trees (excluding residuals). Although stem analysis techniques can *only* be used to estimate site quality in even-aged stands, the information obtained can be applied to uneven-aged stands growing on comparable sites nearby.
2. Fully stocked with closed canopy.
3. Unaffected by excessive mortality caused by wind, insects, or disease; not disturbed by fire, grazing, or heavy thinnings from above since establishment.
4. At least 20 and preferably more than 50 years old measured at ground line. Site index estimates in younger stands are not as valid because of large variations in tree heights and growth rates in young stands.

5. Often composed of mixtures of hardwood species. The widely distributed sugar and red maples provide the best source of information for comparisons among northern hardwood species in the Lake States. However, when suitable maples are not present, reliable SI estimates can be obtained with other hardwood species.
6. At least 40 acres in size.

Choose high quality sample trees. They must be:

1. Dominants or strong codominants.
2. Above average diameter (considering all trees over 5 inches at breast height).
3. Single-stemmed — not from a sprout clump.
4. No more than 6 years old at breast height (free from evidences of past suppression).
5. Without serious insect, disease, and fire injuries. Don't use trees with rotten cores to determine age unless all rings are still evident.
6. At least their own height away from the influence of residual trees.
7. Straight, without crooks or pronounced lean.
8. Clean-stemmed, without many epicormic branches, bumps, dead branch stubs, or other surface defects. A few small surface wounds, bark scrapes, and scars are acceptable.
9. Full-crowned, without dead tops or large forks. Small (1 inch in diameter) correcting forks are permissible.

Fell, Measure, and Section Sample Trees

Horizontally mark selected trees (3 or more) at stump and breast height. Measure diameters and then record them on the stem analysis data form (fig. 1).

Figure 1.—*Sample stem analysis data form.*

Location: T47N, R25W, Sec. 36, NE1/4 of SW1/4 Date November 5, 1979

Compartment 5, Stand 3. Crew R. Oberg & R. Peterson

AGE COUNTS FROM CROSS-SECTIONAL DISKS

Tree 1 cc Codom Species Red maple			Tree 2 cc Codom Species Red maple			Tree 3 cc Condom Species Red maple		
1 Sectioning height above ground line	2 Tree age at section height	3 Number of rings counted	1 Sectioning height above ground line	2 Tree age at section height	3 Number of rings counted	1 Sectioning height above ground line	2 Tree age at section height	3 Number of rings counted
Feet	Years	Years	Feet	Years	Years	Feet	Years	Years
0(GL)	0	57	0	0	53	0	0	53
1-foot stump	1	56	1	1	52	1	1	52
4.5	4	53	4.5	3	50	4.5	3	50
9.3	9	48	9.3	8	45	9.3	7	46
17.6	16	41	17.6	12	41	17.6	12	41
25.9	21	36	25.9	17	36	25.9	19	34
34.2	25	32	34.2	24	29	34.2	25	28
42.5	33	24	42.5	32	21	42.5	32	21
50.8	41	16	50.8	36	17	50.8	38	15
59.1	48	9	59.1	44	9	59.1	45	8
67.4	54	3[1/]	67.4	51	2[1/]	67.4	50	2[1/]
Total Tree Height (feet)		68.2			69.2			69.2

HEIGHT AND AGE VALUES FROM INTERNODE MEASUREMENTS

Height	Age	Year[2/]	Annual leader growth	Height	Age	Year[2/]	Annual leader growth	Height	Age	Year[2/]	Annual leader growth
Feet	Years		Feet	Feet	Years		Feet	Feet	Years		Feet
68.2	57	0		69.2	53	0		69.2	53	0	
68.0	56	1	0.2	68.6	52	1	0.6	68.2	52	1	1.0
67.8	55	2	0.2	67.4	51	2	1.2	66.0	51	2	2.2
67.3	54	3	0.5	65.6	50	3	1.8	64.5	50	3	1.5
66.5	53	4	0.8	64.3	49	4	1.3	62.5	49	4	2.0
65.0	52	5	1.0	62.5	48	5	1.8	61.3	48	5	1.2
64.1	51	6	1.1	61.3	47	6	1.2				

Soil type fine sand Rousseau Aspect east Slope position: ridge, slope, (bottom,) cove (circle)
Slope steepness (%) 0-6 Total length of slope (feet) 1200
Slope shape: convex (linear), concave Distance to ridge (feet) _____

1/ Disk ring count overlaps annual leader growth measurements below.

2/ Year 0 represents tree total height at ground line at the end of the 1979 growing season; tree heights for preceding years are obtained by subtracting annual leader growth values from the previous years total tree height.

Carefully undercut the trees above stump height and fell them to avoid tip breakage, hang-ups, and splitting. Remove all limbs. If any broken stem sections cannot be accurately joined together, discard the entire tree. Next, mark sectioning points at ground line, 1 foot, 4.5 feet, 9.3 feet, and then at 8-foot intervals up the stem (column 1). Measure total tree height to the nearest tenth of a foot and record it before sectioning the tree.

Measure down from the tree's tip between apical bud scars to find the annual height growth during the last 6 to 10 years; record on the same form (fig. 1). Take care in identifying bud scars beyond the sixth growth period where they may be obscured by diameter growth. Beginning as near the ground line as possible, cut 1- to 2-inch disks at each of the sectioning points. Cut high enough to overlap the measurements between apical bud scars. The overlapping section serves as a check on ages in plotting individual tree height-growth curves. Label (with red grease pencil or crayon) each disk according to the stand, tree, and sectioning height where it was taken. (A suitable label might be: 3-2-4.5—a disk sampled in stand 3 from tree number 2 at 4.5 feet above ground line.) Be sure to record tree location, date of sectioning, crew members, tree number, crown position (as dominant or strong codominant), species, and other pertinent soil information on the stem analysis form. If you desire, collect other information such as Girard form class, merchantable stem lengths, and diameters inside and outside bark for volume determinations.

Counting the Rings

To help distinguish annual growth rings, use an electric planer or belt sander to smooth disk surfaces. Usually rings can be distinguished easily a few days after planing, but magnification, ample lighting, and staining (phloroglucinol in hydrochloric acid and Bismark brown stains) can be used to bring out growth rings on difficult disks. Record ring counts from disks taken at various sectioning points in column 3 on the stem analysis form (fig. 1). Count rings from the pith toward the perimeter of each disk and mark at 10-year intervals for easy checks. Take care to count every ring in periods of slow growth where they are closely spaced and avoid counting false (incomplete) rings.

Make Tree Height-Age Curves

Make a height-age curve for each sample tree (fig. 2) by plotting measured height (column 1) over the corresponding age (column 2) from the stem analysis data (fig. 1). Height is the distance in feet above ground line to a particular sectioning point; age is the number of years required for the tree to reach that point (or the difference between the tree's total age at ground line and the ring count (column 3) at that sectioning point). Then connect lines through the plotted height-age values for each sample tree height-age curve. Next compare the individual height growth patterns of all sample trees within the stand and discard trees that took more than 6 years to reach d.b.h. or that have grown irregularly because of top breakage or dieback.

After this, read heights at 5-year intervals and heights at the greatest common age from the height-age curves for each sample tree. Combine and average the data (table 1). Add a correction of one-half the average annual leader growth to each mean sectioning height to remove the bias caused by sectioning points not being cut exactly on the tips of terminal leaders. Obtain an average site index curve for your stand by plotting mean total height values over age values with the correction for bias added in table 1 and drawing a smooth freehand through the plotted values. Read your site index directly from the combined curve at index age 50 (65.0 in the example).

Some foresters prefer to fix d.b.h. height as the 0-age starting point, so they can save sample trees that suffered from early suppression but grew like free-growing trees after reaching breast height. This procedure brings all tree height-age curves to the same starting point. The average height-age curve is then determined and *then 4 years is added to the ring count at breast height to get total age.*

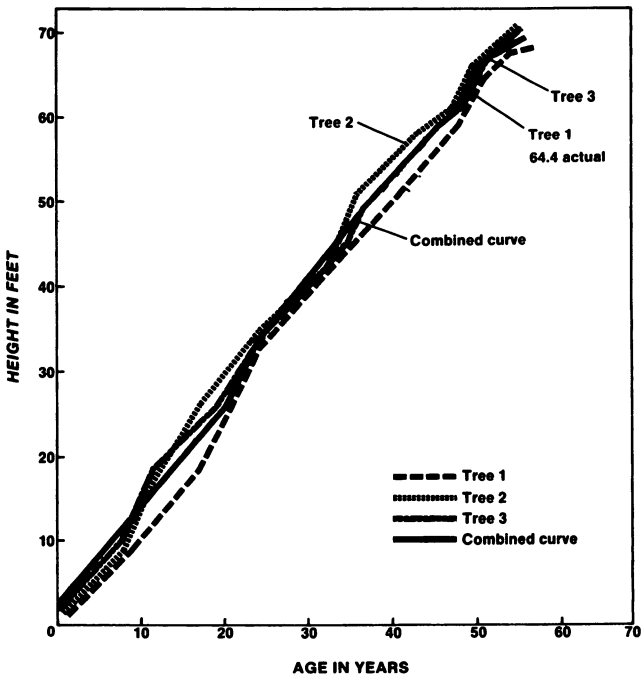

Figure 2.—*Height-age curves and a combined curve for three red maple trees.*

Table 1.—Red maple heights read from free hand sample-tree curves

(In feet)

Tree number	Total height at age (years)											
	5	10	15	20	25	30	35	40	45	50	53[1]	57[2]
1	5.2	10.2	16.4	24.3	31.4	38.3	44.6	50.2	55.9	63.0	66.5	68.2
2	6.0	13.4	22.5	29.4	35.3	40.6	48.3	55.0	59.8	65.6	69.2	
3	6.8	14.4	21.2	26.3	34.2	40.0	46.7	53.0	59.1	64.5	69.2	
Mean height	6.0	12.7	20.0	26.7	33.6	39.5	46.5	52.7	58.3	64.4	68.3[4]	
Correction to mean height[3]	0.6	0.6	0.7	0.6	0.6	0.6	0.6	0.6	0.5	0.6	[4]	
Mean height with correction added	6.6	13.3	20.7	27.3	34.2	40.2	47.1	53.3	58.8	65.0		

Mean leader growth by periods										
1-5	5-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45	46-50	51-53
1.0	1.2	1.3	1.2	1.3	1.1	1.3	1.1	1.0	1.1	1.3

[1] Height at greatest common age.
[2] Height of oldest tree.
[3] A correction of ½ the average annual leader growth is added to each mean sectioning height to remove the bias caused by sectioning points not being cut exactly on tips of terminal leaders.
[4] No correction is needed because total height measurements were taken from the apical bud tip down the stem between annual terminal bud scars.

Ideally, foresters should compare stand yields from different areas at rotation age so they can maximize returns on their investments or at least be able to identify their most productive areas and work on them first. High quality northern hardwood saw logs can be produced in about 75 to 80 years in managed even-aged stands growing on good sites in the Lake States. It would be better to develop your own curves in stands near rotation age than to use Carmean's (1978) curves, which are based on reference age 50 and are most accurate for stands between 35 and 65 years old.

DETERMINING SITE INDEX FROM EXISTING CURVES

Select 5 or more well formed trees from representative portions of older stands. Ten or more trees are needed in young (20- to 30-year-old) stands where growth is more irregular. Fell each sample tree carefully to avoid breaking the top or losing the tip. Measure the total tree height to the nearest foot. Cut a 1- to 2-inch cross-section (disk) from the tree at breast height and label it. Estimate total age by counting the rings on the disk and adding 4 years. Use Carmean's (1978) polymorphic site index curves to determine the site index for each tree and then calculate an average site index estimate for the stand. You can use Carmean's (1979) site index comparisons for estimating site indices of other species.

TECHNICAL REFERENCES

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