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Stocking, Growth, and Habitat Relations in New Hampshire Hardwoods

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Abstract

Data from hardwood stands in New Hampshire substantiated the crown-width relationships used to develop the B-line (based on circular crowns) in the 1969 northern hardwood stocking guide, and produced an A-line slightly lower than the original line. Position of the A-line was unrelated to site or forest type. Diameter growth of hardwoods on moist and dry soils declined rapidly with increasing tree diameter. On fine till, diameter growth was nearly constant over tree diameter but positively related to relative crown size. Based on diameter-growth regressions, calculations of stand growth indicated that the minimum basal area for adequate even-aged stand growth was quite low (30 to 60 square feet) and roughly constant over mean stand diameter.

Introduction

Stocking guides for even-aged stands have been developed for many of the forest types in the East, based upon work with crown areas in upland oaks (Gingrich 1967). These guides have been widely used in both practice and research. However, recent comparisons indicate that stocking levels recommended in certain of these guides do not correspond to the stocking limits implied by published growth studies (Leak 1981). Northern hardwoods and upland oaks produced full growth per acre at basal areas up to about 20 square feet below minimum stocking (the B-line), while white pine and red pine produced full growth only at basal areas well above the B-line. Possible reasons for these discrepancies are: (1) crown-area approaches may not adequately define stocking; (2) alternative definitions of crown or tree-area shapes (square versus circular) or the acceptable range in crown class (all trees taller than 4.5 feet versus trees in the main crown canopy); (3) differences in site or species composition might affect the influence of stocking or the nature of the growth response; and (4) relationships between growth and stocking might not be evident until stands are in a fully managed condition.

This study aids our understanding of these sources of discrepancy by providing information on stocking estimates, diameter-growth, and simulated growth per acre of free-to-grow trees as related to crown dimensions and forest type/habitat combinations.

Methods

A cluster of plots of three 10-factor prism points was located in 32 even-aged hardwood stands in the southern White Mountains of New Hampshire. As defined by the habitat classes (Leak 1980) recognized in the White Mountains, the sites were: (1) fine till soils (fine till habitat), (2) moist soils (wet compact, dry compact, and silty sediment habitats), (3) dry soils (coarse and fine washed till, and sandy sediment habitats), and (4) rocky soils (shallow-to-bedrock and loose rock habitats). The forest types were typical northern hardwoods (beech/sugar maple) on the fine soils, and beech/red maple/birch on the other three soils. Average stand diameters (main canopy) ranged from 1 to 14 inches (Table 1).

On each point, all trees were recorded by species, dbh, and canopy position (main crown canopy or suppressed). In addition, 2 or 3 dominant, essentially free-to-grow sample trees were selected on or near each plot cluster. Crown widths along the major and minor axes were measured on each sample tree, using a range pole leveling bubble to vertically project the edges of the crown. Species, dbh, and distance (bole to bole) to each competitor were recorded. A competitor was a tree in the main crown canopy touching the crown of the sample tree. An increment boring over the last 10 years of growth (except on trees younger than 10 at dbh) was taken on four sides (uphill, downhill, right, and left sides) of each sample tree at dbh.

Average diameter growth inside bark (ib) per tree over each of the last two 5-year periods was determined. Predicted diameter (ib) growth over the next 5-year period was determined by linear projection of the trend from the previous two 5-year periods. However, if the projected trend was upward (rather than level or declining), predicted diameter growth was taken as the diameter growth over the last measured 5-year period. (There were a few obviously undersized rings in the earliest 5-year period.) This procedure is conservative, and tends to capture the gradual declining trend in diameter growth usually evident in free-to-grow trees. We used predicted diameter growth instead of

Table 1.—Data characteristics, main crown canopy

Forest type	Soils	Plot Clusters	Range: Dbh	Range: Trees/acre	Sugar maple %	Sugar maple No.	Beech %	Beech No.	Red maple %	Red maple No.	Yellow birth %	Yellow birth No.	Paper birch %	Paper birch No.	Other %	Other No.
		No.	*In*	*No.*	%	*No.*	%	*No.*	%	*No.*	%	*No.*	%	*No.*	%	*No.*
Northern hardwoods	Fine till	7	1.8—13.7	118—3,231	25	9	31	5	2	—	12	5	14	4	16	—
Beech-Red Maple-Birch	Moist	7	1.2—10.2	167—4,506	1	—	9	1	37	6	15	3	27	7	11	—
Beech-Red Maple-Birch	Dry	14	1.6—12.5	126—3,424	1	—	40	9	23	8	5	3	24	12	7	—
Beech-Red Maple-Birch	Rocky	4	7.0—9.0	187—417	4	—	29	3	31	1	9	3	11	3	16	—

Percentage of species composition,[a] and no. of sample trees

[a] Percentage of species composition in terms of basal area in the main canopy.

past diameter growth because we wished to develop regressions that would be useful in predicting future growth. To do this, it is necessary either to use predicted future diameter growth or to attempt to recast the independent variables such as tree diameter, spacing, crown width, and so on.

A comparison of average past 5-year growth and future 5-year growth in diameter (ib), predicted as described above, showed a decline in growth of about 9 percent for paper birch and less for other species:

Species	*Past*	*Future*
	- - - - *Inches* - - - -	
Sugar maple	0.93	0.88
Beech	.90	.88
Yellow birch	.66	.64
Paper birch	.90	.82
Red Maple	.69	.64

In analyzing results of the study, 5-year growth in diameter (ib) was converted to diameter outside bark (ob) using double bark thickness data from New York (Belyea 1933).

Results

A-line

The upper limit of stocking in most eastern stocking guides is defined by the A-line, which is a fitted or constructed curve of basal area per acre over numbers of trees for essentially undisturbed stands. In developing the northern hardwood stocking guide (Solomon and Leak 1969), this curve was fitted to trees in the main crown canopy, but guides for certain other regions (for example, Roach 1977) emphasize the need to include all trees. A polynomial was used to fit the curve in both ways to the 32 cluster averages in this study:

$$BA(\text{all trees}) = 146.88 - 0.020963\,(\text{no. trees}) + 0.0000012\,(\text{no. trees})^2 \quad (1)$$

R = 0.73

Standard deviation = 23.3 (20.0% of mean)

$$BA(\text{main canopy}) = 116.72 - 0.027488\,(\text{no. trees}) + 0.000002219\,(\text{no. trees})^2 \quad (2)$$

R = 0.87

Standard deviation = 13.4 (13.7% of mean)

The fit was better using only the main canopy because groups of small trees occur sporadically in northern hardwood stands, causing added variation in both numbers of trees and basal area. In addition, use of all trees sometimes results in an unusually low mean stand diameter. A stand of sawtimber averaging 13 inches in the main crown canopy might have an average diameter of as little as 7 inches when all trees are measured.

Average deviations (1969 A-line minus equation 2 estimates) in basal area of the main canopy were similar for all forest type or soils classes:

Forest type	*Soils*	*Average deviation ft^2*
Northern hardwood	Fine till	+7.1
Beech/red maple/birch	Moist soils	+5.9
Beech/red maple/birch	Dry soils	+5.7
Beech/red maple/birch	Rocky soils	+7.2

Differences between the original A-line and the new data were significant (0.05 level) for all types or soils combined, based on comparisons within the range of the 1969 curve. However, the average differences are not large. The new curve tends to run lower than the original curve in the largest sizes (smaller tree numbers) only (Fig. 1).

B-line

In most eastern stocking guides, minimum stocking for full site utilization is defined by the B-line, which is a curve of basal area over number of trees. This curve is developed by defining the relationships between crown diameter and dbh of open-grown or dominant trees, calculating the area requirements of various sized trees, and finally determining the number and basal area of the trees that will fit on an acre of land.

In the present study, relationships of average crown diameter (feet) to dbh were developed for dominant trees of all five major species:

Sugar maple

$$CD = 4.9294 + 1.5548\,(dbh) \quad (3)$$
r = 0.99

Beech

$$CD = 3.9778 + 1.9948\,(dbh) \quad (4)$$
r = 0.98

Yellow birch

$$CD = 5.9087 + 1.8612\,(dbh) - 0.02545\,(dbh)^2 \quad (5)$$
R = 0.82

Paper birch

$$CD = 1.8194 + 2.1638\,(dbh) - 0.02328\,(dbh)^2 \quad (6)$$
R = 0.98

Red maple

$$CD = 6.9932 + 1.3900\,(dbh) \quad (7)$$
r = 0.81

Figure 1.—Curve of basal area over number of trees for undisturbed, even-aged northern hardwoods and beech/red maple/birch. Original A-line from the northern hardwood stocking guide (Solomon and Leak 1969) is shown for comparison.

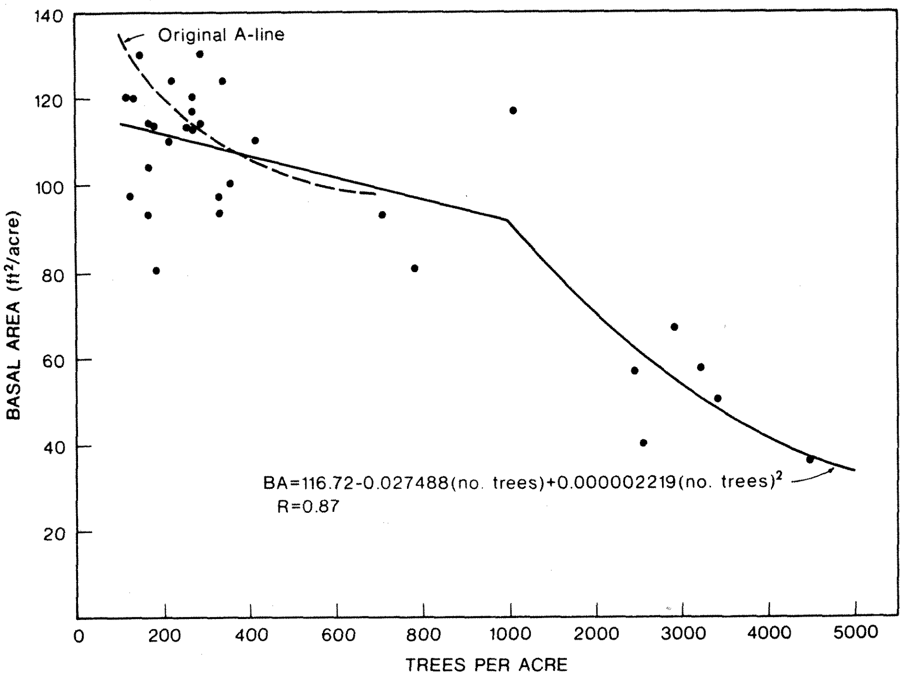
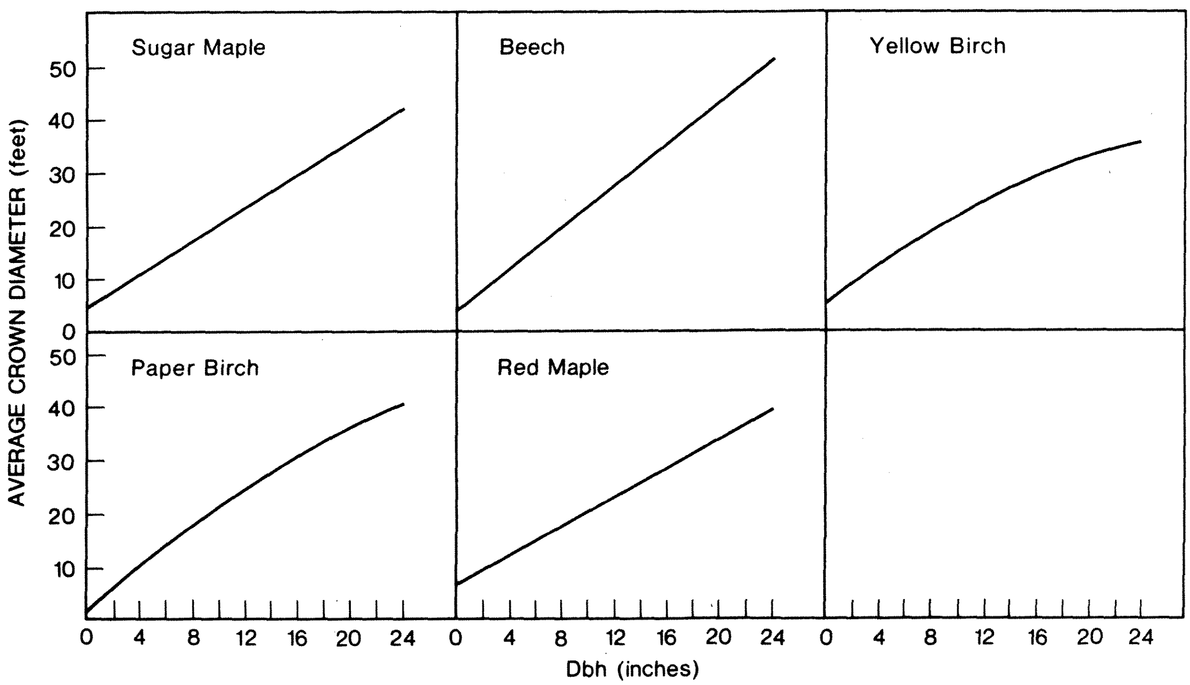


Figure 2.—Crown width regressed over dbh for sugar maple, beech, yellow birch, paper birch, and red maple.



Paper and yellow birch exhibited curvilinearity in the relationship of crown diameter to dbh. Beech had the largest crowns in trees above 8 inches dbh (Fig. 2). Sugar maple, red maple, and paper birch exhibited crown diameter relationships that plotted quite closely to one another in most size classes. Plottings gave no indication that crown diameters varied with site. These crown diameter equations are similar to those summarized for other parts of New England.[1] Except for yellow birch, the New England equations provide slightly lower crown diameter estimates in medium to large trees.

[1]Solomon, D.; Schnell, J. Crown diameter—dbh relationships for commercial tree species in New England. Orono, ME: Northeastern Forest Experiment Station. Manuscript in preparation.

By assuming either circular or square crowns (or tree areas), the number of trees and basal area per acre required by dominant or free-to-grow trees of each species were calculated (Table 2). The calculated basal areas for sugar maple, under the assumption of circular crowns; closely followed the recommended basal areas in the original 1969 B-line; other species were either lower or higher. Under the assumption of square crowns, calculated B-line basal areas for sugar maple fell 15 to 25 square feet below the original B-line. An earlier paper indicated that growth per acre of northern hardwoods and upland oaks remains high at basal areas up to about 20 square feet below recommended B-lines based on circular-crown areas (Leak 1981). Further, it is logical that crowns should be able to occupy an acre without spaces or overlap. Thus, the assumption of square-crown areas for hardwoods seems more reasonable than that of circular-crown areas.

Diameter-Growth Variability

The data from the increment borings provided the opportunity to compare rates and variability in radial growth (last 5-year period) on different sides of the tree, and to draw some conclusions on the most efficient way to sample diameter growth using increment borings.

There were no important differences in average growth among the four positions for any species. However, a few paper birch trees growing on the steepest slopes in the study area did exhibit up to 25 percent less growth on the uphill side than on the other sides.

More important, about 50 to 90 percent of the variation in diameter growth was due to variation among trees, whereas only 1 to 3 percent was due to variation among positions on the same tree. The most efficient sampling method is that which will give the most accurate estimate for a given time or cost. Because the variation among trees is large and the cost of sampling another tree is relatively small, statistical analysis[2] indicates that the most efficient way to estimate mean diameter growth from increment cores is to take one boring per tree on as many trees as time or money permit. Although differences among positions on a tree are small, except perhaps on steep slopes, I suggest taking the one core at a random position around the tree circumference to avoid consistent errors.

[2]To obtain the smallest variance for a given cost, the number of borings per tree equals $\frac{C_1}{C_2} \cdot \frac{S_2^2}{S_1^2}$, where C_1 and C_2 are the total costs of going to another tree and taking one boring, respectively, and S_1^2 and S_2^2 are the estimated variances among trees and among borings within a tree. C_1/C_2 represents the ratio between the costs of taking another tree and taking one boring per tree.

Table 2.—Calculated B-lines in basal area per acre by species for square and round crowns

Dbh	Square crowns					Circular crowns					Original 1969 B-line
	Sugar maple	Beech	Red maple	Yellow birch	Paper birch	Sugar maple	Beech	Red maple	Yellow birch	Paper birch	
	(Square feet per acre)										
2	15	15	10	10	26	19	19	13	13	33	—
4	31	27	24	23	37	39	34	31	29	47	—
6	42	34	36	33	44	54	43	46	42	56	57
8	50	38	46	41	49	64	49	59	53	62	66
10	57	42	54	49	53	72	53	69	63	68	75
12	61	44	61	57	57	78	56	78	72	73	83
14	65	46	67	64	61	83	58	85	81	78	89
16	68	47	71	71	66	87	60	91	91	83	93
18	71	48	75	79	70	90	62	96	101	89	96

Diameter-Growth Predictions

Projected 5-year diameter growth of paper birch on moist and dry soils was rapid in small trees but declined steeply as tree size became larger (Fig. 3):

5-year dbh growth (paper birch) = 1.8275 − 0.1029 (dbh) (8)

r = 0.85

Standard deviation = 0.32

Trees about 14 inches (approximately 80 to 100 years old) or larger grew very slowly, even if completely free from surrounding competition. The average deviation per tree from the regression was −0.05 for dry soils and +0.08 for wet soil.

Projected diameter growth of beech, red maple, and yellow birch on moist and dry soils followed a declining trend similar to paper birch, though less steep (Fig. 3):

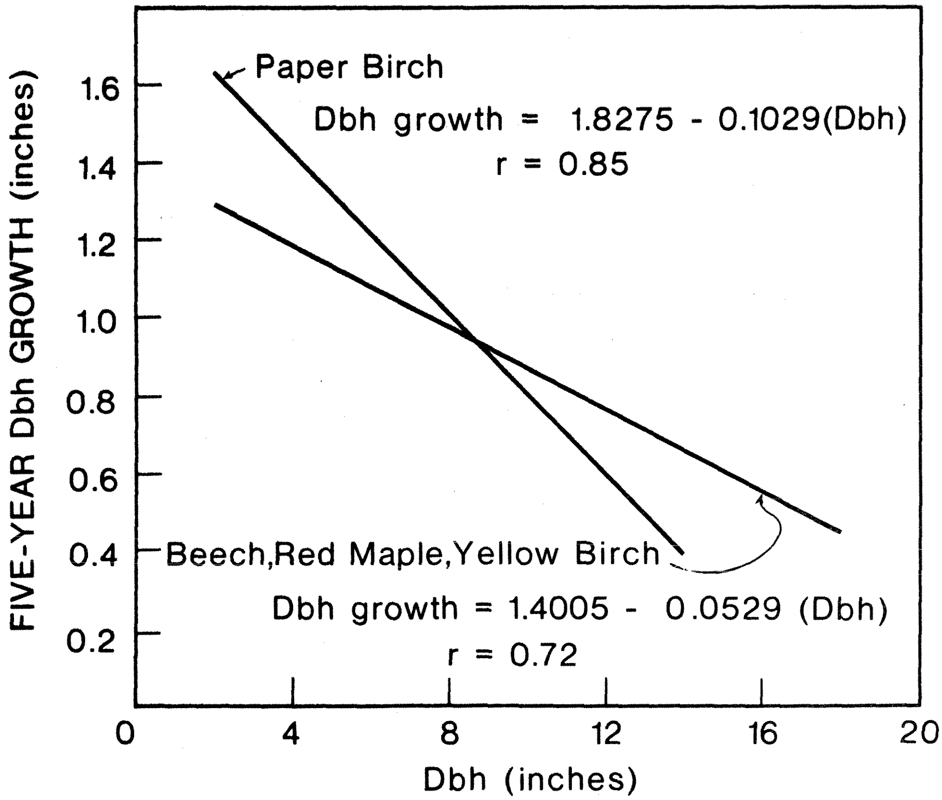
5-year dbh growth (beech, red maple, yellow birch)

= 1.4005 − 0.0529 (dbh) (9)

r = 0.72

Standard deviation = 0.24

Figure 3.—Five-year dbh growth regressed over dbh for paper birch and beech, red maple, and yellow birch on moist or dry soils.



Although differences among the three species represented in equation (9) were nonsignificant, average deviations in 5-year growth from the regression were moderate:

Beech 0.10 Yellow birch −0.20 Red maple 0.01

Thus, red maple fell closest to the regression line, while beech grew a little faster and yellow birch somewhat slower.

Neither regression on moist or dry soils showed any relationship between growth and deviations in either crown width or spacing; this could indicate that growth responses in relation to spacing or stocking are less on these moist or dry soils than on the fine tills described next. Although it may seem unusual to have a common growth relationship for moist and dry soils, both of these site groups have a similar successional sequence: softwoods are climax, and the hardwoods (beech, red maple, and birch) are subclimax.

A different form of relationship was evident for sugar maple, beech, yellow birch, and paper birch on fine till. Here, projected 5-year diameter growth showed almost no relationship to crown size expressed as actual crown width minus predicted crown width (predicted from the appropriate crown width regression (equations 3 through 6) by species):

5-year dbh growth (sugar maple, beech, yellow birch, and paper birch) = 0.9017 + 0.0006 (dbh) + 0.0758 (Actual minus predicted crown width) (10)

R = 0.56

Standard deviation = 0.25

Although R is not large, the standard deviation is about as small as or smaller than that in the previous two equations (8 and 9). Average deviations by species from the regression were small:

Sugar maple	0.024
Beech	0.028
Yellow birch	−0.046
Paper birch	−0.035

Even one very large paper birch was growing well on fine till. No small paper birch were sampled; thus, the equation probably does not apply to small paper birch.

A logical question is whether larger-than-average crowns are due to inherent differences among trees, or to variations in spacing. Average spacing around each sample tree was determined by measuring distance to each main-canopy competitor (usually four competitors per sample tree). Each distance was subdivided in proportion to the diameter of the sample tree versus the diameter of the competitor. An average spacing figure[3] was calculated for each sample tree, and spacing was regressed over dbh. Finally, the correlation between actual minus predicted spacing and actual minus predicted crown width was 0.45 (significant at 0.05 level). This correlation indicates that larger crown widths are related to spacing and that the faster growth rates exhibited by larger crowned trees can be attained by increasing spacing or lowering stand density.

When figures 3 and 4 are compared, they show that hardwood diameter growth on moist and dry soils begins rapidly but tapers off quickly with size or age. However, growth is sustained up to large sizes on fine till. These growth trends probably explain why successsional hardwoods on softwood sites produce about as much standing cubic-foot volume, but less than two-thirds the board-foot volume, as northern hardwoods on fine till (Leak 1982).

Diameter growth of sample trees growing on rocky soils was extremely variable, probably because rocky soils are variable in nature. These sample trees were not used in developing growth relationships.

Calculated Growth

By repeated application of the diameter-growth equations (8, 9, and 10),[4] you can project tree size over age (Figs. 5 and 6). Projected tree sizes for dominant, free-to-grow stems of beech, red maple, yellow birch, and paper birch on moist or dry soils follow a decreasing parabolic trend. Tree size over age for northern hardwoods on fine till is essentially a straight-line relationship. The possibilities for growing larger sized trees rapidly are obviously best on fine till.

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[3]For example, the bole-to-bole distances between a 16-inch sample tree and four 8-inch competitors were 20, 20, 24, and 24 feet: the average spacing figure would be calculated as: $\frac{16}{16+8}(20 + 20 + 24 + 24) \times 2 \div 4 = 29.3$ feet.

[4]Projected tree size can be represented by a difference equation:

$Y_{t+5} - Y_t = a - bY_t$
which has the solution
$Y_t = a(1 - (1 - b)^{t/5})/b$
where
Y = tree diameter
t = time in years

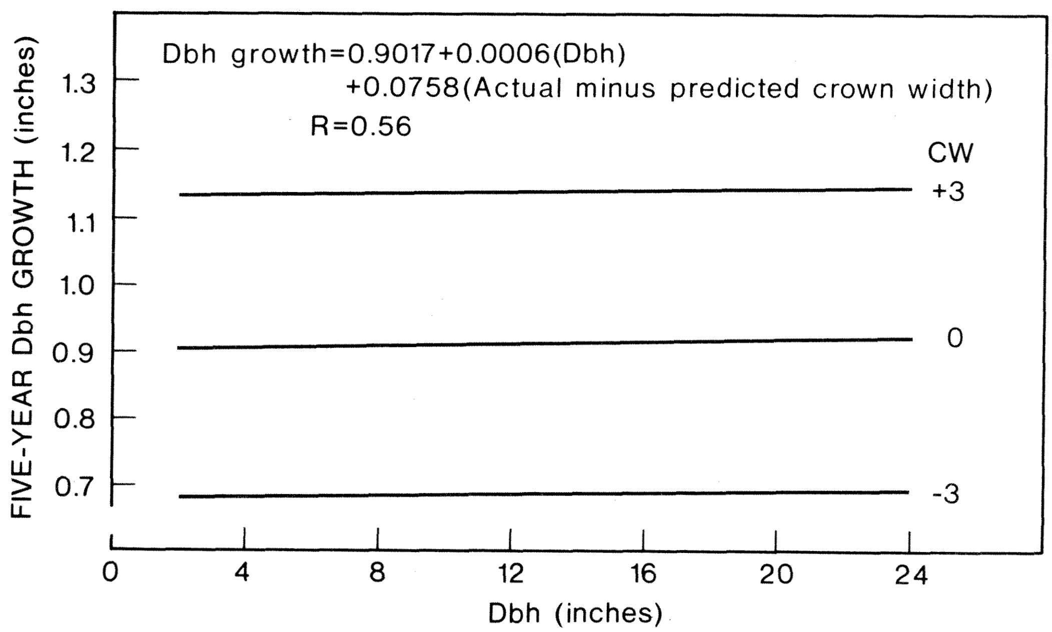

Figure 4.—Five-year dbh growth regressed over dbh and actual minus predicted crown width for sugar maple, beech, yellow birch, and paper birch on fine till.

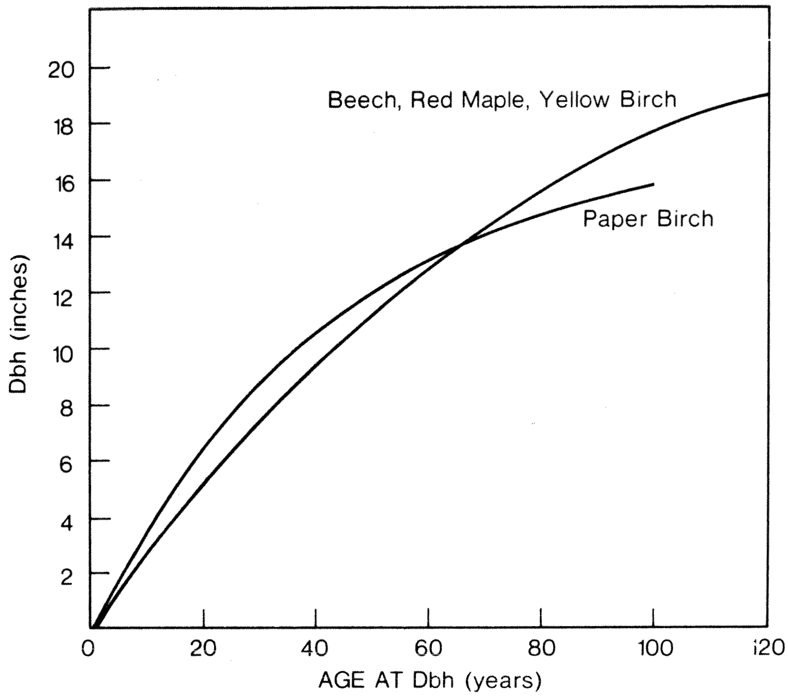

Figure 5.—Cumulative dbh over age for paper birch and beech, red maple, yellow birch on moist or dry soils simulated from regressions of 5-year diameter growth over dbh.

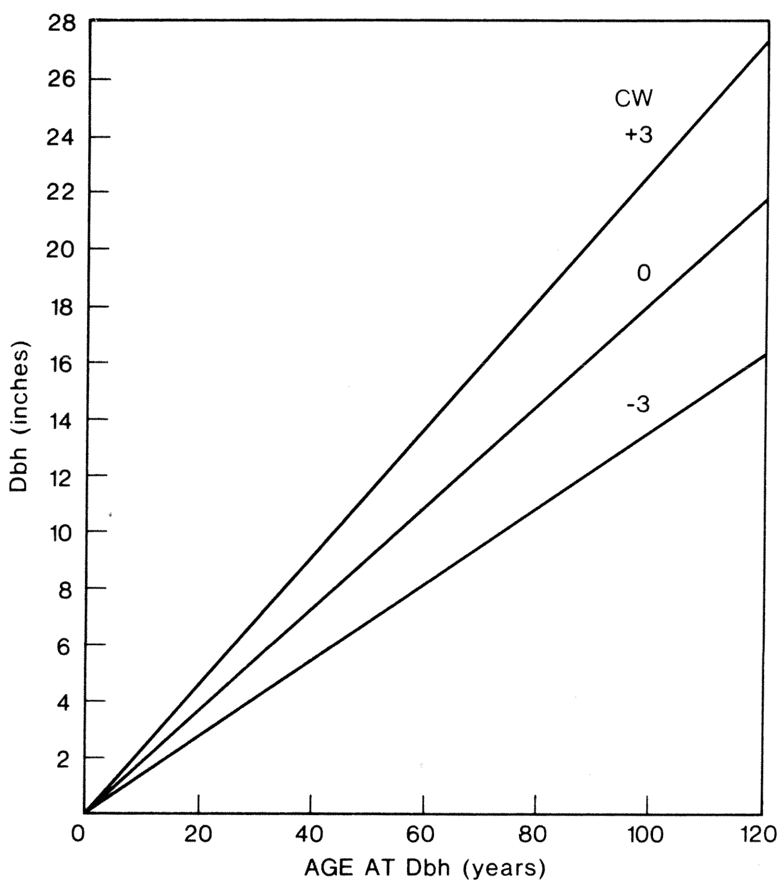

Figure 6.—Cumulative dbh over age for actual minus predicted crown widths of +3, 0, and −3 for sugar maple, beech, yellow birch, and paper birch on fine till. Simulated from regressions of 5-year dbh growth over age and actual minus predicted crown width.

Numbers of free-growing trees per acre (B-line) can be estimated under assumption of either square or circular crowns by using crown-width relationships (equations 3 through 7). By applying the appropriate diameter-growth equation (8, 9, or 10) and calculating change in basal area, you can calculate basal-area growth per acre for stands at the B-line. These growth figures represent survivor growth on dominant crop trees, without losses to mortality or additions from ingrowth. Growth in basal area and cubic volume are quite well correlated in northern hardwoods.

On the basis of square crowns, annual growth in basal area per acre was calculated for stands of the major species on both moist and dry soils (Table 3) and fine till (Table 4). The growth figures represent well-managed, even-aged stands at the low residual densities calculated from square crowns. If growth had been calculated under the assumption of circular crowns, the growth figures (Table 3 and 4) and residual basal areas (Tables 2 and 5) would be multiplied by 1.27. Calculated growth figures are fairly close to published data. Stands of mixed hardwoods on moist and dry soils averaging about 9 to 10 inches dbh (main canopy), cut to a range of residual densities, produced accretion figures of 1.7 to 2.0 square feet (Solomon 1977). A young stand of northern hardwoods on fine till, with a mean stand diameter of 3.5 to 4 inches in the main canopy, produced net growth of 4.0 square feet for the entire stand and 3.2 square feet for the sample trees alone following heavy thinning (Marquis 1969).

The influence of various stand densities on growth per acre is reflected by the growth calculations for fine till (Table 4) and the corresponding table of residual basal areas (Table 5). For example, calculated annual growth per acre for a 4-inch sugar maple stand is 4.20 square feet (Table 4) when the crowns average 3 feet (– 3 feet) below predicted, and the trend in growth per acre apparently is decreasing as the crowns get smaller. Table 5 shows that a 4-inch sugar maple stand with a – 3-foot average crown corresponds to 57 square feet of basal area per acre. A 12-inch sugar maple stand produces about the same basal-area growth (1.88 to 1.93 square feet) over all average crown widths (Table 4), or at any basal area between 48 and 81 square feet per acre (Table 5). If you use this approach, minimum basal area for nearly maximum growth per acre of sugar maple, beech, and yellow birch is approximately:

Dbh	*Sugar maple*	*Beech*	*Yellow birch*
		ft²	
4	57+	47+	38+
6	67+	51+	49+
8	37-74	29-53	41-58
10	43	33	38
12	48	36	45
14	53	38	52
16	56	40	59
18	60	42	66

This tabulation of minimum residual basal area corresponds reasonably well with the published record. In the 25-year-old northern hardwood stand previously mentioned, averaging about 3.5 to 4 inches in the main crown canopy, a heavy thinning to 56 square feet total basal area (with 31 square feet in sample trees) produced better net stand growth per acre than a light thinning to 72 square feet (with 33.5 square feet in sample trees). Growth on sample trees alone, which accounted for about 80 percent of the stand growth, also was best following the heavy thinning. In mixed northern hardwoods (beech/red maple/birch) averaging about 9 to 10 inches in the main canopy, accretion was best at 60 square feet (50 to 55 square feet in the main canopy) residual density. Accretion at 40 square feet (30 to 35 square feet in the main canopy) residual density was only 7 percent less. Keep in mind that these studies were in previously unmanaged (untreated) stands. Under intensive management, crown development per tree and spacing would be better, which would tend to allow fewer trees (lower basal areas) to occupy a site.

This tabulation also illustrates that minimum basal area for full growth per acre apparently does not increase markedly with increasing stand size or age; the trend varies among species from roughly constant to slightly rising to concave in shape. The data are too limited to reveal trends for various species mixtures. Eastern stocking guides all show that minimum stocking (B-line) increases consistently with increasing stand size or age. However, well-designed growth studies in hardwoods tend to support the view that minimum basal area remains more-or-less constant over age and presumably size as well. Optimum residual density for basal-area growth of upland oaks ranges from only 40 to 50 square feet for stands ranging in age from 20 to 110 years (Dale 1972). A similar trend is evident for yellow-poplar (Beck and Della-Bianca 1972). For example, on an average site (SI = 110), peak basal-area growth of yellow-poplar is attained (with only two minor exceptions) at residual basal areas of 80 to 90 square feet for stands ranging in age from 20 to 80 years. In this study, the basal-area growth was very flat over a broad range in residual density. If minimum basal area is constant over age, then the optimum residual stocking percent (B-line basal area as a percentage of A-line basal area) will decrease markedly as the stands get older or larger.

Table 3.—Projected annual growth per acre on moist and dry soils in basal area by species and mean stand dbh

Stand Dbh	Beech	Yellow birch	Paper birch	Red maple
4	3.63	3.10	6.21	3.30
6	2.65	2.58	3.90	2.87
8	1.98	2.15	2.61	2.40
10	1.51	1.79	1.77	1.98
12	1.16	1.49	1.16	1.61
14	.88	1.24	.69	1.29
16	.67	1.01	.30	1.00
18	.49	.80	—	.76

Table 4.—Projected annual growth per acre on fine till in basal area by mean dbh, species, and actual minus predicted crown widths of +3, 0, and −3 feet

Dbh	Sugar maple			Beech			Yellow birch		
	+3	0	−3	+3	0	−3	+3	0	−3
	Square feet								
4	2.45	3.08	4.20	2.19	2.67	3.47	1.93	2.28	2.82
6	2.37	2.73	3.22	1.97	2.18	2.44	1.92	2.13	2.36
8	2.22	2.41	2.61	1.75	1.83	1.88	1.88	1.98	2.06
10	2.07	2.15	2.19	1.57	1.57	1.53	1.83	1.87	1.85
12	1.92	1.93	1.88	1.42	1.38	1.29	1.78	1.78	1.72
14	1.78	1.75	1.65	1.29	1.23	1.11	1.75	1.72	1.62
16	1.66	1.60	1.48	1.18	1.11	.98	1.73	1.67	1.55
18	1.56	1.48	1.33	1.09	1.01	.88	1.72	1.65	1.51

Table 5.—Basal areas per acre by mean dbh, species, and actual minus predicted crown widths of +3, 0, and −3 feet

Dbh	Sugar maple			Beech			Yellow birch		
	+3	0	−3	+3	0	−3	+3	0	−3
	Square feet								
2	8	15	37	8	15	38	6	10	22
4	19	31	57	17	27	47	15	23	38
6	29	42	67	24	34	51	23	33	49
8	37	50	74	29	38	53	31	41	58
10	43	57	78	33	42	54	38	49	66
12	48	61	81	36	44	55	45	57	73
14	53	65	83	38	46	56	52	64	81
16	56	68	85	40	47	56	59	71	89
18	60	71	86	42	48	57	66	79	97
20	62	73	87	43	49	57	74	88	106
22	65	75	88	44	50	57	82	96	116
24	67	77	89	45	51	57	90	106	126
26	69	78	90	46	52	58	100	117	138

Quality

Quality was subjectively rated on the sample trees used to develop crown and growth relationships in this study. Only 35 to 40 percent of the beech and sugar maple were judged good or adequate in terms of form or clear boles, while over 80 percent of the red maple and paper birch and 60 percent of the yellow birch fell in these categories. The quality evaluation was not precise, but it indicates that quality of sugar maple, beech, and yellow birch could be an important problem if grown at the minimum densities indicated in tables 2 and 5. If grown at such low densities, to preserve quality take steps such as pruning or providing adequate trainers in the suppressed- and intermediate-crown classes, especially until the trees develop acceptable clear lengths. Marking guides for low-density management will need to recognize species differences in quality potential and the need to maintain trainers.

Conclusions

Results from this study confirmed the accuracy of the crown-width relationships used to develop the B-line (based on circular tree areas) in the northern hardwood stocking guide, and indicated that the A-line might be lowered for the larger stand diameters. Crown widths, or the resultant B-lines, did not vary with site; however, because certain species have appreciably wider or narrower crowns than others, it is possible that B-lines would vary with hardwood species composition. The A-line did not vary with site or hardwood forest type. An A-line regression based on trees in the main crown canopy was less variable than one based on all trees in the stand.

Simulated growth results and published growth information indicate that the minimum basal area for maximum growth is quite low (30 to 60 square feet) and roughly constant with increasing stand diameter. Thus, stocking guides based on crown area, which produces an increasing trend in minimum basal area over stand diameter, may not accurately define minimum required stand densities.

Diameter growth of dominant beech/red maple/birch trees on moist or dry soils declined sharply with increasing tree diameter. Hardwood diameter growth on fine till, however, was nearly constant over tree size and related to relative crown size. Calculations indicated that well-spaced hardwoods on fine till at age 100 could be up to 7 inches larger than beech, red maple, yellow birch, or paper birch on moist or dry soils. In growing trees at low densities, however, stem quality will be a problem with sugar maple, beech, and perhaps yellow birch. Artificial pruning or the maintenance of suppressed or intermediate trainers will be necessary at least until sufficient clear length is developed.

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Errata Sheet for Research Paper NE-523

Page 5, middle column, last paragraph, 2nd sentence should read:

"...no relationship to tree size (Eyre and Zillgitt 1953), but a significant relationship to crown size expressed as actual..."

Leak, William B. **Stocking, growth, and habitat relations in New Hampshire hardwoods.** Res. Pap. NE-523. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station; 1983. 11 p.

Data from hardwood stands in New Hampshire substantiated the crown-width relationships used to develop the B-line (based on circular crowns) in the 1969 northern hardwood stocking guide, and produced an A-line slightly lower than the original line. Position of the A-line was unrelated to site or forest type. Diameter growth of hardwoods on moist and dry soils declined rapidly with increasing tree diameter. On fine till, diameter growth was nearly constant over tree diameter but positively related to relative crown size. Based on diameter-growth regressions, calculations of stand growth indicated that the minimum basal area for adequate even-aged stand growth was quite low (30 to 60 square feet) and roughly constant over mean stand diameter.

Keywords: Stocking, growth, habitat, site, northern hardwoods

Headquarters of the Northeastern Forest Experiment Station are in Broomall, Pa. Field laboratories are maintained at:

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