Growth of Northern Hardwoods in New England: A 25-Year Update

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ABSTRACT

Twenty-five-year results from a study of four stand density levels and three percentages of sawtimber in a beech-red maple-birch-hemlock stand in New Hampshire showed that moderate stand densities of 60- to 80-ft^2/ac with 25- to 30-ft^{2}of sawtimber produced the best growth responses. Ingrowth was dominated by beech, red maple, and hemlock. Treatments with low initial numbers of poletimber stems had well-developed J-shaped or slightly sigmoid diameter distributions after 25 years. Results apply to the first entries into northern hardwood stands of moderate vigor and quality.

Keywords: northern hardwoods, stand density, stand structure, growth

Long-term growth information is basic for forest management planning. A designed study in northern hardwoods on the Bartlett Experimental Forest, New Hampshire, was initiated in 1964. This study examined four levels of residual stand density coupled with three levels of stand structure measured as percent of basal area in sawtimber. The treatments were designed to examine the range of possible harvest methods that might be used to convert an even-aged stand to an uneven-aged condition using single-tree selection. Ten-year results were presented in 1977 (Solomon 1977) and were revisited in 2003 (Leak 2003). Based on remeasurements since initiation of the study, growth results after the one initial treatment over a 25-year period (1964–1989) are presented in this article.

Methods

Forty-eight square ⅓-ac plots, each surrounded by a 50-ft-wide isolation strip, were established in 1964 in an even-aged northern hardwood stand about 70 years old. Species composition was primarily beech (*Fagus grandifolia*), red maple (*Acer rubrum*), and paper birch (*Betula papyrifera*), about 20–35% each; yellow birch (*Betula alleghaniensis*) and hemlock (*Tsuga canadensis*), 6–9% each; and minor amounts of sugar maple (*Acer saccharum*), white ash (*Fraxinus americana*), and red spruce (*Picea rubens*). The stand, growing on sandy granitic till, is of only moderate vigor and quality. Four levels of residual basal area were applied: 40, 60, 80, and 100 ft^2/ac (trees, 4.5 in. dbh plus) coupled with three levels of percent basal area in sawtimber (more than 10.5 in. dbh): 30, 45, and 60%. These 12 treatment combinations, replicated four times, were designed to represent a range of individual-tree selection options. Trees were numbered and periodic remeasurements were conducted about every 3–5 years, with new trees (ingrowth) numbered as they reached 4.5 in. dbh.

Results

Basal area growth components and diameter growth were averaged over the four plots in each treatment combination.

Four growth components are presented (Table 1). Production (or net growth) is simply the change in basal area over time, separated into the change in basal area of sawtimber and poletimber. Accretion (or survivor growth) is the basal area growth on trees that were alive at the beginning and the end of the 25-year growth period; this is separated into growth on trees before (poletimber) and after (sawtimber) reaching 10.5 in. dbh. Poletimber ingrowth is the basal area of trees that reached 4.5 in. dbh during the growth period; growth after reaching 4.5 in. was counted as accretion if the tree lived to the end of the period; sawtimber ingrowth is the basal area of trees reaching 10.5 in. dbh. Mortality is the basal area of trees that died during the period. Production of the whole stand equals all accretion plus poletimber ingrowth minus all mortality. Sawtimber production equals sawtimber accretion plus sawtimber ingrowth minus sawtimber mortality. However, poletimber production equals poletimber accretion plus poletimber ingrowth minus poletimber mortality minus sawtimber ingrowth (sometimes called poletimber outgrowth). Sawtimber accretion minus mortality and sawtimber accretion as a percent of initial sawtimber basal area also are presented in Table 1.

What is the best treatment for timber production? The choice depends on a careful assessment of the growth components (Table 1). Sawtimber production should be high, characteristic of the 60/30, 60/45, 80/30, and 100/30 treatments. In addition, the sawtimber accretion minus sawtimber mortality should be high, characteristic of the 60/45, 60/60, 80/30, 80/60, and 100/60 treatments. This component reflects growth on the existing sawtimber as contrasted to sawtimber production, which includes a sizeable component of ingrowth. The treatments that rank high on both measures are 60/45 and 80/30 representing only 24–27 ft^2/ac of initial sawtimber basal area. This level of stocking is similar to that recommended for uneven-aged northern hardwoods in New York for long cutting cycles (Nyland 1998) but considerably lower than recommendations for sugar maple in the Lake States (Crow et al. 1981). Note also in Table 1 and Figure 1 that growth efficiency, reflected by accretion as a percentage of initial sawtimber basal area, declines as initial stocking and percent sawtimber increase. Repeated application of the stocking and percent sawtimber levels discussed previously should produce the most sawtimber volume over time

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Table 1. Annual growth components (1964–1989) in basal area (ft^2/ac) by residual basal area, percent sawtimber, and tree size: poletimber (trees 4.5–10.5 in. dbh) or sawtimber (trees > 10.5 in. dbh).

	Treatments: Basal area/acre and percent sawtimber											
	40			60			80			100		
Size	30	45	60	30	45	60	30	45	60	30	45	60
Production												
Pole	0.82	0.84	1.13	0.22	0.57	0.46	−0.22	0.08	0.0	−0.13	−0.17	−0.24
Saw	1.42	1.37	1.18	1.59	1.69	1.52	1.82	1.47	1.38	1.80	1.49	1.44
All	2.24	2.21	2.31	1.81	2.26	1.98	1.60	1.55	1.38	1.67	1.32	1.20
Accretion												
Pole	1.48	1.27	1.40	1.30	1.16	0.95	1.13	1.13	0.70	1.25	1.02	0.61
Saw	0.65	0.83	0.76	0.77	0.92	0.98	0.87	0.81	0.99	0.86	0.93	1.18
All	2.13	2.10	2.16	2.07	2.08	1.93	2.00	1.94	1.69	2.11	1.95	1.79
Ingrowth												
Pole	0.65	0.68	0.75	0.43	0.55	0.52	0.28	0.34	0.29	0.33	0.34	0.20
Saw	1.06	0.87	0.87	1.19	0.97	0.83	1.23	1.05	0.81	1.26	1.03	0.67
Mortality												
Pole	0.25	0.24	0.15	0.32	0.17	0.18	0.40	0.34	0.18	0.45	0.50	0.38
Saw	0.29	0.33	0.45	0.37	0.20	0.29	0.28	0.39	0.42	0.32	0.47	0.41
All	0.54	0.57	0.60	0.69	0.37	0.47	0.68	0.73	0.60	0.77	0.97	0.79
Sawtimber accretion minus mortality												
Saw	0.36	0.50	0.31	0.40	0.72	0.69	0.59	0.42	0.57	0.54	0.46	0.77
Percent sawtimber accretion												
Saw	5.4	4.6	3.2	4.3	3.4	2.7	3.6	2.2	2.1	2.9	2.1	2.0

Table 2. Annual ingrowth in basal area (ft^2/ac) by residual basal area, percent sawtimber, and species.

Residual basal area	Percent saw	Beech	Yellow birch	Paper birch	Red maple	Hem-lock	Other	All
40	30	0.28	0.02	0.01	0.16	0.16	0.02	0.65
	45	0.37	0.02	0.00	0.11	0.12	0.06	0.68
	60	0.35	0.01	0.00	0.07	0.24	0.08	0.75
60	30	0.25	0.03	0.00	0.02	0.12	0.01	0.43
	45	0.30	0.03	0.00	0.03	0.16	0.03	0.55
	60	0.25	0.01	0.00	0.07	0.13	0.05	0.52
80	30	0.14	0.00	0.00	0.03	0.08	0.03	0.28
	45	0.17	0.01	0.01	0.03	0.10	0.02	0.34
	60	0.13	0.01	0.00	0.06	0.07	0.02	0.29
100	30	0.15	0.01	0.00	0.05	0.08	0.03	0.32
	45	0.21	0.01	0.00	0.01	0.10	0.01	0.34
	60	0.14	0.01	0.00	0.03	0.02	0.01	0.20

Table 3. Annual dbh growth (in.) by residual basal area (ft^2/ac), percent sawtimber, tree size, and species.

	Treatments: basal area/acre (ft^2) and percent sawtimber											
	40			60			80			100		
Size	30	45	60	30	45	60	30	45	60	30	45	60
Beech												
Pole	0.14	0.15	0.16	0.12	0.12	0.12	0.10	0.10	0.10	0.09	0.09	0.09
Saw	0.16	0.12	0.13	0.13	0.14	0.10	0.11	0.11	0.11	—	0.11	0.13
Yellow birch												
Pole	0.14	0.16	0.07	0.10	0.09	0.07	0.06	0.07	0.06	0.05	0.05	0.04
Saw	0.08	—	0.10	0.09	0.05	0.11	0.12	0.06	0.08	0.07	0.04	0.03
Paper birch												
Pole	0.07	0.09	0.11	0.08	0.07	0.06	0.07	0.08	0.10	0.05	0.04	0.08
Saw	0.08	0.07	0.09	0.06	0.10	0.07	0.08	0.07	0.09	0.07	0.06	0.06
Red maple												
Pole	0.14	0.13	0.16	0.14	0.12	0.11	0.09	0.11	0.10	0.07	0.08	0.07
Saw	0.11	0.17	0.16	0.14	0.12	0.13	0.09	0.12	0.13	0.11	0.10	0.10
Hemlock												
Pole	0.21	0.26	0.27	0.16	0.16	0.20	0.17	0.15	0.08	0.12	0.12	0.22
Saw	0.30	0.28	0.19	0.21	0.20	0.22	0.20	—	0.16	0.22	0.19	0.18

based on our information to date. The initial harvest, of course, will be greatest using the lower recommended stocking levels.

To help interpret these basal area growth figures, some simple conversion factors might be useful. One square foot of basal area is equivalent to about 20 ft^3 in poletimber and 25 ft^3 in small sawtimber. A cord is about 85 ft^3. One cord of sawtimber-sized wood is about 500 bd ft. Therefore, the 60 ft^2/45% treatment that annually produced 0.57 and 1.69 ft^2 of poletimber and sawtimber, respectively, was growing at an annual rate of about 54 ft^3 (whole stand) or 250 bd ft.

Ingrowth (Table 2) was dominated by beech, red maple, and hemlock. Although ingrowth was highest under the lowest residual basal areas, both beech and hemlock maintained fairly high rates under the

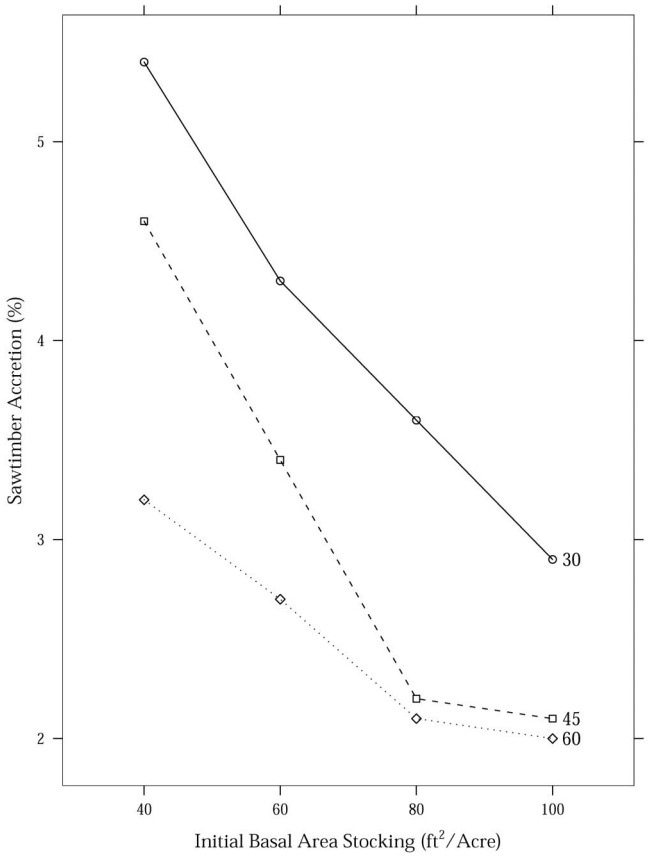

Figure 1. Sawtimber accretion as a percent of initial basal area per acre.

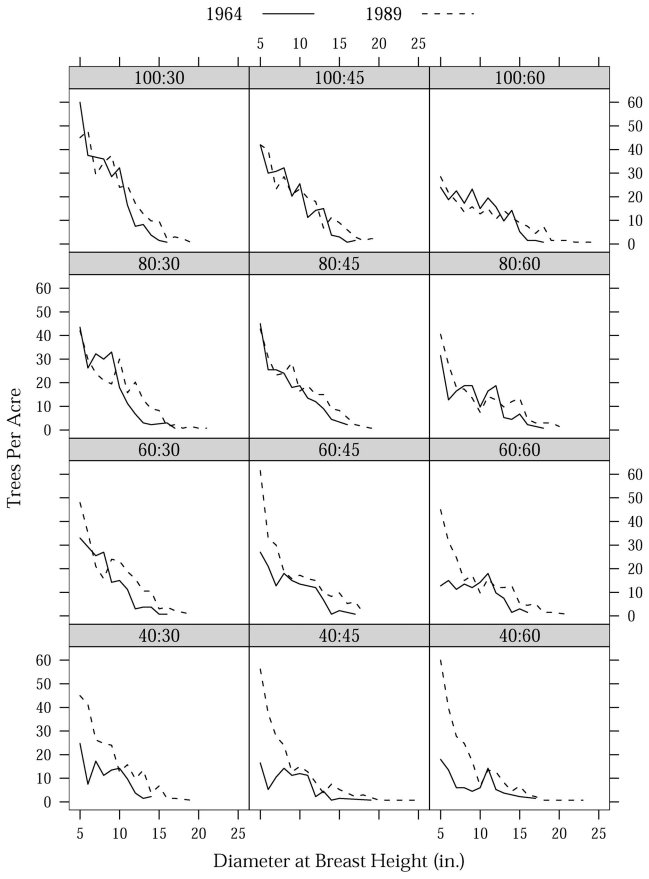

Figure 2. Numbers of trees per acre in 1-in. dbh classes by residual basal area and percent sawtimber treatments in 1964 and 1989.

Table 4. Numbers of trees per acre (4.5 in. dbh and larger) in 1964 and 1989 and final basal area (ft²) per acre by residual basal area and percent sawtimber treatments.

			Percent sawtimber		
Residual basal area	Measure	Year	30	45	60
40	No. trees	1964	106	91	84
	No. trees	1989	227	218	228
	Basal area	1989	96	96	97
60	No. trees	1964	167	142	120
	No. trees	1989	230	246	212
	Basal area	1989	106	117	109
80	No. trees	1964	210	198	163
	No. trees	1989	233	238	200
	Basal area	1989	119	119	115
100	No. trees	1964	269	230	189
	No. trees	1989	296	251	193
	Basal area	1989	142	132	130

80- and 100-residual basal areas, while red maple ingrowth declined. The birches produced little ingrowth under even the lowest basal area treatments. The message is that this range of single-tree selection harvests will produce primarily tolerant species over time, beech and some hemlock on mediocre sites and sugar maple on good sites.

Diameter growth (Table 3) varied appreciably among species and residual stand densities. As expected, rates dropped with increasing basal area, and sawtimber grew faster than poletimber. Hemlock produced the highest rates; hemlock sawtimber grew at about 1-in. in dbh in 3–5 years depending on stand density. Red maple sawtimber grew at about an inch in 6–10 years, followed by beech. At basal areas of 60–80, the yellow and paper birch sawtimber generally grew at about an inch in 10 years or more.

Stand structure and stocking of the low basal area treatments changed appreciably over the 25-year period. Note (Figure 2) that treatments with low initial numbers of poletimber stems, e.g., the 40-ft² and the 60:60 treatments, had well-developed J-shaped or slightly sigmoid diameter distributions after 25 years. Diameter distributions of the 80- and 100-ft² treatments changed little over time because of partly the low or negative poletimber ingrowth. Numbers of trees more than doubled in the lowest density treatments but changed only slightly in highest density treatments (Table 4). By 1989, basal area per acre ranged from the mid-90s in 40-ft² treatments to 130 ft² or more in the 100-ft² treatments.

Management Implications

The 25-year results from this study confirm earlier findings that northern hardwood stands composed of beech, red maple, birches, and hemlock grow well at moderate stand densities of 60–80 ft² residual basal area with about 25–30 ft² of sawtimber. These results apply to the first single-tree selection entries in stands of only moderate vigor and quality. On better sites, those that support higher proportions of sugar maple and white ash, higher residual densities, and, certainly, higher amounts of sawtimber probably will be optimum. In addition, remember that the results represent a single study, unreplicated over the wide range of sites found in New England.

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