Influence of Residual Stand Density on Regeneration of Northern Hardwoods

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6816 MARKET STREET, UPPER DARBY, PA. 19082
F. BRYAN CLARK, STATION DIRECTOR

THE AUTHORS

W. B. LEAK joined the Northeastern Forest Experiment Station in 1956, and now is engaged in silvicultural research at the Forestry Sciences Laboratory, Durham, N.H.

DALE S. SOLOMON, Mensurationist, joined the Northeastern Forest Experiment Station in June 1962 after earning his Master's Degree in Forestry from Yale University. He received a Bachelor of Science degree in Forestry from the Pennsylvania State University in 1961. For 8 years he has worked on the Station's beech-birch-maple silviculture project located in Durham, New Hampshire. Since 1970 he has been assigned to the staff of the Station's spruce-fir silviculture project at Orono, Maine.

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SPECIES LIST

Common Name	*Latin Name*
American beech	*Fagus grandifolia* Ehrh.
Yellow birch	*Betula alleghaniensis* Britton
Sugar maple	*Acer saccharum* Marsh.
Red maple	*Acer rubrum* L.
Paper birch	*Betula papyrifera* Marsh.
White ash	*Fraxinus americana* L.
Red spruce	*Picea rubens* Sarg.
Eastern hemlock	*Tsuga canadensis* (L.) Carr.
Balsam-fir	*Abies balsamea* (L.) Mill.
Pin cherry	*Prunus pensylvanica* L. f.
Striped maple	*Acer pensylvanicum* L.
Raspberry	*Rubus* spp.
American yew	*Taxus canadensis* Marsh.
Hobblebush	*Viburnum alnifolium* Marsh.

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by W. B. Leak
and D. S. Solomon

ABSTRACT

In a study of hardwood regeneration, experimental plots were treated to produce residual densities of 40, 60, 80, and 100 square feet of basal area per acre with 30, 45, and 60 percent sawtimber. After 9 years, numbers of stems and percent stocking were estimated for each species and they were rated for reproductive potential under different residual densities. Data from a 3-year-old patch cutting are given for comparison.

CONTROLLING stand density is probably the most common and most feasible method available to a forester for molding stand development. Residual stand density must be specified in a thinning operation since it affects growth per acre and the growth of individual crop trees. In prescribing shelterwood or selection cuttings, the effects of the residual stand on the amount and development of regeneration must be carefully considered. In scenic, recreational, and wildlife areas, more and more attention is being given to the control of understory development through manipulation of residual stand density and structure.

Past research with northern hardwoods in New England has provided guidelines for regeneration or understory development after clearcutting, patch cutting, and selection cutting (Leak and Wilson 1958; Marquis 1965; Marquis 1967). However, none of the published information on this subject specifies a range of residual densities and structures.

In 1963 and 1964 we began a study of the effects of residual stand density and stand structure (in terms of the percentage of sawtimber). Our main purpose was to determine the effects of residual stand conditions on tree and stand growth; these results will be reported separately. The effects of residual stand density and structure on understory development are described here.

METHODS

The study was established in second-growth northern hardwoods on the Bartlett Experimental Forest at Bartlett, N. H. These stands had originated after clearcutting 70 to 90 years before. Species composition was typical: primarily beech, red maple, and paper birch, together with some yellow birch and sugar maple and a few white ash and miscellaneous softwoods. The site apparently was not especially favorable for sugar maple, white ash, or the softwoods.

Forty-eight plots of ⅓ acre each were laid out. Each was surrounded by a 50-foot isolation strip, so that the plot proper plus its isolation strip occupied a little more than 1 acre.

Four levels of residual stand density were randomly assigned to these plots: 100, 80, 60, and 40 square feet of basal area per acre in trees 4.5 inches dbh and larger. Within each level of residual stand density, three residual stand structures were randomly assigned: 60, 45, and 30 percent sawtimber (trees 10.5 inches dbh and larger). Thus, the study comprised 12 combinations, each represented by four plots in a completely randomized design.

The plots were treated in the fall of 1963 by frilling and chemically treating the unwanted trees. Within the specifications of each treatment, the trees to be disposed of were chosen essentially at random. On a few plots, however, some effort was made to bring the species composition more in line with the average for the area (table 1). Trees that did not die were again treated in the spring of 1964. A few trees had to be cut before the 1965 growing season to complete the treatment. Treatment specifications were met almost exactly on both the ⅓-acre plots and the surrounding isolation strips.

In early summer of 1973, nine growing seasons after the main impact of the treatments, regeneration was sampled in eight 1-square-meter (10.8 sq. ft.) subplots on a diagonal across each ⅓-acre plot. For each subplot, all stems 2 mm (.04 inch) or larger in diameter at a point just above the root swell were recorded by species and diameter. For each plot, each treatment, and each species, the data were used to estimate the number of stems per hectare (2.47 acres)

Table 1.—Initial species composition of plots in percentage of basal area, by species, residual basal area, and percentage of sawtimber

Residual basal area	Sawtimber	Beech	Yellow birch	Sugar maple	Red maple	Paper birch	White ash	Red spruce	Eastern hemlock	Other
Sq. ft.						*Percent*				
100	30	7.6	4.6	3.4	46.1	23.0	1.2	.4	10.1	3.5
	45	36.4	13.7	1.0	22.8	17.8	0.0	.3	8.1	0.0
	60	21.7	9.4	11.1	34.4	14.7	2.0	.5	6.4	0.0
	All	21.8	9.2	5.2	34.5	18.5	1.1	.4	8.2	1.2
80	30	22.6	9.3	6.6	35.8	14.1	2.0	0.0	9.4	.3
	45	36.5	6.4	8.6	16.0	27.2	.9	1.1	3.2	0.0
	60	35.3	12.0	11.5	16.3	12.5	5.3	1.7	5.3	0.0
	All	31.5	9.2	8.9	22.6	18.0	2.7	1.0	6.0	.1
60	30	51.7	12.5	6.0	6.5	10.4	7.5	1.0	4.4	0.0
	45	37.6	11.1	3.7	21.3	19.0	.7	0.0	6.7	0.0
	60	14.7	3.8	5.5	37.7	28.9	0.0	0.0	9.4	0.0
	All	34.7	9.2	5.1	21.7	19.4	2.7	.4	6.8	0.0
40	30	28.0	10.0	0.0	32.2	23.8	.9	0.0	5.2	0.0
	45	24.5	3.4	3.6	26.4	21.5	7.6	0.0	13.0	0.0
	60	39.0	7.8	5.5	21.9	19.1	1.0	0.0	5.5	.3
	All	30.5	7.0	3.1	26.9	21.5	3.2	0.0	7.9	.1

and the percentage of subplots that contained at least one stem of that species (percent stocking). The summaries include only stems between 2 and 25 mm (.98 inch) in diameter since this size range covered the major differences in understory condition among treatments. Some of the stems tallied in 1973 were, of course, present before the treatment in 1963.

RESULTS

Percentage Stocking

On the average, stocking of the regeneration after 9 years was higher where the initial residual basal area was lower (table 2). Using the average stocking percentage of nine abundant species,[1] we found the effects of residual basal area to be significant. However, the response differed by species. Beech stocking —always high — increased slightly but consistently with lower residual basal area. Yellow birch stocking was less than 10 percent under 100 square feet and about doubled under lower residual densities. Sugar maple stocking varied little under all densities. Red maple stocking remained consistently high under the 60- to 100-square-foot densities, but increased markedly under 40 square feet. Paper birch responded somewhat to the 40-square-foot treatment. White ash stocking increased to some extent under 80-square-foot density or lower. Hemlock differed little. Stocking of pin cherry and *Rubus* increased slightly with lower stocking, but never became high. Striped maple reacted erratically to residual density. Hobblebush increased slightly with lower residual density. American yew also increased with lower density, especially at the 40-square-foot level.

Analysis of the average stocking for the nine species indicated that stocking was also related to some extent to percentage of sawtimber. There was a tendency toward higher stocking in plots with higher percentages of sawtimber; the probability of such differences occurring by chance was about 10 percent. These results confirm the practice of many foresters who feel that high shade (from large, tall trees) has less influence than low shade. However, the data in table 2 for individual species indicate that the relationship between percentage stocking and percentage of sawtimber is not consistent enough to support any conclusions.

Numbers of Stems

In most cases, numbers of stems per hectare followed much the same trends as percentage stocking (table 3); however, numbers probably give a more specific indication of regeneration ability than the presence or absence of a species, which determines percentage stocking. Table 3 also provides, for comparison, numbers of 3-year-old seedlings per hectare obtained on ⅔-acre plots by complete removal of everything down to 2 inches dbh (Marquis 1965). These patch cuts were made in second-growth stands on the Bartlett Experimental Forest very similar to those we used for this study. All the figures in table 3 are for undisturbed (not scarified) seedbeds.

Keeping in mind that there are more total stems per acre under the patch cuts, partly because the regeneration is younger, we can make some general observations about the effects of zero density compared to various other levels of residual density.

In comparison with any of the partial removals, patch cutting discouraged beech and red maple regeneration. Paper birch, and to a lesser extent yellow birch and sugar maple, was more abundant on the patch cuttings than under any of the residual densities. Ash responded somewhat better to the 40- and 80-square-foot residual densities than to patch cutting, although the species never became abundant. Pin cherry and *Rubus* were much more abundant on the patch cuts.

A somewhat more general picture of the effects of residual density is produced by combining commercial tree species into three recognized shade-tolerance groups: tolerant (beech, sugar maple, hemlock, red spruce, balsam-fir), intermediate (yellow birch, red maple, white ash), and intolerant (paper birch). Total numbers of stems per hectare

[1] Beech, yellow birch, sugar maple, red maple, paper birch, white ash, eastern hemlock, pin cherry, striped maple.

Table 2.—Average stocking of square meter plots by species, residual basal area, and percentage of sawtimber.

Residual basal area	Saw-timber	Beech	Yellow birch	Sugar maple	Red maple	Paper birch	White ash	Red spruce	Eastern hemlock	Balsam fir	Pin cherry	Striped maple	Rubus	Yew	Hobble-bush
Sq. ft.							*Percent*								
100	30	62.5	0.0	10.9	18.8	0.0	6.2	0.0	6.2	1.6	0.0	28.1	0.0	0.0	28.1
	45	71.9	15.6	3.1	43.8	15.6	9.4	3.1	3.1	0.0	21.9	6.2	6.2	0.0	0.0
	60	71.9	12.5	25.0	62.5	6.2	15.6	0.0	6.2	0.0	3.1	28.1	0.0	15.6	34.4
	All	68.8	9.4	13.0	41.7	7.3	10.4	1.0	5.2	0.5	8.3	20.8	2.1	5.2	20.8
80	30	75.0	12.5	9.4	34.4	3.1	6.2	3.1	3.1	0.0	9.4	40.6	0.0	3.1	21.9
	45	78.1	18.8	12.5	46.5	15.6	18.8	0.0	0.0	0.0	9.4	25.0	9.4	0.0	3.1
	60	79.7	21.9	23.4	60.9	10.9	32.8	0.0	9.4	0.0	14.1	51.6	3.1	0.0	39.1
	All	77.6	17.7	15.1	47.4	9.9	19.3	1.0	4.2	0.0	11.0	39.1	4.2	1.0	21.4
60	30	84.4	37.5	15.6	43.8	15.6	25.0	0.0	3.1	0.0	12.5	25.0	9.4	18.8	25.0
	45	87.5	18.8	12.5	34.4	6.2	3.1	0.0	9.4	0.0	18.8	21.9	9.4	0.0	21.9
	60	65.6	6.2	18.8	46.9	0.0	43.8	0.0	3.1	9.4	3.1	37.5	3.1	9.4	28.1
	All	79.2	20.8	15.6	41.7	7.3	24.0	0.0	5.2	3.1	11.5	28.1	7.3	9.4	25.0
40	30	90.6	21.9	6.2	81.2	18.8	9.4	0.0	0.0	0.0	12.5	40.6	9.4	0.0	12.5
	45	75.0	15.6	12.5	50.0	21.9	15.6	3.1	21.9	0.0	3.1	37.5	3.1	21.9	43.8
	60	81.2	25.0	21.9	59.4	12.5	46.9	0.0	3.1	0.0	21.9	53.1	12.5	28.1	28.1
	All	82.3	20.8	13.5	63.5	17.7	24.0	1.0	8.3	0.0	12.5	43.7	8.3	16.7	28.1

Table 3.—Numbers of stems (2 to 25 mm diameter) by species, residual basal area, and percentage of sawtimber

(In thousands of stems per hectare)

Residual basal area	Sawtimber	Beech	Yellow birch	Sugar maple	Red maple	Paper birch	White ash	Red spruce	Eastern hemlock	Balsam fir	Pin cherry	Striped maple	Rubus	Yew	Hobblebush	Other	Total
Sq. ft.	—	—	—	—	—	—	—	*Percent*	—	—	—	—	—	—	—	—	—
100	30	15.0	0.0	1.4	5.6	0	.6	0.0	.3	.2	0.0	8.8	0.0	0.0	18.6	1.7	52.2
	45	35.0	5.3	.3	22.8	2.8	.9	0.0	0.0	0.0	8.8	.6	1.9	0.0	0.0	0.0	78.4
	60	32.2	1.6	5.9	23.1	.6	6.2	0.0	.6	0.0	.6	3.1	0.0	19.4	44.4	1.4	139.1
	All	27.4	2.3	2.5	17.2	1.1	2.6	0.0	0.3	.1	3.1	4.2	.6	6.5	21.0	1.0	89.9
80	30	50.9	4.1	1.2	7.8	1.2	2.2	.3	.6	0.0	2.5	9.1	0.0	3.1	20.9	.2	104.1
	45	37.5	14.7	9.4	14.7	3.4	4.4	0.0	0.0	0.0	2.2	4.7	6.9	0.0	4.4	.2	102.5
	60	26.6	7.3	4.2	20.8	1.7	10.6	0.0	1.6	0.0	5.8	15.6	0.3	0.0	45.5	.3	140.3
	All	38.3	8.7	4.9	14.4	2.1	5.7	0.1	.7	0.0	3.5	9.8	2.4	1.0	23.6	.2	115.6
60	30	57.2	20.3	9.4	16.2	4.1	12.2	0.0	.9	0.0	5.6	5.6	2.5	35.6	15.0	0.0	184.6
	45	57.2	5.3	1.9	11.6	.9	.3	0.0	2.8	0.0	4.4	5.9	.9	0.0	18.8	.3	110.3
	60	38.4	3.1	4.7	26.9	0.0	11.2	0.0	.3	.9	.3	10.6	.3	19.1	23.8	3.8	143.4
	All	50.9	9.6	5.3	18.2	1.7	7.9	0.0	1.3	.3	3.4	7.4	1.2	18.2	19.2	1.4	146.1
40	30	41.6	2.5	.9	87.2	3.4	2.2	0.0	0.0	0.0	12.2	15.3	5.6	0.0	25.6	0.0	196.5
	45	31.6	1.6	3.4	51.9	3.8	4.1	.3	2.8	0.0	.3	11.2	.3	54.1	45.3	2.4	213.1
	60	37.5	11.9	6.6	49.7	6.6	18.8	0.0	.3	0.0	7.8	15.9	3.1	59.1	33.8	.2	251.3
	All	36.9	5.3	3.6	62.9	4.6	8.4	0.1	1.0	0.0	6.8	14.1	3.0	37.7	34.9	.9	220.3
0[a]	0	14.8	24.0	17.5	11.1	42.0	4.4				58.1	5.4	100.8			35.1	313.2

[a]Second-growth patches (Marquis 1965), 3-year regeneration, undisturbed seedbeds only.

were graphed over density level, combining all percentages of sawtimber (figure 1). Although total numbers of stems increase between 100 and 60 square feet residual density, the proportions of the tolerance groups are not greatly affected. At 40 square feet, there is a great increase in the intermediate group — almost entirely due to the increase in red maple. At zero square feet residual density, the numbers in each tolerance group are about equal.

Figure 1.—Average numbers of stems (in thousands per hectare) of commercial timber species by residual basal area and tolerance group: tolerant (beech, sugar maple, hemlock, red spruce, balsam-fir), intermediate (yellow birch, red maple, white ash), and intolerant (paper birch). Numbers under zero residual density based on 3-year-old patch cuttings *(Marquis 1965)*.

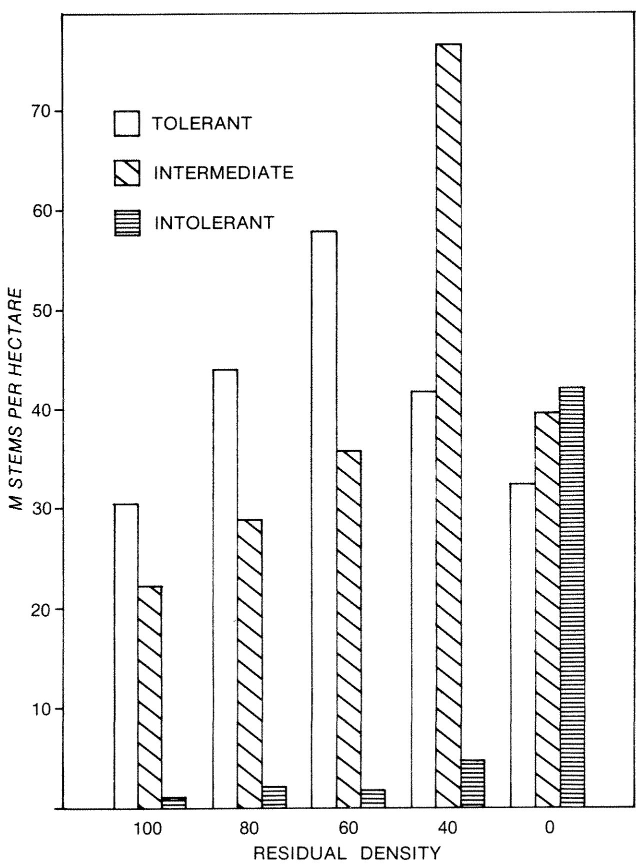
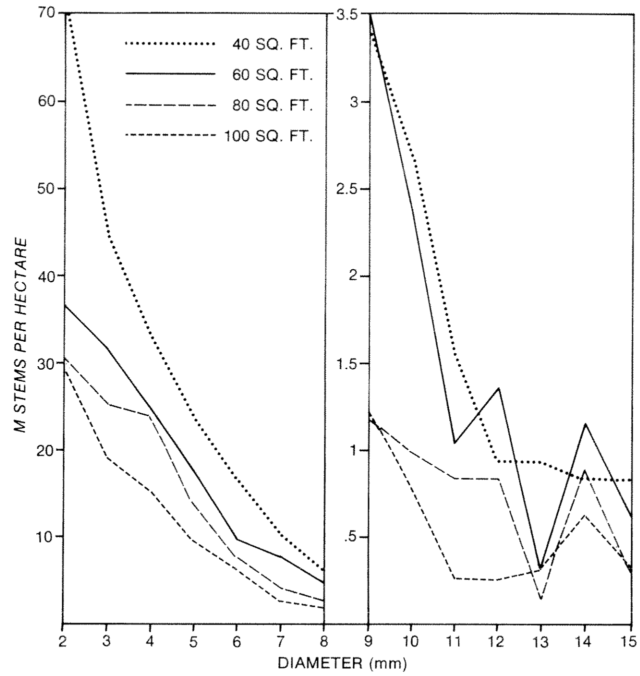


Figure 2.—Average numbers of understory stems per hectare (all species) over diameter class for four residual density levels.



Size

The understory on the low-density plots was noticeably thicker than on the higher-density ones. A summary of the size distribution of the understories indicates that the lower-density plots had increased numbers of stems up through the 12 to 13 mm diameter class. Beyond that point, the differences were not so distinct (figure 2).

CONCLUSION

The relative reproductive potentials of major species were rated as shown in table 4. Each rating is based on the number of stems per hectare (from table 3) expressed as a percentage of the total number of hardwood stems (ignoring shrubs and softwoods). If reproductive potential were ranked on the basis of numbers of stems *per se* — rather than percentage composition — the rankings would increase somewhat as the residual density became lower. Keep in mind that a more specific evaluation of response by species may

Table 4.—Reproductive potential of second-growth northern hardwood stands by species and residual density

Residual density	Beech	Yellow birch	Sugar maple	Red maple	Paper birch	White ash	Pin cherry	maple Striped
Sq. ft./acre								
100	VH	VL	VL	M	VL	VL	VL	VL
80	VH	L	VL	L	VL	VL	VL	L
60	VH	VL	VL	L	VL	VL	VL	VL
40	MH	VL	VL	VH	VL	VL	VL	L
0	VL	L	L	VL	M	VL	H	VL

Key:
VH = Very high — 40–49 percent of hardwood stems
H = High — 30–39 percent of hardwood stems
M = Medium — 20–29 percent of hardwood stems
L = Low — 10–19 percent of hardwood stems
VL = Very low — 0– 9 percent of hardwood stems

be obtained by careful examination of the data in tables 2 and 3 on percentage stocking and numbers of stems.

Where the seedbed is scarified, intentionally or through logging, the rankings of paper and yellow birch will rise. However, even under these conditions, it is doubtful whether any of the partial removals would surpass zero residual density (patch cutting, not large-scale clearcutting) for these two species.

The rankings in table 4 will not apply very well to those sites that are unusually favorable for sugar maple, white ash, or softwoods. At present, such sites can best be detected by examining the vegetation already present.

In applying shelterwood, selection, or patch cutting to second-growth northern hardwoods, these ratings and the underlying basic data should be useful. They show how alternative residual densities will favor or discourage certain species. For recommendations for Allegheny hardwoods, with emphasis on black cherry, refer to the work by Marquis (1973).

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