Investment in PRECOMMERCIAL THINNING of NORTHERN HARDWOODS

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U.S.D.A. FOREST SERVICE RESEARCH PAPER NE-245
1972
NORTHEASTERN FOREST EXPERIMENT STATION, UPPER DARBY, PA.
FOREST SERVICE, U. S. DEPARTMENT OF AGRICULTURE
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MANUSCRIPT RECEIVED FOR PUBLICATION 28 OCTOBER 1971

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INTRODUCTION

PRECOMMERCIAL THINNING in young northern hardwood stands can increase value yields by concentrating growth on the more valuable trees. But is the increased value yield large enough to offset the compounded costs of the thinnings?

The answer to this question depends upon the product goals, the investment return desired, and the time periods under consideration. The solution to the question appears simple, but becomes complex when we consider the objectives of the forest owner in terms of product, investment return, time period, and the owner's objective in the land investment itself.

Because of this complexity, the analyses reported in this paper are limited to the defined and specified goals. Essentially, the procedures for finding answers to different objectives or goals than those specified in this report will remain the same. The primary purpose of this report is to show how biological data can be used to provide useful economic information.

METHODS

Data used in these economic evaluations came from a study of precommercial thinning in a 25-year-old northern hardwood stand in New Hampshire. Stand composition and size distribution before thinning are shown in table 7, (appendix). Of approximately 400 crop trees selected per acre in this stand, about half were paper birch; the other half were yellow birch, white ash, sugar maple, red maple, or beech (table 8, appendix).

Other reports have been made on the biological aspects of this study since its initiation in 1959. The stand history and condition at the time of thinning have been described in detail (*Marquis 1967*). The effects of thinning on growth and quality of the residual stems,

as well as further details of how the thinnings were analyzed, have been reported elsewhere (*Marquis 1969*). This report has incorporated the necessary physical data from those earlier studies.

The thinning study involved three thinning techniques based on crown competition for growing space, plus a control. Treatments were applied on 1/4-acre plots, and each was replicated 5 times for a total of 20 plots. The treatments were as follows:

1. No thinning.—These plots were left undisturbed to develop naturally. They constituted a control or standard against which to measure the response of other groups of plots.

2. Light thinning.—For each crop tree, the one nearby tree offering the greatest competition was removed.

3. Species thinning.—Aspen, pin cherry, and striped maple were eliminated, and red maple sprout clumps of three or more stems were thinned. The relationship of thinned trees to crop trees was not considered.

4. Heavy thinning.—All trees competing directly with the crop trees were removed.

The thinning study provided a record of species and sizes of trees present before thinning, those removed in thinning, and those present 5 years after thinning in 1964 when the stand was 30 years old. Growth data from selected individual crop trees of all sizes and species were also obtained from the thinning study (table 9, appendix). From the 1964 growth, mortality, and stand-table records, stand-table projections were made for each plot to: (1) 10 years after thinning or a stand age of 35 years; (2) 15 years after thinning or a stand age of 40 years; (3) 20 years after thinning or a stand age of 45 years. These projections were then used as a basis for a series of tests to determine which thinning treatment—species, light, heavy or control—performed better under varying product and investment return goals.

Stand Projections

The stand-table projections were made by using tree-diameter-movement ratios developed from the growth data, using the method described by Davis (*1954*). After projection, estimated mortality was deducted to produce the final stand tables for 10, 15, and 20 years after thinning. Mortality was not considered in the crop-tree stand projections.

Timber volumes, measured in cords, were estimated by multiplying numbers of trees shown in the stand tables by appropriate volumes. Local volume tables were constructed by applying height-diameter relationships for trees on the Bartlett Experimental Forest in New Hampshire (where the thinning-study plots were located) to the standard Gevorkiantz and Olsen volume tables for hardwoods, to a 4-inch top inside bark (*1955*). Conversions were also made to reflect volumes to a 6-inch top for estimating outcomes for higher-grade products such as boltwood. The final product of the projections was the volume of each plot by species and size class, in cords to a 4-inch top and to a 6-inch top as summarized in tables 10 and 11 (appendix).

To make the stand projections, it was necessary to assume that:

1. All trees would maintain the same growth rate during the three subsequent 5-year projection periods as they actually achieved during the first 5-year study period. For example, 6-inch paper birch trees in the heavy-thinning plots grew an average of 1.13 inches in the first 5-year study period, so we projected the same growth rate for the next three 5-year periods for these trees.

2. Mortality by treatment and species would continue at the same relative rate as during the first 5-year period; it would occur in the smallest size classes first; and no mortality would occur after the trees had reached 6 inches d.b.h.

Neither of these assumptions is entirely valid. Both growth rate and mortality can be expected to change as the stands close and the initial effects of the thinning disappear. To guard against the introduction of large errors,

we tested our projection procedures by projecting the original (1959) stand tables for 5 years and comparing the results with the actual 1964 stand tables. Projections made for the other three 5-year periods were also compared with published yield tables for northern hardwood stands of these ages (*Leak, Solomon, and Filip 1969*). Since the projected yields conformed reasonably well to the published yield tables, and since the differences of yield among the various thinning practices were logical, the projected stand tables were judged satisfactory for our purposes.

Economic Evaluation

Cost and value of the precommercial thinnings were made by using the most reliable cost estimates available. Cost for removal of precommercially thinned trees are not well established, but were estimated at 1 cent per diameter inch for the trees removed. For most of this evaluation we did not include the cost of marking timber, land, taxes, or supervisory management. Although the latter three costs are constant for any thinning method, we have used the costs shown in table 1 for this analysis.

Product values were estimated from specifications and price quotations of several wood-products manufacturers. The following schedule of prices and specifications was adopted:

Product	*Specifications*	*Unit stumpage price (per cord)*
Pulpwood	All merchantable species; volume measured to 4-inch top.	$ 2.00
Small boltwood	Paper birch, yellow birch, and white ash trees only; volume measured to 6-inch top.	$ 8.00
Large boltwood	Not calculated unless stand contained at least 20 paper birch, yellow birch, or white ash trees per acre 12-inches d.b.h. and larger; volume measured to 6-inch top.	$14.00

Using the stand volume projections and cost and product price estimates described above, we calculated the value attained by each of the plots after 5, 10, 15, and 20 years. These values were calculated for several products or product combinations as follows:

1. *Pulpwood.*—Value of all trees to a 4-inch merchantable top height, including non-crop trees.
2. *Small boltwood.*—Value of birch and ash trees 6-inches d.b.h. or larger to a 6-inch merchantable top height.
3. *Large boltwood.*—Value of birch and ash trees 6-inches d.b.h. or larger; minimum requirement at least 20 trees 12 inches d.b.h. or larger/acre.
4. *Combined pulpwood-boltwood.*—
   a. *Small boltwood-pulpwood.*—All merchantable trees evaluated; values included small boltwood plus pulpwood value of all other trees.
   b. *Large boltwood-pulpwood.*—All merchantable trees evaluated; values included large boltwood plus pulpwood value of all other trees.

To test the performance of the thinning methods, the five values for each thinning-practice plot were then compared with similar values for the unthinned plots for a total of 25 comparisons between a thinned and unthinned treatment to see how much the thinning had increased the stand value. All com-

Table 1.—Cost estimates used in the economic evaluation

Thinning method	Average cost/acre for tree removal	Initial timber land costs/acre	Annual tax costs/acre	Marking costs/acre	Annual supervision and protection costs/acre
No thinning	—	$20.00	$0.25	—	$0.25
Species thinning	$17.84	20.00	.25	—	.25
Light thinning	10.90	20.00	.25	$3.00	.25
Heavy thinning	19.76	20.00	.25	3.00	.25

parisons showing positive value differences were then divided by tree-removal costs to determine the value ratio between a thinned plot and each unthinned plot. Each ratio was then used to determine the rate of return.

Rate of return $= (1 + i)^n = \frac{V_n}{V_0}$, where i = interest rate; n = period of years; V_n = net income due to thinning after n years; and V_0 = present capital value of investment (cost of thinning).

In addition to the individual plot values, we calculated the average treatment volume (in cords per acre) and value for each age-product situation for the *crop trees only* and the volume and value for each age-product situation for the total stand (tables 2 and 3).

RESULTS AND DISCUSSION

Thinning Investment Under Limited Costs

We first considered an investment in thinning where a forest owner considered the cost of thinning only. Table 4 shows the proportion of the thinning investment comparisons that equal or exceed 0, 2, 4, 6, and 10 percent return on thinning investment. For example, the 96 percent at the right hand side of the first row of table 4 means that species thinning produced a positive return from thinning at age 45 in 96 percent (24 of 25) of the comparisons, under a combination pulpwood-bolt-

Table 2.—Average volume and value in standard cords/acre generated by selected product and time period for crop trees only

Thinning method	Small boltwood @ $8/cord								Large boltwood @ $14/cord	
	Age 30		Age 35		Age 40		Age 45		Age 45	
	Volume	Value	Volume	Value	Volume	Value	Volume	Value	Volume	Value
	Cords		*Cords*		*Cords*		*Cords*		*Cords*	
No thinning	(1)	(1)	(1)	(1)	6.9	$55	10.0	$80	(1, 2)	(1, 2)
Species thinning	(1)	(1)	6.4	$51	10.1	81	14.7	117	14.7	$206
Light thinning	(1)	(1)	6.4	51	9.7	78	13.6	109	13.5	190
Heavy thinning	(1)	(1)	5.3	42	8.9	71	13.2	106	(1, 2)	(1, 2)

[1] Insufficient volume to meet the specification for products.
[2] Maximum volume and value would equal that shown for small boltwood and pulpwood at age 45. See specifications.

Table 3.—Average volume and value in standard cords/acre generated by selected product and time period for the total stand

Thinning method	Pulpwood		Small boltwood and pulpwood @ $8/cord & $2/cord				Large boltwood and pulpwood @ $14/cord & $2/cord	
	Age 45		Age 40		Age 45		Age 45	
	Volume	Value	Volume	Value	Volume	Value	Volume	Value
	Cords		*Cords*		*Cords*		*Cords*	
No thinning	24.5	$49	17.1	$87	24.5	$124	(1)	(1)
Species thinning	27.0	54	18.1	107	27.0	157	27.0	$260
Light thinning	25.6	51	18.2	97	25.6	134	25.6	216
Heavy thinning	24.9	50	15.8	86	24.9	131	(1)	(1)

[1] Insufficient volume to meet the specification for large boltwood; maximum volume and value would equal that shown for small boltwood and pulpwood at age 45. See specifications.

Table 4.—Rate of return from investment in precommercial thinning: proportion of comparisons meeting selected rates of return in various potential markets

Treatments compared	Pulpwood @ $2/cord	Boltwood					Combination of pulpwood @ $2/cord and boltwood @ $8/cord		Combination of pulpwood @ $2/cord, small boltwood @ $8/cord, and large boltwood @ $14/cord
		Small @ $8/cord				Large @ $14/cord			
	Age 45	Age 30	Age 35	Age 40	Age 45	Age 45	Age 40	Age 45	Age 45
					0 PERCENT OR MORE RATE OF RETURN				
Species vs. no thinning	96	0	76	76	80	80	80	80	96
Heavy vs. no thinning	100	0	36	68	76	40	68	92	88
Light vs. no thinning	80	0	60	80	80	76	80	80	92
					2 PERCENT OR MORE RATE OF RETURN				
Species vs. no thinning	20	0	64	56	64	76	56	64	76
Heavy vs. no thinning	0	0	32	44	52	40	44	56	76
Light vs. no thinning	48	0	52	60	64	76	60	64	88
					4 PERCENT OR MORE RATE OF RETURN				
Species vs. no thinning	0	0	64	52	56	76	52	56	76
Heavy vs. no thinning	0	0	32	32	32	40	28	44	64
Light vs. no thinning	8	0	48	60	60	76	60	60	80
					6 PERCENT OR MORE RATE OF RETURN				
Species vs. no thinning	0	0	64	44	40	72	44	36	76
Heavy vs. no thinning	0	0	32	16	12	40	12	12	44
Light vs. no thinning	0	0	48	56	48	76	56	48	80
					10 PERCENT OR MORE RATE OF RETURN				
Species vs. no thinning	0	0	48	12	4	64	12	4	64
Heavy vs. no thinning	0	0	32	8	0	32	4	0	32
Light vs. no thinning	0	0	48	20	8	64	20	8	52

wood market situation. The 76 percent in the next group below indicates that species thinning yielded at least 2 percent return on investment in 76 percent of the comparisons.

The study results revealed several general trends. First, returns from precommercial thinnings are low during the first 5 to 10 years after thinning. Higher returns are not obtained for at least 15 to 20 years. Second, returns from thinning are low if low-value products such as pulpwood are the goal. Much higher returns are realized when high-value products such as boltwood are to be obtained.

Thus, investments in precommercial thinning are most likely to be justified when high-value products are the goal and where short rotations or early returns are not required. This makes sense, for precommercial thinning has relatively little effect on total stand growth; it serves merely to distribute growth to the crop trees, which have high market value.

Another general conclusion may be drawn from table 4: that fairly attractive returns may be expected from precommercial thinnings where high-value boltwood products are the management goal. For example, after 20 years the more successful thinning techniques had produced 6 percent or more return on investment in 75 to 80 percent of the comparisons, and they had produced 10 percent return on investment in 50 to 65 percent of the comparisons analyzed. Although currently-available data did not justify analysis beyond a 20-year time span, it seems possible that analyses performed at the end of the rotation (normally 60 to 100 years for these species) would reveal even more attractive returns when sawtimber and veneer would be obtained.

Thinning Investment For Various Owners

The 0-, 2-, and 4-percent interest rates shown in table 4 apply to land on which the owner would continue to hold the land even if he could not realize a profit from timber-growing activites alone. This situation is common among public land owners and some private owners who hold their land for multiple benefits such as wildlife, water, and recreation. It might also apply to those who hold forest land to insure a steady or guaranteed source of wood for their own mills. Generally, the fixed costs of taxes, protection, and land management do not influence decision-making on these lands.

Table 5.—Expected gross per-acre income from growing northern hardwood timber to age 45, with and without thinning on land owned for multiple-benefits

Item	No thinning	Species thinning	Light thinning	Heavy thinning
1. Average merchantable volume in standard cords/acre[1]	24.5	27.0	25.6	24.9
2. Highest merchantable value from harvesting both pulpwood and boltwood in 20-year period	$124	$260	$216	$131
3. Present value of wood attributable to thinning (item 2 minus $124)	0	136	92	7
4. Marking and tree-removal cost[2]	0	17.84	13.90	22.76
5. Investment cost for marking and tree removal after 20 years @ 6-percent compound interest rate	0	57	45	73
6. Percent return on thinning investment	—	10.6%	9.9%	(3)
7. Gross income on investment—(item 2 minus 5)	$124	$203	$171	$58
8. Gain or loss in 20-year period attributed to thinning (item 3 minus 5)[4]	—	79	47	—66

[1] Volume and values shown in items 1 and 2 are those derived in table 3.
[2] All costs are based on values shown in table 1.
[3] Negative.
[4] Neither capital gains nor timber price changes are considered in determining gain or loss.

Table 6.—Expected gross per-acre income from growing northern hardwood timber to age 45, with and without thinning on land held solely as an investment in timber production

Item	No thinning	Species thinning	Light thinning	Heavy thinning
1. Average merchantable volume in standard cords/acre[1]	24.5	27.0	25.6	24.9
2. Highest merchantable value from harvesting both pulpwood and boltwood in 20-year period	$124	$260	$216	$131
3. Present value of wood attributable to thinning (item 2 minus $124)	0	136	92	7
4. Average marking and tree-removal cost[2]	0	17.84	13.90	22.76
5. Investment cost for marking and tree removal after 20 years @ 6-percent compound interest rate	0	57	45	73
6. Investment costs of taxes, supervision, and protection after 20 years @ 6-percent compound interest rate	18	18	18	18
7. Investment cost of land after 20 years @ 6-percent compound interest rate	64	64	64	64
8. Total costs (items 5 + 6 + 7)	91	148	136	164
9. Expected gross income on investment (item 2 minus 8)[3]	42	121	89	—24

[1] Volume and values shown in items 1 and 2 are those derived in table 3.
[2] All costs are based on values shown in table 1.
[3] Neither capital gains nor timber price changes are considered in determining gain or loss.

Another point of view we want to illustrate is that of an owner who will not continue to hold his forest land unless the timber-management activities *alone* will provide an acceptable return on investment. In this illustration of the economics applied to our thinning study, we used the costs shown in table 1 and the volume and value data for the various products shown in tables 2 and 3.

First, we illustrate how a multiple-use forest owner might treat these costs. He would consider only those direct costs affecting timber-production activities when selecting an activity or alternative activity. In our analysis, these costs are similar to our timber-marking and tree-removal costs (table 1). Table 5 shows how a multiple-use forest owner might look at an investment in one of the thinning methods.

Now, a single-use investor in timber management might not only consider the thinning-investment cost, but also the fixed costs of protection, taxes, and forest management. These costs are fixed because they will remain the same whether he thins the forest stand or lets nature take its course. Table 6 illustrates this point. These fixed costs *do* enter into the decision to apply a thinning method or to select the best thinning method.

From these illustrations (tables 5 and 6), we can see that precommercial thinning materially increases the volume and value realized from growing northern hardwoods. To maintain this accelerated increase in value, thinning costs must be kept at a minimum. There is every indication that thinning can increase stand growth and quality, but the value of the increases must exceed thinning costs to be profitable.

Thinning Methods

Of the three thinning methods studied, the light crop-tree thinning and the species thinning generally produced higher returns than the heavy crop-tree thinning. The higher returns from these two treatments are due to the fact that very few merchantable trees were removed in these thinnings; relatively few trees of any kind were removed in the light

thinning, and all trees removed in the species thinning were noncommercial tree species. Thus residual stands treated by light or species thinning contained more volume than did residual stands treated by heavy thinning. Although growth rate of the residuals was highest after heavy thinning, this was not enough to offset the lower residual volume and higher treatment costs during the 20-year time span considered here. However, the heavy treatment shows promise of outperforming the others over a longer time span.

After random assignment of plots to treatments, it was found that the heavy-thinning plots had fewer paper birch trees in the 5- to 8-inch d.b.h. classes than the other three treatments (61 versus 90 to 104). Since paper birch represents the major part of the yields reported here, this initial difference in stocking has tended to reduce the early yields on the heavy thinning plots more than they would have been had all plots had equal initial stocking. No adjustments in the data and discussion have been made for this difference.

Differences in tree-removal costs and the greater volume in larger trees also account for the better performance of light thinning than species thinning for some of the comparisons. However, we must recognize that under certain market criteria, species thinning would be preferred because this thinning method leaves more merchantable birch and ash trees in the stand than the light crop-tree thinning. The considerably higher cost of tree removal in the species thinning is more than offset by the better growth rate achieved by this thinning.

However, the difference in rate of return between these two treatments was generally small. In fact, when costs of marking timber and tree removal are included, the species-thinning investment return is 10.6 percent as compared to 9.9 percent for the light thinning (table 5).

CONCLUSIONS

The desirability of an investment in precommercial thinning in young northern hardwood stands depends upon the product goals and the time periods under consideration. Where pulpwood or other low-value products are to be grown on short rotations, investments in precommercial thinning are seldom justified.

But where high-value products such as large and small boltwood are to be grown over a long enough rotation to achieve large trees of high quality, investments in precommercial thinning frequently produce 6 percent or more return on investment. Precommercial thinning investments are particularly attractive on areas where timber production is the major land use.

Of the several thinning methods analyzed in this study, the light crop-tree and species thinning offered an investment advantage over the heavy-thinning method. This was due to the fact that the initial thinning costs are low for the light thinning and that there were no marking costs in the species thinning. In addition, relatively few trees of commercial species were removed in the light and species thinnings, so that a commercial thinning is possible somewhat earlier than in the other treatments. Growth rates were better in both the species thinning and the heavy crop-tree thinning, and crown closure will probably occur sooner in the light thinning. There is some indication that these factors will be important enough to offset the lower treatment costs of the light thinning.

Since initial treatment costs and the volume in merchantable non-crop trees were such important factors, it seems likely that a reduction in the number of crop trees selected would be advisable. If 200, rather than 400, crop trees were selected and the stand was thinned, there would still be more than enough crop trees at maturity, costs of precommercial thinning would be reduced, more non-crop trees would be available for an early commercial thinning, and the costs and benefits of the thinning would be concentrated on those few stems that will be carried long enough to yield high-value products. Such a thinning should combine the silvicultural advantages of a heavy thinning with the economic advantages of lower initial cost and higher residual stand volume.

APPENDIX

Table 7.—Average number of trees per acre on all thinning plots, by species and diameter class, before thinning

Diameter class (inches)	Paper birch	Yellow birch	White ash	Sugar maple	Red maple	Beech	Aspen	Conifers	Others[1]	Total trees/ acre
1	85	248	32	807	80	759	1	25	205	2,242
2	112	142	26	159	48	213	5	23	287	1,015
3	78	61	18	40	25	41	7	6	179	455
4	61	20	13	8	18	3	8	3	70	204
5	41	2	3	1	3	1	7	1	15	74
6	21	1	1	1	1	—	10	—	2	37
7	7	—	—	—	—	—	4	—	1	12
8	1	—	—	—	—	—	3	—	—	4
9	—	—	—	—	—	—	1	—	—	1
10	—	—	—	—	—	—	1	—	—	1
11	—	—	—	—	—	—	—	—	—	—
12	—	—	—	—	—	—	—	—	—	—
13	—	—	—	—	—	—	—	—	—	—
14	—	—	—	—	—	—	—	—	—	—
15	—	—	—	—	—	—	—	—	—	—
Total	406	474	93	1,016	175	1,017	47	58	759	4,045

[1] Others consisted mainly of pin cherry and striped maple.

Table 8.—Average number of crop trees per acre on all thinning plots, by species and diameter class, before thinning

Diameter class (inches)	Paper birch	Yellow birch	White ash	Sugar maple	Red maple	Beech	Others[1]	Total trees/ acre
1	—	—	—	—	—	—	—	—
2	14	14	3	28	4	11	—	74
3	38	32	8	33	6	9	—	126
4	41	18	12	9	8	3	1	92
5	40	4	6	2	2	—	—	54
6	24	1	1	1	1	—	—	28
7[2]	11	—	—	—	—	—	—	11
8	2	—	—	—	—	—	—	2
Total	170	69	30	73	21	23	1	387

[1] Others consisted mainly of conifers.

[2] Discrepancies in total and crop-tree stand tables occur because in some cases the crop trees were selected one growing season after original inventory.

Table 9.—The diameter growth in inches of selected crop trees by diameters and precommercial thinning method for the first 5 years after thinning

Crop-tree diameter (inches)	Thinning method			
	None	Light	Species	Heavy
		PAPER BIRCH		
2	0.11	0.20	0.44	0.53
3	.36	.37	.55	.63
4	.62	.65	.68	.72
5	.82	.88	.85	.94
6	.98	1.07	1.06	1.13
		YELLOW BIRCH		
2	.21	.27	.30	.55
3	.39	.48	.45	.69
4	.58	.66	.60	.88
5	.68	.80	.86	1.05
6	.85	.91	1.00	1.16
		WHITE ASH		
2	.50	.44	.59	.82
3	.68	.67	.70	.91
4	.86	.90	.87	1.07
5	1.00	1.10	1.14	1.18
6	1.12	1.28	1.51	1.25
		SUGAR MAPLE		
2	.10	.27	.46	.45
3	.28	.46	.63	.66
4	.67	.85	.85	.85
5	1.00	1.10	1.00	1.00
6	1.17	1.24	1.10	1.15
		RED MAPLE		
2	.35	.18	.46	.34
3	.60	.34	.66	.50
4	.79	.72	.96	.70
5	.86	1.11	1.08	1.60
6	.92	1.33	1.15	1.75
		BEECH		
2	.23	.26	.27	.60
3	.34	.43	.47	1.00
4	.49	.62	.77	1.22
5	.66	.82	1.00	1.34
6	.82	1.02	1.12	1.42

Table 10.—Average number of crop trees, by volume, for each thinning practice, by 5-year period for all plots[1]

Species	1959		1964		1969		1974		1979	
	Average trees/ plot	Volume	Average trees/ plot	Volume	Average trees/ plot	Volume	Average trees/ plot	Volume	Average trees/ plot	Volume
	No.	*Cords*	*No.*	*Cords*	*No.*	*Cords*	*No.*	*Cords*	*No.*	*Cords*
					NO THINNING					
Paper birch	196	1.3	191	3.0	191	5.6	191	8.4	191	11.7
Yellow birch	69	+	69	.1	69	.2	69	.5	69	.9
White ash	12	.1	12	.1	12	.2	12	.4	12	.7
Sugar maple	69	—	69	+	69	.1	69	.3	69	.5
Red maple	21	+	21	+	21	.2	21	.4	21	.7
Beech	19	—	19	—	19	—	19	—	19	+
Others	6	—	6	+	6	.1	6	.1	6	.2
Total	392	1.4	387	3.2	387	6.4	387	10.1	387	14.7
					LIGHT THINNING					
Paper birch	170	2.1	170	4.6	170	7.7	170	11.3	170	15.3
Yellow birch	52	+	44	.1	44	.2	44	.4	44	.8
White ash	24	+	24	.2	24	.6	24	1.3	24	2.0
Sugar maple	96	+	95	.1	95	.4	95	1.1	95	2.0
Red maple	8	—	8	+	8	.2	8	.3	8	.5
Beech	30	—	30	—	30	+	30	.1	30	.2
Others	1	+	1	+	—	—	—	—	—	—
Total	381	2.1	372	5.0	371	9.1	371	14.5	371	20.8
					SPECIES THINNING					
Paper birch	166	1.4	165	4.0	165	7.0	165	10.5	165	14.4
Yellow birch	82	—	82	.1	82	.4	82	.9	82	1.6
White ash	42	—	42	.3	42	1.1	42	2.1	42	3.6
Sugar maple	48	+	48	+	48	.1	48	.4	48	.8
Red maple	29	.1	29	.2	29	.6	29	1.1	29	1.7
Beech	36	+	37	+	37	.1	37	.3	37	.5
Total	403	1.5	403	4.6	403	9.3	403	15.3	403	22.6
					HEAVY THINNING					
Paper birch	146	1.0	146	2.7	146	5.0	146	7.9	146	11.0
Yellow birch	75	+	74	.1	74	.5	74	1.2	74	2.1
White ash	46	.1	46	.5	46	1.5	46	2.8	46	4.5
Sugar maple	79	+	80	.1	80	.6	80	1.3	80	2.4
Red maple	26	—	26	.2	26	.9	26	1.7	26	2.7
Beech	10	—	10	—	10	—	10	.1	10	.2
Total	382	1.1	382	3.6	382	8.5	382	15.0	382	22.9

[1] Mortality was not considered in crop-tree projections.

Table 11.—Average number of trees (total stand) by volume for each thinning practice by 5-year period for all plots

Species	1959		1964		1969		1974		1979	
	Average trees/ plot	Volume	Average trees/ plot	Volume	Average trees/ plot	Volume	Average trees/ plot	Volume	Average trees/ plot	Volume
	No.	*Cords*	*No.*	*Cords*	*No.*	*Cords*	*No.*	*Cords*	*No.*	*Cords*
					NO THINNING					
Paper birch	494	1.1	362	3.6	268	6.8	200	10.2	177	14.3
Yellow birch	521	+	357	.2	249	.5	177	.9	128	1.7
White ash	31	+	22	.1	15	.2	11	.5	11	.8
Sugar maple	864	—	644	+	482	.1	363	.4	274	.7
Red maple	185	+	118	+	76	.3	50	.6	33	1.0
Beech	1,068	+	816	.1	633	.1	498	.2	398	.3
Conifers	138	—	117	.1	99	.2	84	.3	72	.5
Aspen	47	.9	41	1.8	36	2.8	34	4.0	34	5.2
Others	906	+	275	.1	—	—	—	—	—	—
Total	4,254	2.0	2,752	6.0	1,858	11.0	1,417	17.1	1,127	24.5
					LIGHT THINNING					
Paper birch	374	1.3	235	4.6	165	7.8	141	11.5	137	15.3
Yellow birch	278	.1	170	.2	111	.3	74	.6	52	1.0
White ash	62	+	46	.2	36	.6	30	1.3	26	2.0
Sugar maple	1,350	.1	985	.2	747	.6	572	1.4	443	2.4
Red maple	70	+	28	+	18	.2	12	.3	10	.5
Beech	1,016	—	820	+	658	.1	534	.2	436	.4
Conifers	18	—	17	+	14	+	13	.1	12	.2
Aspen	70	.9	30	1.0	27	1.9	26	2.8	26	3.8
Others	671	+	123	.1	—	—	—	—	—	—
Total	3,909	2.4	2,454	6.3	1,776	11.5	1,402	18.2	1,142	25.6
					SPECIES THINNING					
Paper birch	345	1.1	281	4.5	229	8.2	188	12.5	182	17.2
Yellow birch	456	+	326	.1	235	.6	170	1.1	125	2.1
White ash	115	—	88	.3	70	1.1	60	2.1	53	3.6
Sugar maple	874	—	655	+	493	.1	373	.5	283	1.0
Red maple	202	.1	91	.2	57	.6	42	1.2	31	1.8
Beech	1,175	—	1,003	+	858	.1	734	.5	630	1.0
Conifers	26	+	23	.1	21	.1	20	.2	18	.3
Aspen	16	.5	—	—	—	—	—	—	—	—
Others	874	+	19	—	—	—	—	—	—	—
Total	4,083	1.7	2,486	5.2	1,963	10.8	1,587	18.1	1,322	27.0
					HEAVY THINNING					
Paper birch	409	.8	238	2.7	175	5.1	137	8.0	121	11.1
Yellow birch	638	.1	387	.1	276	.5	203	1.4	154	2.4
White ash	161	.3	80	.5	54	1.5	40	2.7	39	4.4
Sugar maple	980	.1	725	.1	574	.6	455	1.4	362	2.5
Red maple	248	—	110	.2	70	1.1	46	2.0	35	3.2
Beech	810	—	675	—	557	+	463	.2	387	1.1
Conifers	51	.1	38	.1	30	.1	22	.1	18	.1
Aspen	58	.6	3	+	2	+	2	+	2	.1
Others	586	—	51	—	—	—	—	—	—	—
Total	3,941	2.0	2,307	3.7	1,738	8.9	1,368	15.8	1,118	24.9

*U.S. GOVERNMENT PRINTING OFFICE: 1972-708-041/387

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