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Early Crop-Tree Release and Species Cleaning in Young Northern Hardwoods: A Financial Analysis

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Abstract

In 1959 a study of crop-tree release and species cleaning was established in a 25-year-old northern hardwood stand growing on an above-average hardwood site that resulted from a silvicultural clearcut in the White Mountains of New Hampshire. Three treatments—light crop-tree release, heavy release, and species cleaning—were randomly assigned to quarter-acre plots, five plots per treatment, including five untreated plots. The stand was followed for 5 years and based on the results, treatment effects were projected to a stand age of 45 years. These projections were subjected to a financial analysis. The treatment plots were tallied at stand ages 56 (1990) and 69 (2003) years. We summarize the results of the early crop-tree release and species cleaning and provide a long-term financial perspective based on the new tallies. Our goal was to repeat the financial analysis and re-examine the results and conclusions of the original study. We found that the return on investment at stand ages 56 and 69 years was not as good as originally reported. The least expensive treatment, a light crop-tree release, gave the greatest return on investment. An opportunity for a commercial thinning between stand age 45 and 56 was missed and most likely would have improved the financial outcome of the treatments. Approximately 400 crop trees per acre were selected for release in 1959 but 200 crop trees per acre would have been more than sufficient and would have improved the financial outcome of the treatments by lowering initial cost. On a similarly good hardwood site, with an equally well stocked young stand, and good markets for small diameter roundwood, we only can speculate that releasing 200 or preferably fewer dominant or codominant trees per acre at stand age 25 followed by a commercial thinning when feasible after stand age 45 could be a good investment for a landowner.

Cover Photo

Seventy-year-old northern hardwoods in an untreated area of the stand originating from a clearcut on the Bartlett Experimental Forest on the White Mountain National Forest, New Hampshire. Photo by Mariko Yamasaki, U.S. Forest Service.

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INTRODUCTION

Effects of early crop-tree release and species cleaning in young hardwood stands have been well documented. In a review of the literature, Heitzman and Nyland (1991) found early crop-tree release results in increased diameter growth of released trees and improvement in species composition of the young stand. On the other hand, bole quality may decrease due to delay in natural pruning, more epicormic branching, and forking at lower levels. They also found agreement that a crown-touching release of crop-trees is adequate, simple to apply, and probably most cost efficient if done manually with a chainsaw. The literature that Heitzman and Nyland reviewed was based on short-term studies with one exception, a case study in Maine. Few data have been collected on long-term effects. This information is critical in assessing the long-term economic benefits of early crop-tree release and species cleaning in hardwoods.

Marquis (1969[1]) reported on 5-year results of species cleaning (hereafter referred to as 'cleaning') and crop-tree release based on three treatments and a control in a 25-year old northern hardwood stand resulting from a clearcut. Using data from the same stand at 25 and 30 years, stand growth was projected in 5-year increments up to stand age of 45 years. Financial analysis also was applied to the projected stand data to determine the investment potential of precommercial treatments in young northern hardwoods (McCauley and Marquis 1972[2]).

In 1990 (stand age 56), trees were measured and Leak and Solomon (1997) reported on long-term growth of crop-trees; Leak and Smith (1997) reported on long-term species and structural changes. The stand was remeasured in 2003, before a planned commercial thinning. We summarize the results of the early crop-tree release and cleaning and provide a long-term financial perspective based on the 1990 and 2003 measurements. Our goal was to repeat the financial analysis and re-examine the results and conclusions reported by McCauley and Marquis (1972).

[1]This publication is available only online at www.treesearch.fs.fed.us/pubs/7064

[2]This publication is available only online at www.treesearch.fs.fed.us/pubs/23652

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Photo: U.S. Forest Service

Figure 1.—Clearcut of a mature northern hardwood stand in the Bartlett Experimental Forest, 1935.

Photo: U.S. Forest Service

Figure 2.—The 25 year old hardwood stand before treatment, 1959.

METHODS

Original Stand

The study occurred in a mature northern hardwood stand on the Bartlett Experimental Forest in the White Mountains of New Hampshire (Fig. 1). The site is on a lower slope of 20-25 percent, at an elevation of 1,100 ft, with a northerly aspect. The soil is a fine-textured till over basal till. It is an excellent hardwood site with a site index for paper birch of 70 (base age 50). The stand was composed mostly of beech (61 percent of basal area, trees ≥4.6 in diameter at breast height [d.b.h.]), yellow birch (15 percent), and sugar maple (15 percent) and smaller amounts of red maple, white ash, and paper birch. Basal area averaged 122 ft^2/ac and advance regeneration was primarily sugar maple, beech, and striped maple. The 22-acre stand was clearcut in the winter months between 1933 and 1935 and all hardwoods ≥1.6 in d.b.h. and conifers ≥4.6 in d.b.h. were cut. A few larger white ash trees were left as seed trees (Marquis 1967[3]). An average of 60 cords/ac of wood was removed after the snow was gone each season.

Experimental Treatments

In 1959, 20 quarter-acre plots were systematically located in the second growth stand and tallies of all trees were taken in 1959 and in 1964 (Fig. 2). Approximately 100 crop trees were selected on each quarter-acre plot and 382 of these were selected for detailed measurement (Fig. 3). In selecting crop trees, preference was given to paper birch (44 percent of crop trees), yellow birch, sugar maple, and white ash; seedlings were preferred over sprouts (Fig. 4); large dominant and codominant trees were preferred; and preference was given to trees of good form. Three precommercial treatments and an uncut control were established on the 20 quarter-acre plots in 1959, each treatment randomly assigned to five quarter-acre plots, with a 1-chain wide isolation strip between plots. The treatments were:

- **Heavy crop-tree release** removed all trees whose crowns competed with each crop tree for growing space (383 crop trees/ac). Under this treatment, 615 trees/ac and 41 ft^2 of basal area were removed, leaving an average residual basal area of 56 ft^2 (trees ≥0.5 in d.b.h.).

[3]This publication is available only online at www.treesearch.fs.fed.us/pubs/3902

Photo: U.S. Forest Service

Figure 3.—Measuring a crop tree, 1959.

Photo: U.S. Forest Service

Figure 4.—Red maple sprout clump marked for cutting to release single stem (double-banded crop tree). Trees of seedling origin were given preference over sprouts but sprouts were selected when necessary.

- **Light crop-tree release** removed a maximum of one of the trees competing with each crop tree (373 crop trees/ac). Under this treatment, an average of 326 trees/ac and 25 ft^2 of basal area were removed, leaving an average residual basal area of 72 ft^2/ac.

- **Species cleaning** or weeding removed all aspen, pin cherry, striped maple, and red maple sprout clumps except sprouts selected as crop trees, whether or not they were competing with crop trees (402 crop trees/ac). Under this treatment, an average of 620 trees/ac and 33 ft^2 of basal area were removed, leaving an average residual basal area of 65.5 ft^2/ac. Note: In 1971 (stand age 37) about 96 crop trees/ac were released from about half of the competing stems, removing about one-third of the basal area and a fertilizer (15-10-10, 2 tons/ac)/lime (4 tons/ac) treatment was applied to about half the crop trees. We could not identify the trees that received the additional fertilizer/lime treatment. The cost of release and fertilizer/lime treatment in 1971 was unknown. Thus we dropped the species cleaning treatment from the financial analyses but included data on numbers of trees and volume.

- Control removed no trees; 392 crop trees were selected and average basal area for the control was 99.6 ft^2/ac.

In 1959, sodium arsenite applied in frills was used to kill unwanted trees. The goal of the heavy and light crop-tree release treatments was to move the stands toward higher proportions of larger high-quality stems of more valuable species, while in the species cleaning treatment the goal was to eliminate undesirable shade-intolerant species, favoring paper birch and longer lived species.

Financial Analysis

McCauley and Marquis (1972) estimated cost of trees removed at 1 cent/diameter-inch and calculated an average cost for treatment: $10.90/ac for light release, $17.84/ac for cleaning, and $19.76/ac for heavy release (see Table 1 in McCauley and Marquis 1972). They estimated initial timber and land cost at $20/ac, annual tax at 25 cents/ac, marking costs at $3/ac, and annual supervision and protection at 25 cents/ac. Values were estimated from price quotes based on product specifications from several wood products firms. The cost and revenue per treated plot were compared with similar values for the untreated control plots for a total of 25 comparisons per treatment. Rate of return was calculated for 30, 35, 40, and 45 years using net income due to treatment at the end of the period and the cost of treatment using the formula:

$$i = [(V_n / V_0)^{1/n}]-1$$

where i is rate of return,
V_n is income due to treatment,
V_0 is cost of treatment (investment), and
n is period of years (see Table 4 in McCauley and Marquis 1972).

McCauley and Marquis also calculated average rate of return by treatment on land owned for multiple benefits, that is, on land that would continue to be held for its other benefits even if it did not realize a profit from timber management activities alone (see Table 5 in McCauley and Marquis 1972). This analysis included the cost of marking timber but not the fixed costs of ownership. They also analyzed the situation where the only purpose for holding land was to make a profit from timber management activities, in which they included fixed costs as well as variable costs of treatment options (see Table 6 in McCauley and Marquis 1972). These analyses assumed an interest rate of 6 percent (implied real rate) and constant product prices. We repeated their analyses on plot data we collected at stand ages 56 and 69 years. We dropped the cleaning treatment because the partially applied fertilizer/lime treatment effects could not be separated from the cleaning/release effects. We also did not include a fixed-cost analysis.

RESULTS

Early Results

Growth response

Five-year growth response on all crop trees resulted in about a one-third increase in diameter and basal-area growth on all released plots compared to the control (Marquis 1969). Growth was greater under heavy release than under other release treatments. Heavy release increased crop-tree basal-area growth by 53 percent and diameter growth by 64 percent over crop trees in the control plots. It was suggested that this result was due to increased crown area and crown volume from heavy release and maintenance of crop trees in the dominant and strong codominant crown classes compared to trees on control plots. There were no reductions in bole quality over the 5-year period that could be attributed to release. Marquis (1969) concluded that early and repeated application of these treatments would increase tree size attainable at a given age.

Financial analysis

McCauley and Marquis (1972) concluded that:

1. Where pulpwood or other low-value products are to be grown on short rotations, investments in cleaning and early crop tree release are not justified.

2. Where high-value products are to be grown over a rotation long enough to produce large trees of high quality, investment in cleaning and early crop tree release produced returns of 6 percent or more.

3. Return on investment for light crop-tree release was greater compared to heavy crop-tree release, primarily due to lower costs associated with that treatment.

4. The number of crop trees selected should be about 200/ac or about half the number released in the study.

Results at Stand Ages 56 and 69

In 1990, when the stand was 56 years old, we tallied the original plots. In 2003 when the stand was 69 years old, prior to commercial thinning, plots were tallied again. Unfortunately by 2003 the crop trees could no longer be identified. However, given that a per acre average of 170 paper birch, 69 yellow birch, 30 white ash, 73 sugar maple, and 45 other trees initially were selected as crop trees, it was assumed that most of the remaining trees were designated crop trees (Table 1). Tree volume in cubic feet (ft^3) was estimated using local species volume tables derived from measurements of trees on the Bartlett Experimental Forest. Volume in cubic feet was converted to standard cords by dividing by 79 to maintain consistency with McCauley and Marquis (1972), who reported volume in standard cords.

McCauley and Marquis estimated wood volume and value of the wood in potential products: pulpwood; small boltwood; large boltwood; combination of pulpwood and small boltwood; and combination of pulpwood, small boltwood, and large boltwood (see Table 3 in McCauley and Marquis 1972). We repeated the original financial analysis using tree data collected at stand ages 56 and 69, assuming the same cost and revenue information reported in 1972 (Tables 2, 3, and 4). There were no significant differences among treatments for wood volume or value at ages 56 and 69 ($p > 0.05$) (Table 2).

McCauley and Marquis compared each treated plot with each untreated plot, 25 comparisons per treatment, and determined the percentage of comparisons that resulted in a ≥ 0 percent, ≥ 2 percent, ≥4 percent, ≥6 percent, and ≥ 10 percent rate of return. At stand age 45 (by stand table projection from the 30-year data) they found that the rate of return for 80 percent of the comparisons was positive. The rate of return for almost a third of the comparisons (31 percent) was ≥6 percent.

At stand age 56, using the same costs and revenues we found that the percentage of plots with positive rates of return had decreased and at each of the threshold rates had decreased substantially (Table 3). There were no plots with rates of return ≥10 percent for any treatment under any of the assumed potential products and few with rates of return ≥ 6 percent. Light release treatment mostly had higher percentages of positive returns compared to the heavy release.

At age 69, percentage of plots with positive rates of return increased somewhat compared to age 56 (Table 4), but most of the rates of return were <6 percent. Ranging from 4 to 6 percent most rates of return were less at stand age 69 than they were at stand age 56. The increases in percentages were at rates of return <4 percent compared to the percentages at age 56.

McCauley and Marquis also considered the direct costs involved for a landowner selecting one of these treatments. At stand age 45, under the same treatment costs previously stated and assuming the highest revenue attainable from harvesting a combination of pulpwood and boltwood, they found percentage returns on investment of approximately 10 percent for light release treatment. Heavy release resulted in a negative return. This result was due to the restriction that to include large boltwood, the highest valued product, there needed to be at least 20 paper birch, yellow birch, or white ash trees/ac ≥12 in d.b.h. Neither the control nor the heavy release treatment met this requirement so that the highest value was for pulpwood and small boltwood (see Table 5 in McCauley and Marquis 1972).

We repeated the analysis at stand ages 56 and 69 using the same assumptions. At age 56, 31 years after treatment, light release gave a 3.5 percent return (Table 5), compared to approximately 10 percent for this treatment at age 45. The return for heavy release could not be determined because the present value of wood attributable to release was a negative number. Again neither the control nor the heavy release treatment met the 20-tree/ac requirement for large boltwood so that their highest value was for pulpwood and small boltwood. At age 69, 44 years after release, light release gave a 2.3 percent return, and heavy release a 0.2 percent return and both treatments and the control met the requirement for large boltwood (Table 6).

Table 1.—Average number of trees and volume by species for each release practice for all plots

Species	1959[a]		1964		1990		2003	
	Trees/ acre	Volume	Trees/ acre	Volume	Trees/ acre[b]	Volume	Trees/ acre[b]	Volume
	No.	*Cords*	*No.*	*Cords*	*No.*	*Cords*	*No.*	*Cords*
				NO RELEASE				
Paper birch	494	1.1	362	3.6	138	17.4	113	21.6
Yellow birch	521	([c])	357	0.2	58	2.6	56	3.0
White ash	31	([c])	22	0.1	3	0.4	9	2.5
Sugar maple	864	--	644	([a])	47	1.7	64	2.6
Red maple	185	([c])	118	([a])	26	1.7	29	2.7
Beech	1,068	([c])	816	0.1	35	1.2	64	2.3
Conifers	138	--	117	0.1	12	0.3	11	0.4
Aspen	47	0.9	41	1.8	30	6.5	20	7.1
Others	906	([c])	275	0.1	--	--	--	--
Total	4,254	2.0	2,752	6.0	349	31.7	366	42.1
				LIGHT RELEASE				
Paper birch	374	1.3	235	4.6	114	18.4	90	21.6
Yellow birch	278	0.1	170	0.2	30	1.2	28	1.7
White ash	62	([c])	46	0.2	14	1.5	22	4.3
Sugar maple	1,350	0.1	985	0.2	78	3.6	94	5.5
Red maple	70	([c])	28	([c])	2	0.1	8	1.0
Beech	1,016	--	820	([c])	34	0.9	43	1.6
Conifers	18	--	17	([c])	3	0.2	2	([d])
Aspen	70	0.9	30	1.0	22	4.3	18	6.2
Others	671	([c])	123	0.1	1	0.2	1	0.3
Total	3,909	2.4	2,454	6.3	298	30.5	307	42.2
				SPECIES CLEANING				
Paper birch	345	1.1	281	4.5	92	14.7	70	17.5
Yellow birch	456	([c])	326	0.1	62	3.1	52	3.5
White ash	115	--	88	0.3	28	3.1	27	5.7
Sugar maple	874	--	655	([c])	33	2.0	49	3.7
Red maple	202	0.1	91	0.2	17	1.7	26	3.8
Beech	1,175	--	1,003	([c])	61	2.0	74	3.6
Conifers	26	([c])	23	0.1	2	0.1	2	0.1
Aspen	16	0.5	--	--	--	--	--	--
Others	874	([c])	19	--	--	--	--	--
Total	4,083	1.7	2,486	5.2	294	26.6	300	37.8
				HEAVY RELEASE				
Paper birch	409	0.8	238	2.7	104	14.3	83	17.5
Yellow birch	638	0.1	387	0.1	62	2.6	56	3.2
White ash	161	0.3	80	0.5	34	4.4	35	7.9
Sugar maple	980	0.1	725	0.1	65	3.2	88	6.2
Red maple	248	--	110	0.2	21	1.9	30	4.3
Beech	810	--	675	--	32	0.9	45	1.5
Conifers	51	0.1	38	0.1	3	([c])	3	0.1
Aspen	58	0.6	3	([c])	2	0.1	--	--
Others	586	--	51	--	--	--	--	--
Total	3,941	2.0	2,307	3.7	322	27.4	341	40.6

[a] Before treatments.
[b] Trees ≥4-in diameter class. In 1959 and 1964, included trees ≥ 1-in diameter class.
[c] Less than 0.01 cord/acre.
[d] Less than 0.1 cord/acre.

Table 2.—Average volume (cords/ac) and value (U.S. $/ac) generated by selected product at stand ages 56 and 69 years for the total stand

Treatment	Pulpwood @ $2/cord		Small boltwood @ $8/cord and pulpwood @ $2/cord		Large boltwood @ $14/cord, small @ $8/cord, and pulpwood @ $2/cord	
	Volume	Value	Volume	Value	Volume	Value
			56 years			
	Cords	$	Cords	$	Cords	$
No release	31.7	64	31.7	179	31.7	179[a]
Species cleaning	26.6	53	26.6	174	26.6	213
Light release	30.5	61	30.5	181	30.5	216
Heavy release	27.4	55	27.4	176	27.4	176[a]
			69 years			
	Cords	$	Cords	$	Cords	$
No release	42.1	84	42.1	244	42.1	312
Species cleaning	37.8	76	37.8	234	37.8	329
Light release	42.2	84	42.2	248	42.2	350
Heavy release	40.6	81	40.6	249	40.6	337

[a] Insufficient volume to meet the specification for large boltwood; maximum volume and value would equal that shown for small boltwood and pulpwood. If specification for minimum volume of large boltwood is ignored, no release value would be $199 and heavy release value $209.

Table 3.—Percentage of comparisons meeting selected threshold rates of return in various potential markets at stand age 56

Treatments compared	Pulpwood @ $2/cord	Boltwood: Small @ $8/cord	Boltwood: Large @ $14/cord	Combination of pulpwood @ $2/cord and boltwood @ $8/cord	Combination of pulpwood @ $2/cord, small boltwood @ $8/cord, and large boltwood @ $14/cord
			0 PERCENT OR MORE RATE OF RETURN		
Heavy vs. no release	0	44	44	28	44
Light vs. no release	4	44	64	40	56
			2 PERCENT OR MORE RATE OF RETURN		
Heavy vs. no release	0	20	40	16	44
Light vs. no release	4	36	60	36	48
			4 PERCENT OR MORE RATE OF RETURN		
Heavy vs. no release	0	12	32	4	20
Light vs. no release	0	28	40	20	32
			6 PERCENT OR MORE RATE OF RETURN		
Heavy vs. no release	0	0	12	0	4
Light vs. no release	0	4	16	4	16
			10 PERCENT OR MORE RATE OF RETURN		
Heavy vs. no release	0	0	0	0	0
Light vs. no release	0	0	0	0	0

Table 4.—Percentage of comparisons meeting selected threshold rates of return in various potential markets at stand age 69

Treatments compared	Pulpwood @ $2/cord	Boltwood: Small @ $8/cord	Boltwood: Large @ $14/cord	Combination of pulpwood @ $2/cord and boltwood @ $8/cord	Combination of pulpwood @ $2/cord, small boltwood @ $8/cord, and large boltwood @ $14/cord
			0 PERCENT OR MORE RATE OF RETURN		
Heavy vs. no release	0	68	64	32	56
Light vs. no release	8	64	68	44	72
			2 PERCENT OR MORE RATE OF RETURN		
Heavy vs. no release	0	44	52	12	32
Light vs. no release	0	48	64	16	60
			4 PERCENT OR MORE RATE OF RETURN		
Heavy vs. no release	0	12	16	0	4
Light vs. no release	0	36	56	4	20
			6 PERCENT OR MORE RATE OF RETURN		
Heavy vs. no release	0	0	0	0	0
Light vs. no release	0	0	8	0	0
			10 PERCENT OR MORE RATE OF RETURN		
Heavy vs. no release	0	0	0	0	0
Light vs. no release	0	0	0	0	0

Table 5.—Gross per-acre income from growing northern hardwoods timber to stand age 56, with and without release, on land owned for multiple-benefits

Item	No release	Light release	Heavy release
1. Average merchantable volume in standard cords/ac[a]	31.7	30.5	27.4
2. Highest merchantable value from harvesting both pulpwood and boltwood	$179	$216	$176
3. Present value of wood attributable to release (item 2 minus $179)	0	$40	($3)
4. Marking and tree removal cost[b]	0	$13.90	$22.76
5. Investment cost for marking and tree removal after 31 years @ 6 percent compound interest rate	0	$85	$139
6. Percent return on release investment	--	3.5%	--
7. Gross income on investment (item 2 minus 5)	$179	$131	$37
8. Gain or loss attributed to release (item 3 minus 5)[c]	--	($45)	($142)

[a] Volume and values shown in items 1 and 2 are those derived in Table 2.
[b] All costs are based on values in Table 1 of McCauley and Marquis (1972).
[c] Neither capital gains nor timber price changes are considered in determining gain or loss.

Table 6.—Gross per-acre income from growing northern hardwoods timber to stand age 69, with and without release, on land owned for multiple-benefits

Item	No release	Light release	Heavy release
1. Average merchantable volume in standard cords/ac[a]	42.1	42.2	40.6
2. Highest merchantable value from harvesting both pulpwood and boltwood	$312	$350	$337
3. Present value of wood attributable to release (item 2 minus $312)	0	$38	$25
4. Marking and tree removal cost[b]	0	$13.90	$22.76
5. Investment cost for marking and tree removal after 44 years@ 6 percent compound interest rate	0	$180	$296
6. Percent return on release investment	--	2.3%	0.2%
7. Gross income on investment (item 2 minus 5)	$312	$170	$41
8. Gain or loss attributed to release (item 3 minus 5)[c]	--	($142)	($271)

[a] Volume and values shown in items 1 and 2 are those derived in Table 2.
[b] All costs are based on values in Table 1 of McCauley and Marquis (1972).
[c] Neither capital gains nor timber price changes are considered in determining gain or loss.

DISCUSSION

Do the results mean that precommercial treatments in young northern hardwoods are at best a marginal enterprise? Accepting for the moment that the assumptions made by McCauley and Marquis are correct, the results indicate that the cost of treatments compounded at an annual rate of 6 percent were increasing faster than the increase in value attributable to treatment. This implies that value was increasing at less than 6 percent annually, on average, from stand age 45 years on. Value/ac increases when volume/ac increases and tree quality improves. Tree quality is largely a function of tree size. A third way value can increase is through real price appreciation; McCauley and Marquis assumed constant real prices.

McCauley and Marquis suggest that rate of return on investment in precommercial treatment could be improved if treatment cost could be decreased, thereby compounding a lesser amount over the time period. This is a good strategy and one that is feasible given the high number of crop trees selected, approximately 400/ac.

By stand age 56 there were fewer than 400 trees per acre ≥4 in d.b.h., all trees. McCauley and Marquis suggest releasing 200 crop trees/ac. In a study in West Virginia comparing methods to release young hardwoods from competition, 80 crop trees/ac were selected and Miller (1984) suggests even fewer crop trees be selected to lower costs. The stand in the West Virginia study was only 12 years old at time of release and treatment required a full-crown release, thus resulting in killing many more trees (1,082 trees/ac compared to 615 trees/ac for the heavy release treatment in the Bartlett study, for example) although the trees were of smaller size compared to the stand treated in the Bartlett study.

McCauley and Marquis (1972) assumed that a market for pulpwood and boltwood would continue to exist, that real prices for products would remain constant over time, and for stand-table projections they assumed that growth and mortality rates by treatment and species observed over the 5-year period from stand age 25 to 30 would remain unchanged. They used a 6 percent interest rate (implied real) to compound the cost of release to

Table 7.—Average number of trees/ac and volume/ac by product size-class[a] and treatment, 2003

Product Size-class	Treatment: Control	Light release	Species cleaning	Heavy release
	----trees per acre----			
Pulpwood	257.6	184.0	199.2	228.0
Small saw-timber	96.0	110.4	83.2	99.2
Large saw-timber	12.0	12.8	17.6	13.6
Total	365.6	307.2	300.0	340.8
	----ft^3 per acre----			
Pulpwood	1,015.4	688.1	822.6	961.0
Small saw-timber	1,838.2	2,177.4	1,549.4	1,799.3
Large saw-timber	473.5	465.5	617.4	451.1
Total	3,327.1	3,331.0	2,989.4	3,211.4

[a]Pulpwood: 4-9 in d.b.h., small sawtimber: 10-14 in d.b.h., and large sawtimber: ≥ 15 in d.b.h.

calculate gross income on investment and gain or loss attributed to treatment.

A good market for pulpwood continues to exist in the region. Although not as important as it once was, a market for boltwood still exists. However, the larger market for saw logs has mostly absorbed the boltwood market. Boltwood is of the same quality as saw logs but of smaller diameter and shorter length than that needed to qualify as a saw log. There is an advantage to boltwood in that its value per unit volume is similar but usually less than that for saw logs but substantially more than that for pulpwood.

Two plots that had the greatest value in 2003, plot 10 under light release and plot 13 under species cleaning and crop tree release were evaluated assuming saw logs were produced. Trees ≥4-in and ≤9-in d.b.h.-class were classified as pulpwood, trees >9-in and <15-in d.b.h.-class were classified as small sawtimber, and trees ≥15-in d.b.h.-class were classified as medium to large sawtimber. Appropriate stumpage prices based on prices reported for New Hampshire and Maine for 2003 were assigned by species. The value for plot 10 was approximately $130 greater (7.6 percent) assuming a saw log market versus boltwood (1972 boltwood prices adjusted for inflation). The value for plot 13 was approximately $335 less (-19 percent) assuming a saw log market versus boltwood. If the saw log market replaced the boltwood market, plot values would change, but unless all plots and treatments were to be re-evaluated it is not clear how they would change and how that would affect treatment means. However, it is unlikely that overall conclusions would change. The number of trees and volume per acre by tree-size class by treatment were not significantly different ($p > 0.05$) in 2003 among treatments (Table 7).

We examined the assumptions of constant real stumpage prices and a 6 percent interest rate. Real stumpage price for paper birch boltwood and hardwood pulpwood in New Hampshire from 1959 to 2000 was constant, increasing at approximately the rate of inflation (3.8 percent) as measured by the Producer Price Index, All commodities.[4] Real stumpage price for paper birch

[4]U.S. Department of Labor, Bureau of Labor Statistics. (http://www.bls.gov/ppi/)

Table 8.— Net present value (rounded to U.S. $/ac) of precommercial treatments of a young northern hardwood stand at different stand ages, interest rates, constant stumpage prices, and increasing prices (1 percent/year)

		Stand age								
Treatment	Prices	45			56			69		
		Interest rate (percent)								
		2	4	6	2	4	6	2	4	6
Control	Constant	83	57	39	108	59	33	131	56	24
	Increasing	102	69	47	147	80	45	178	76	33
Light	Constant	131	85	53	105	51	22	133	48	13
	Increasing	163	106	68	147	74	35	186	71	23
Heavy	Constant	65	37	18	91	39	12	118	37	3
	Increasing	85	50	27	132	62	24	169	59	13

sawlogs increased at approximately 1 percent annually from 1961 to 2000. In nearby Maine, real stumpage price for paper birch boltwood and sawlogs from 1959 to 2003 increased at approximately 1.3 percent annually. Hardwood pulpwood stumpage price increased at approximately 1 percent annually during the same period of time. Depending upon the time series, real stumpage prices were either constant or increased at a modest rate, making the assumption of constant real stumpage prices reasonable or a little conservative. Appreciating real prices (1 percent per year) would of course improve the return on investment in precommercial treatments, as shown in present value of treatment at ages 45, 56, and 69 at interest rates of 2 percent, 4 percent, and 6 percent (Table 8). The net present values (NPV) of treatments at age 45 reflect the results of McCauley and Marquis (1972) with light release having greater NPV than control, while heavy release had lower NPVs. As expected, NPVs decreased with increasing interest rate and increased with increasing price. At ages 56 and 69, almost all combinations of interest rates, prices, and treatments had lower NPVs than the control. The exceptions were for light release at the 2 percent rate with increasing prices at age 56 and light release at the 2 percent rate with constant and increasing prices at age 69.

Cost of release in 1959 was adjusted for inflation to 2003 dollars. This assumes that real cost was constant. If precommercial thinning were to be applied today, it would be done in a similar way. It is a labor-intensive operation. Crop trees need to be selected and marked and competing trees need to be killed. In 1959, sodium arsenite applied in a frill chopped around the stem was used to kill unwanted trees. Though today, unwanted trees might be killed by basal spraying or injection using a herbicide other than sodium arsenite, or possibly by chainsaw felling, these methods are equally as labor intensive as the method used in 1959 (Miller 1984). We do not see that methods for precommercial treatments in young northern hardwood stands have achieved any significant gains in productivity since 1959 and so will remain a significant cost.

In 1990, when the stand was 56 years old, there were no significant differences between treatments and control in volume or value per acre ($p > 0.05$) (Table 2). The result was the same whether assuming the more stringent requirement for large boltwood or ignoring it (see Table 2, footnote a). Treated or not, by stand age 56 differences in volume or value per acre among treatments were not statistically or practically significant. Leak and Smith (1997) found no significant differences among treatments in species and structural characteristics in the 56-year-old stand and concluded that the impact of the treatments on long-term stand development was relatively minor. Leak and Solomon (1997) found that 1990 d.b.h. was positively related to initial sample tree d.b.h. and negatively related to initial basal area. They concluded that only larger-than-average trees, trees in the dominant and codominant crown classes, should be released. But they questioned whether the resulting increase in diameter growth was large enough to offset the cost of treatment.

McCauley and Marquis (1972) were correct in their assessment that, at least up to age 45 (20 years after release and cleaning), the financial benefits of treatment outweighed the compounded costs of applying the light release and species cleaning treatments. However, during the period from stand age 45 to 56 years the stand should have been commercially thinned when it could have supported a commercial operation. This would have provided revenue to offset the compounding treatment costs and maintained a greater rate of growth and concentrated growth on crop trees. At age 56 the control and treatments were clustered near the A-Line of the hardwood-stocking guide (see Leak et al. 1987) ranging from 95 to 113 ft^2/ac basal area and 294 to 349 trees/ac (trees ≥4 in d.b.h.). At age 69 the control and treatments were even more tightly clustered well above the A-Line on the stocking guide ranging from 130 to 145 ft^2/ac basal area and 300 to 366 trees/ac.

CONCLUSIONS

- Precommercial treatment in a 25-year-old northern hardwood stand regenerated by a silvicultural clearcut projected to a stand age of 45 years looked promising as an investment.

- The cheapest treatment, light release, had the greatest return on investment.

- The opportunity for a commercial thinning between 45 and 56 years of age was missed but it could have improved the financial outcome.

- The early (up to age 45) species cleaning treatment, though intermediate in cost between the light and heavy release treatments, probably was not as effective because it did not specifically target crop trees for release from competition. Rather it removed trees that would soon lose out to competition, specifically pin cherry and striped maple, or aspen. We did not evaluate this treatment with respect to the later release that was applied in 1971, 12 years after the initial cleaning, because we could not identify trees that received the fertilizer/lime application. The treatment was thus confounded with the partial application of fertilizer/lime. However, the 1971 crop-tree release and application of fertilizer/lime would have made this the most expensive treatment in the study.

- Approximately 400 crop trees/ac were selected for release. Two hundred crop trees per acre would have been more than sufficient. McCauley and Marquis speculated that 200 trees would have provided enough crop trees at the end of the rotation and more non-crop trees to harvest in earlier commercial thinning. Fewer crop trees would have lowered costs significantly and perhaps would have made it financially possible to provide a full crown release as was done in the heavy release treatment.

- There were many advantages at this site: the clearcut removed almost all trees, caused significant soil disturbance, and regenerated a fully stocked stand of intolerant, mid-tolerant, and tolerant hardwoods. On a similarly good hardwood site, with an equally well stocked young stand, and good markets for small diameter roundwood, we only can speculate that releasing 200 or preferably fewer dominant or codominant trees per acre at stand age 25 followed by a commercial thinning when feasible after stand age 45, could be a good investment for a landowner.

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In 1959 a study of crop-tree release and species cleaning was established in a 25-year-old northern hardwood stand growing on an above-average hardwood site that resulted from a silvicultural clearcut in the White Mountains of New Hampshire. The stand was followed for 5 years and based on the results, treatment effects were projected to a stand age of 45 years. These projections were subjected to a financial analysis. The treatment plots were tallied at stand ages 56 years (1990) and 69 years (2003). The financial analyses were repeated based on these more recent data and the original results and conclusions were re-examined.

KEY WORDS: Precommercial treatments, hardwood silviculture, economic evaluation, paper birch, American beech, sugar maple, yellow birch

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