FOREST RESEARCH REPORT

No. 52   December, 1994

THE PRODUCTIVITY OF A MODIFIED METHOD OF PRE-COMMERCIAL THINNING

Introduction

Between 1983 and 1992; 49,000 hectares of pre-commercial thinnings (PCT) were completed in Nova Scotia (Figure 1). This treatment is expensive using conventional methods, costing on average $700/ha in 1993. To reduce the cost of PCT in stands containing patches of softwood and hardwood, Stora Forest Industries (SFI), together with the Nova Scotia Department of Natural Resources (NSDNR), developed an alternative treatment method. This method involves mechanically mowing corridors and then manually thinning the leave-strips, using modified procedures. The results of field trials undertaken to determine the cost and productivity of this treatment are reported below.

Site Description

The trial was located on the Cape Breton Highlands on land that was clearcut in the late 1970's during a severe budworm infestation. At the time of treatment (July 1993), softwood stocking averaged 69%, most of which was balsam fir (*Abies balsamea* L. Mill.). The softwood component averaged 2.6 metres in height and 14,153 stems/ha (Table 1). In this area of the Cape Breton Highlands, the softwood grows in dense clumps and will eventually outgrow most hardwood competition providing they are not overtopped.

The hardwood component consisted of pin cherry (*Prunus pensylvanica* L. f.) and white birch (*Betula papyrifera* Marsh.) and averaged 1.7 metres in height and 9372 stems/ha.
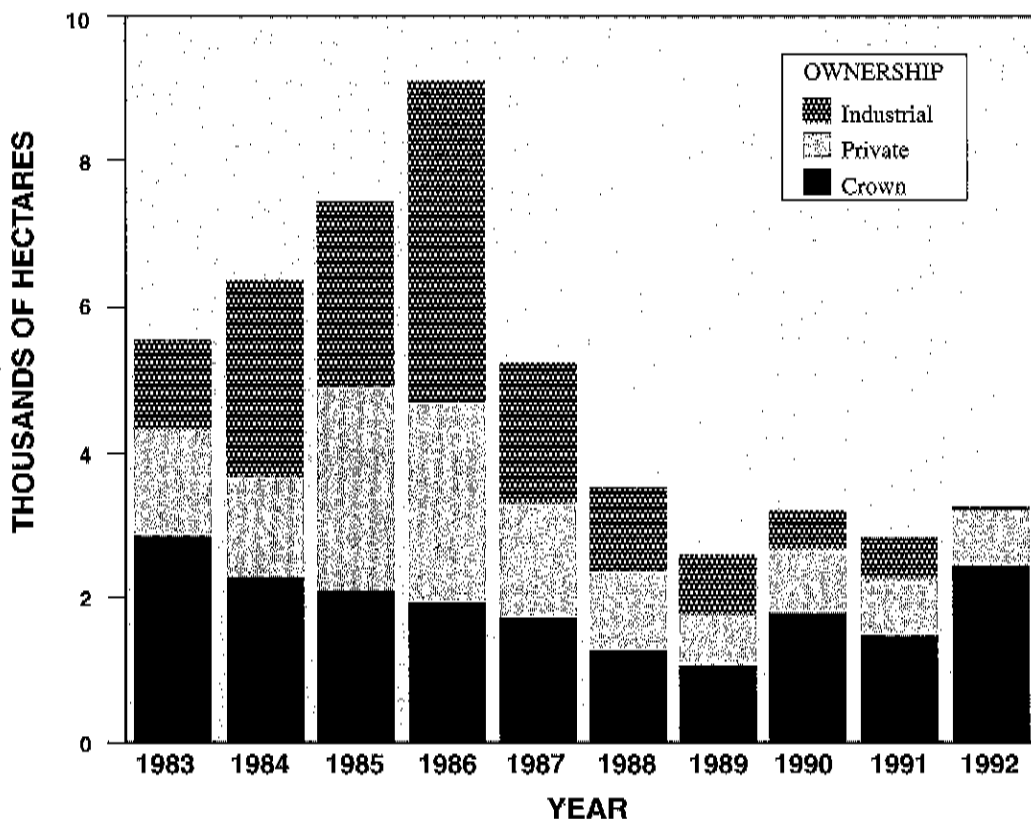
Canadä

Nova Scotia

Figure 1. Area pre-commercially thinned in Nova Scotia between 1983 and 1992.

Table 1. Pretreatment stand conditions by location.

| Location | Area (ha) | Pretreatment | | | | |
| | | Stand Density (stems/ha) | | | Height (m) | |
		Swd	Hwd	Total	Swd	Hwd
1	42.7	14931	10140	25071	2.5	1.7
2	10.0	10830	6095	16925	3.1	1.9
Total/Average[1]	52.7	14153	9372	23525	2.6	1.7

[1] Weighted by area.

Methods

Modified Pre-commercial Thinning

The modified pre-commercial thinning method was designed for moderately-stocked (60 - 80% softwood stocking) softwood and mixedwood stands on the Cape Breton Highlands. This method should not be applied to other parts of Nova Scotia or in stands with greater than 80% softwood stocking without further testing.

The modified method consists of two operations. First, parallel, 2.95 m wide corridors are mowed by a Hydro-Ax 721E (Figure 2).

The corridors occupy approximately 30% of the stand area and are separated by 7 to 8 m wide leave strips. Second, the leave strips are manually spaced with brushsaws using "modified" PCT rules. Under the modified rules, only the trees causing severe competition to softwood crop trees are cut (Table 2, Figure 3). This results in leaving many trees, especially hardwood, that would have been cut in a conventional precommercial thinning operation.
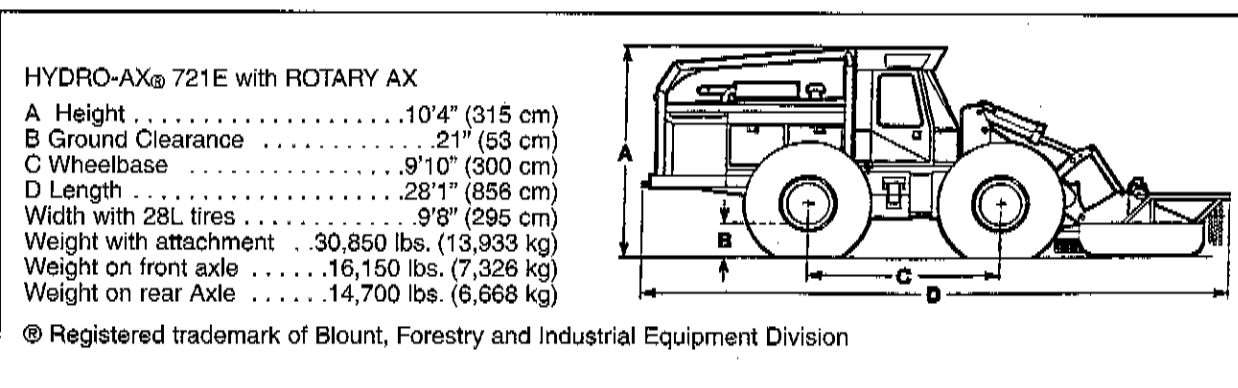

HYDRO-AX® 721E with ROTARY AX

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A  Height . . . . . . . . . . . . . . . . . . . . .10'4" (315 cm)
B  Ground Clearance  . . . . . . . . . . . . .21" (53 cm)
C  Wheelbase  . . . . . . . . . . . . . . .9'10" (300 cm)
D  Length . . . . . . . . . . . . . . . . . . . .28'1" (856 cm)
Width with 28L tires . . . . . . . . . . . . .9'8" (295 cm)
Weight with attachment  . .30,850 lbs. (13,933 kg)
Weight on front axle . . . . . .16,150 lbs. (7,326 kg)
Weight on rear Axle . . . . . .14,700 lbs. (6,668 kg)
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Figure 2. Machine specifications for the Model 721E Hydro-Ax.

Table 2. Modified rules for pre-commercial thinning

Where softwood competition exists

- space to 8 feet (2.4 m) by cutting all softwood trees greater than 1/2 the height of the crop tree (softwood less than 1/2 height of a crop tree are expected to be suppressed out with little effect on the diameter growth of the crop tree), or

- space competing softwood trees next to an opening or mowed area according to the 1 foot rule. That is, cut competing trees to a distance equal to the height differential between the competing tree and the crop tree plus 1 foot. This will leave more trees adjacent to openings.

Height differential in feet	Cut trees within the following number of feet
1	2
2	3
3	4
4	5
>4	DO NOT CUT

Where hardwood competition exists

- cut only hardwood trees that are overtopping or causing mechanical damage to the leaders of softwood crop trees. Leave pure hardwood clumps unspaced.

Field Procedures

Two locations with similar site and stand conditions were selected for the trial. Both treatments (mowing and PCT) were performed at each location, however, for the purpose of the time study, only one treatment was monitored per location. Appendix I provides information on time study procedures.

Each location was divided into operational blocks. Pre-treatment data were collected in each block on species composition, height, density and stocking (Appendices II and III). Following treatment, plots were established at both locations to determine the change in softwood stocking and density.
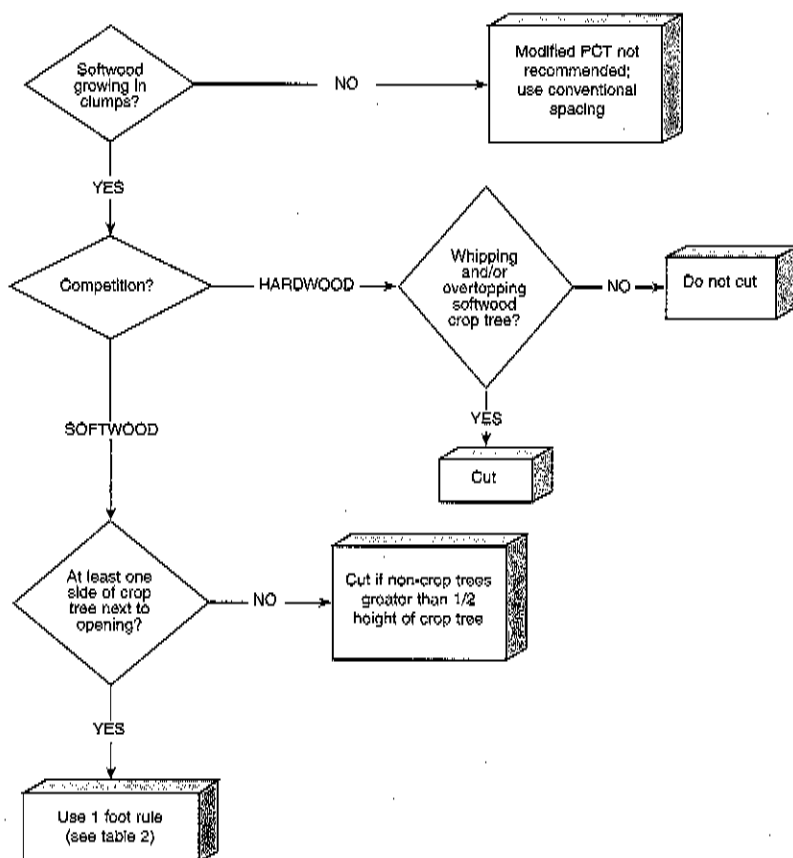

Figure 3. Modified PCT guide for moderately stocked softwood and mixedwood stands of the Cape Breton Highlands.

Table 3. Treatments (performed and studied) and post-treatment site descriptions by location.

Location	Treatment		Area (ha)	No. of Blocks (#)	Leave Strip		Mowed Corridor	
	Preformed	Studied[1]			Average Width (m)	Percent of Total Area (%)	Average Width (m)	Percent of Total Area (%)
1	Mowing + PCT	Mowing	42.7	10	5.75	66	2.95	34
2	Mowing + PCT	PCT	10.0	21	7.80	74	2.95	28
Total/Avg[2]			52.7	31	6.14	67	2.95[3]	33

[1] Only mowing was time studied at location 1, while only the PCT was time studied at location 2.
[2] Weighted average by area.
[3] Width of machine to outside of tires.

Results & Discussion

The amount of area corridor mowed was within 4% of the planned 30%; covering 28% of one site and 34% of the other. (Table 3). Mowed corridors averaged 2.95 m wide, as anticipated, however, leave-strips were narrower than planned; averaging 6.1 m wide instead of between 7 and 8 m. The leave-strip widths ranged from 3 to 20 m. This variation resulted from the operator veering off course while in rough ground conditions. The corridors had not been marked prior to mowing.

Stumps along the corridors were cut at 50 cm above ground level to avoid hitting rocks. As a result, some trees were cut above their lower live limbs. Previous experience with mowed strips indicates that these live limbs will not seriously impede the growth or development of crop trees in the leave strips.

Post-treatment Assessment

Post-treatment stand density in the leave-strips averaged 6330 stems/ha; 2454 stems/ha of softwood and 3876 stems/ha of hardwood (Appendix III). This is approximately triple the expected post-treatment density resulting from a conventional PCT (2.4 m spacing). The higher density of remaining trees resulted from leaving hardwood patches and individual hardwood and softwood trees that were not directly impeding crop trees.

Approximately 77% of the softwood stems and 36% of the hardwood stems were cut during the leave-strip thinning. Mowing and manual cutting decreased softwood stocking by 13%, from 69 to 56% (Table 4). To minimize the effect of this loss on stand volume at rotation, trees were left closer together in the areas adjacent to corridors and other openings.

Productivity

Mowing
Mowing was monitored for 45.6 hours. During this period 14.5 ha of corridors were completed in 33.5 productive hours for an average productivity of 0.43 hectares per productive hour (ha/PH). Productivity ranged from 0.33 to 0.75 ha/PH (Table 5 and Appendix II). Machine speed during mowing averaged 33 metres per minute (m/min or 2.0 km/hr) and varied from 24 to 49 m/min (1.4 to 2.9 km/hr).

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Modified Leave-Strip Thinning

Thinning was monitored for 54.8 PH. During this period 10.0 hectares of leave strips were thinned, for an average productivity of 0.18 ha/PH (Table 5 and Appendix III). Thinning productivity varied from 0.11 to 0.33 ha/PH. Based on a 5.7 PH work day, a worker could be expected to thin 1.1 ha/day of leave-strip.

Table 4. Pre- and post-treatment softwood stocking by location.

Location	Stocking (%)	
	Pre Treatment	Post Treatment
1	68	57
2	74	52
Average[1]	69	56

[1] Weighted average by area.

Table 5. Modified pre-commercial thinning productivity by location.

Location	Area (ha)	Area Treated[1] (ha)		Productive Hours (PH)	Productivity (ha/PH)		Average Machine Speed[4] (m/min)
		PCT	Corridor Mowing[2]		Treated	Total[3]	
1	42.7	NA[5]	14.5	33.5	0.43	1.27	33
2	10.0	10.0	NA	54.8	0.18	NA	NA

[1] Only one time study was performed per treatment per location.
[2] 34% of the area of location #1 was corridor mowed.
[3] Total ground covered per productive hour worked.
[4] Average travel speed over block, excluding delays.
[5] Data not collected.

Productivity versus Density

From previous studies (NSDNR, 1992), it was found that PCT productivity decreased curvilinearly with total pre-treatment density (hardwood and softwood). In this study, the best predictor of productivity was softwood density. Productivity was not strongly related to total density. This may be a result of the low and variable proportion of hardwoods cut using the modified rules for thinning (Appendix III). Figure 4 shows the relationship between worker productivity and pre-treatment softwood density. As an example from this regression, predicted productivity decreases by 22% from 0.18 to 0.14 ha/PH, as softwood density increases from 10,000 to 20,000 stems/ha.

Conventional versus Modified

As mentioned previously, the productivity of conventional PCTs is related to combined hardwood and softwood density. In order to compare the productivity of conventional versus modified methods, productivity of the modified PCT was regressed against total density (Figure 5). This comparison shows
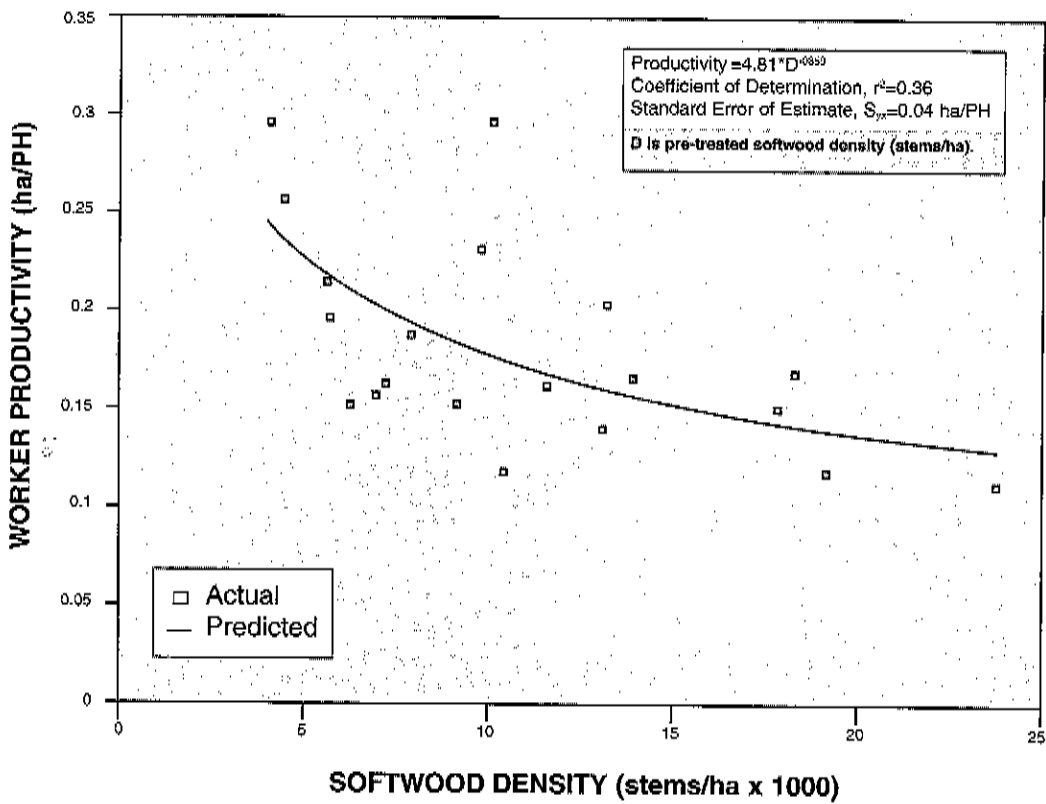
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Productivity = $4.81 \ast D^{-0.859}$
Coefficient of Determination, $r^2 = 0.36$
Standard Error of Estimate, $S_{yx} = 0.04$ ha/PH

D is pre-treated softwood density (stems/ha).

Figure 4. Worker productivity in modified pre-commercial thinning leave-strips using brushsaws and modified methods.

productivity was substantially increased by using modified methods. For example, at a total stand density (softwood and hardwood) of 20,000 stems/ha, predicted worker productivity in modified PCT was roughly double that for conventional spacing using brushsaws and triple the conventional spacing productivity using chain saws (0.17, 0.08 and 0.05 ha/PH respectively). Based on a 5.7 productive hour work day and using brushsaws, a worker could be expected to thin 0.97 ha of leave-strip using the modified methods as opposed to 0.46 ha using conventional methods. When using chain saws with conventional rules, productivity is expected to be only 0.29 ha/day.

Treatment Costs

Information on workers' wages, machine costs and productivity data in this report are based on NSDNR estimates and do not necessarily reflect SFI's costs. Costs and wages do not include contractor overhead or employee benefits.

Operating costs for the Hydro-Ax, including operator's wages, were assumed to be $80/PH. Modified PCT costs were determined by assuming workers would earn $125/day based on a 5.7 productive hour (PH) work day.

Corridor Mowing

The cost of mowing corridors was estimated

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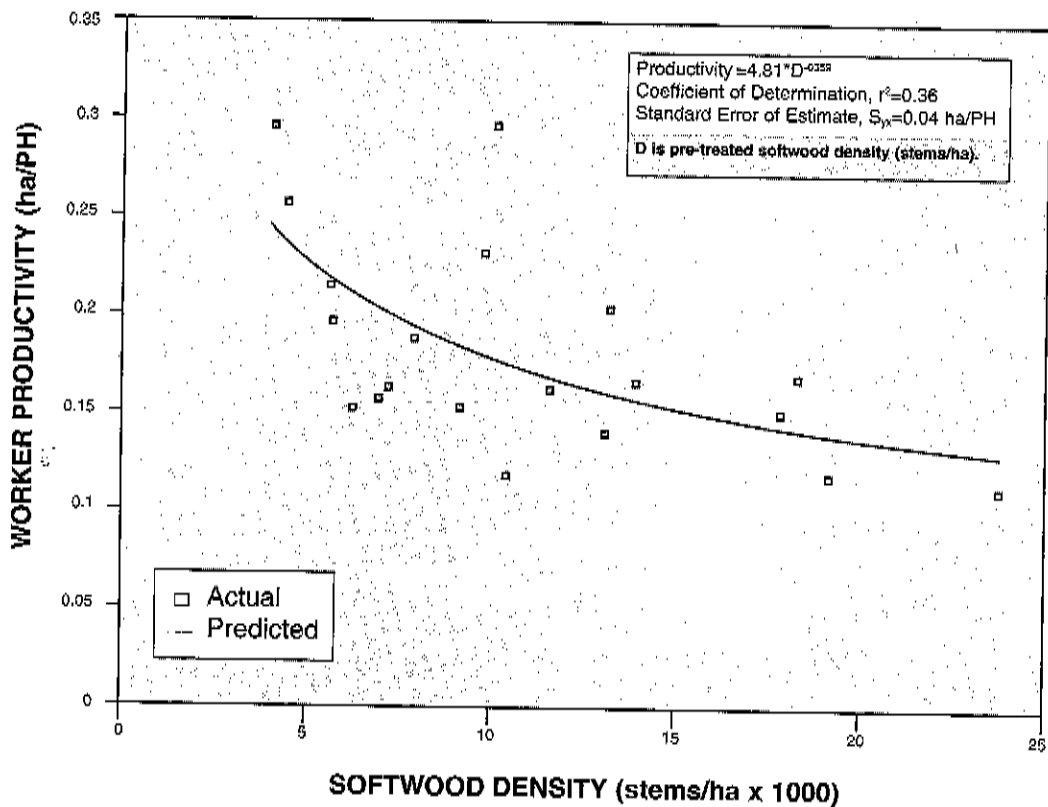
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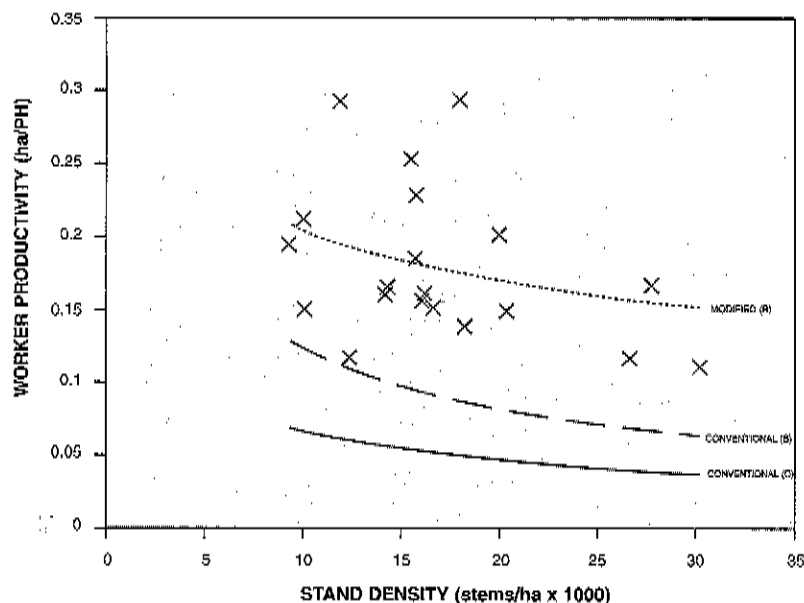
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Corridor Mowing

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X ACTUAL MODIFIED (D)
··· PREDICTED MODIFIED (B)
-- PRED. CONVENTIONAL (B)
— PRED. CONVENTIONAL (C)

Figure 5. Worker productivity in pre-commercial thinnings; modified versus conventional methods using bushsaws (B) or chainsaws (C).

at $186/ha and varied from $107 to $242/ha (Appendix II). Since only 33% of each hectare was mowed into strips, the mowing cost of one hectare on the ground (mowed and leave strips combined) was estimated at $61/ha, and varied from $35 to $80/ha.

Modified versus Conventional PCT

Conventional and modified pre-commercial thinning costs based on using chainsaws and brushsaws are presented in Figure 6. For each of the methods presented, costs increased in a curvilinear manner with increasing stand density.

Based on a stand density of 20,000 stems/ha, modified PCT (excluding the cost of corridor mowing) was the least expensive treatment at $129/ha of leave-strip. This cost assumes productivity would not be reduced as a result of eliminating the mowing. When corridor mowing costs are included, the modified method increases in price to $147/ha. Based on the combined costs, the modified pre-commercial method was $121/ha less expensive to perform than conventional thinning with brushsaws ($268/ha).

Summary

The major results of a trial to determine the cost and productivity of an alternative method of performing PCTs, are listed below. This method combines corridor mowing and a modified method of thinning leave-strips using brushsaws.

1. The average productivity of corridor mowing (mowed strips only) was 0.43 ha/PH. Average machine speed was 33 metres/minute or 2.0 km/hour.

2. Worker productivity in unmowed strips using brushsaws and modified pre-commercial thinning rules averaged 0.18 ha/PH
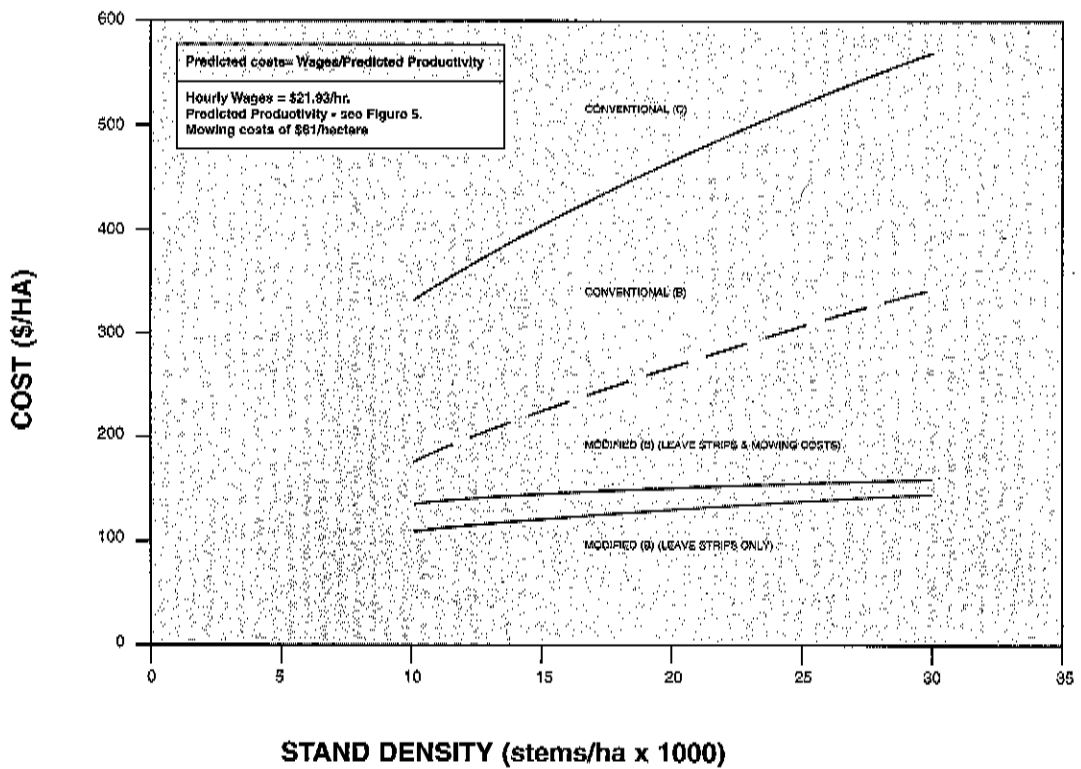
Figure 6. Predicted pre-commercial thinning costs: modified versus conventional methods using bushsaws (B) or chainsaws (C).

and ranged from 0.11 to 0.33 ha/PH.

3. Worker productivity decreased curvilinearly with increasing softwood density.

4. Pretreatment softwood stocking was decreased 13% from 69 to 56%, following modified pre-commercial thinning (corridor mowing and PCT).

5. The cost of corridor mowing using a Hydro-Ax 721E averaged $186/ha. Since only 33% of each hectare was mowed, the cost of mowing corridors on a total area basis was estimated at $61/ha.

6. The cost of a manual pre-commercial thinning with brushsaws using modified rules averaged $129/ha of leave-strip, based on 20,000 stems/ha. If only 67% of the total area was covered (because of mowing), the leave-strip thinning cost would amount to $86/ha.

7. The total cost of this method, including mowing (1/3 of the area) and thinning leave-strips (2/3 of the area) is $147/ha for stands with 20,000 stems/ha. Costs of the modified methods are 25 - 55% less than costs using conventional methods with brushsaws at densities between 10,000 - 30,000 total stems/ha.

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Literature Cited

NSDNR, 1992. *Worker productivity in precommercial thinnings*, Nova Scotia Department of Natural Resources, For. Res. Rept. No. 34, 10pp.

Appendix I

Field Procedures for Data Collection and Time Studies on Mowing and Pre-commercial Thinning Operations

A. Data Collection

Pre and post-treatment density were determined by placing 4 m radius plots along the mowed corridors, then counting the number of stumps and standing trees in each plot.

Stocking was determined from 4 m radius plots placed at fixed intervals across the site in both the mowed and leave strips. Full stocking was 8 trees/plot, based on a spacing of 2.44 m (8 ft) between trees.

B. Time Studies

1) Mowing

Mowing was completed over a 2 week period in July of 1993. Blocks were selected based on operational availability. The percentage of each block that was mowed was determined by dividing the width of the mowed strips by the total width of the block (mowed and leave strips combined). Productivity (ha/PH) was determined by dividing the area in strips (ha) by the productive time required to mow each strip (PH). Productive time excluded all stoppages greater than 5 minutes.

The average travel speed of the mower (metres/minute) was determined throughout each block by dividing the length of the strip being mowed (m) by the productive mowing time (PH).

2) Pre-commercial Thinning

Data on worker productivity in pre-commercial thinning was collected over a 3 week period in July of 1993. The study blocks were selected to sample the range of density classes (stems/ha). Productivity (ha/PH) was determined by dividing the area in leave strips spaced (ha) by the productive time required to space it (PH). Productive time excluded all stoppages greater than 5 minutes.

Appendix II
Productivity and Cost of Corridor Mowing Using a Hydro-ax 721E

Location	Block (#)	Area (ha)	Area Mowed		Hours Worked			Productivity2 (ha/PH)	Cost3 ($/Ha)	Stand Height (m)		Stand Density (stems/ha)		
			hectares	%	Total Hours	Productive Hours (PH)	Productive Time (%)			Swd	Hwd	Swd	Hwd4	Total
1	1	4.50	1.26	28.1	4.65	3.17	68	0.40	200	2.6	1.4	18296	8334	26630
1	2	4.40	1.22	27.8	2.82	2.54	90	0.48	167	2.5	1.7	13647	5955	19602
1	3	3.56	1.24	34.7	2.67	2.52	94	0.49	163	2.8	1.8	7717	13168	20885
1	4	8.60	2.70	31.4	7.58	5.71	75	0.47	170	2.2	1.4	13088	2680	15768
1	5	3.04	1.17	38.5	5.88	3.58	61	0.33	242	2.8	1.9	4866	16809	21675
1	6	3.00	0.97	32.5	1.52	1.30	86	0.75	107	2.1	1.7	16003	5892	21895
1	7	3.02	1.08	35.7	3.58	2.45	68	0.44	182	2.6	1.7	15884	15694	31578
1	8	4.86	1.90	39.1	7.02	5.05	72	0.38	211	2.6	2.0	21555	10156	31711
1	9	5.55	2.16	38.8	7.40	4.92	66	0.44	182	2.7	2.0	11246	16446	27692
1	10	2.16	0.83	38.3	2.47	2.25	91	0.37	216	2.4	1.5	27004	6270	33274
1	TotAvg	42.69	14.53	34.0	45.59	33.49	73	0.43	186	2.5	1.7	14931	10140	25071

1. Productive hours (PH). Excludes all stoppages >5 minutes in duration.
2. Hectares mowed per productive hour.
3. Assuming an hourly cost of $80.
4. Includes non-commercial species.

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Appendix III
Worker Productivity and Pre and Post Stand Conditions for Modified Pre-Commercial Thinning[1]

Location (#)	Block (#)	Area[2] (ha)	Productive Hours (PH)	Productivity (ha/PH)	Pre-treatment Density (stems/ha)			Post-treatment Density (stems/ha)			Stand Height (m)	
					Swd	Hwd[3]	Total	Swd	Hwd	Total	Swd	Hwd
2	1	1.11	6.90	0.16	7136	9047	16183	2016	7190	9206	3.1	1.9
2	2	0.14	0.55	0.26	4455	11031	15486	3182	9121	12303	3.0	1.6
2	3	0.19	1.14	0.17	18243	9546	27789	5303	8061	13364	3.2	2.0
2	4	0.30	2.70	0.11	23758	6412	30170	4714	3583	8297	3.5	1.6
2	5	0.81	2.75	0.29	4054	7826	11880	1697	6600	8297	3.2	2.2
2	6	0.26	1.73	0.15	17819	2546	20365	1980	283	2263	3.2	2.6
2	7	0.60	3.73	0.16	11540	2602	14142	2489	1910	4399	3.2	1.8
2	8	0.40	1.88	0.21	5601	4412	10013	1358	2715	4073	3.8	1.9
2	9	0.21	1.79	0.12	19151	7515	26666	3636	3394	7030	2.6	1.5
2	10	0.48	4.11	0.12	10381	1897	12278	3194	1098	4292	2.8	1.9
2	11	0.25	1.65	0.15	9121	7425	16546	1909	2970	4879	2.8	1.0
2	12	1.11	3.76	0.30	10040	7920	17960	2121	4950	7071	3.2	2.4
2	13	0.66	3.26	0.20	13185	6788	19973	2611	3916	6527	2.6	1.8
2	14	0.62	2.70	0.23	9757	5939	15696	2121	4242	6363	3.1	1.9
2	15	0.73	4.67	0.16	6929	9051	15980	1697	6081	7778	3.3	2.0
2	16	0.22	1.58	0.14	13092	5090	18182	3152	3878	7030	2.9	1.6
2	17	0.47	3.12	0.15	6222	3866	10088	1508	2169	3677	3.1	2.0
2	18	0.41	1.25	0.33	9503	7298	16801	1188	2546	3734	3.1	1.9
2	19	0.31	1.67	0.19	7848	7849	15697	2333	3394	5727	3.7	1.8
2	20	0.37	1.90	0.20	5679	3590	9269	1632	3133	4765	2.6	1.8
2	21	0.32	1.94	0.17	13915	340	14255	1697	170	1867	2.6	1.9
2	Tot/Avg	9.97	54.78	0.18	10830	6095	16925	2454	3876	6330	3.1	1.9

[1] Manual PCT productivity in leave strips only, performed using brushsaws.
[2] Area of leave strips only.
[3] Includes non-commercial species.

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