COMMERCIAL STRIP THINNING IN A 45-YEAR-OLD JACK PINE STAND

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INTRODUCTION

Whether a forest stand is established artificially or naturally, it is certain that spacing which is optimal for development at the seedling and sapling stages will lead to overcrowding during the polewood stage. High densities reduce the growth rate of individual stems, increase losses due to mortality, and may extend the length of the rotation. Commercial thinning is one method of reducing these undesirable effects but, because of the availability of mature stands, the higher cost of removing small stems, and the difficulty of controlling the operation, the practice has been little used in Ontario's boreal forest. However, given the high cost of harvesting and transporting wood from distant stands, and the increasing need to maximize yield from a shrinking land base, the feasibility of commercial thinning warrants re-examination.

Biologically, best results from commercial thinning can be achieved through a well-conceived single tree cutting system, as each crop tree can then be given the proper amount of growing space (Jameson 1956). However, operational difficulties and control problems tend to make harvesting costs prohibitively high for single tree thinning. Strip thinning should produce some of the biological benefits of single tree thinning, without incurring the high costs. It will permit the harvest of some trees that would die through overcrowding and concentrate growth on fewer stems, thus increasing their size at maturity (Best 1933). Strip thinning costs, compared with those of single tree thinning, should be lower as a result of simpler ground control and easier access and manoeuvrability for men and machines. Furthermore, strip thinning is amenable to mechanization, and this should make the technique even more attractive economically.

To determine the feasiblity of strip thinning in natural stands, the Great Lakes Forest Research Centre initiated and supervised an operational trial in a dense, semimature stand of jack pine (*Pinus banksiana* Lamb.) using a conventional shortwood harvesting system. A relatively intensive thinning was prescribed because this would tend to increase the profitability of the operation, and it was assumed that only one commercial thinning would be feasible during a rotation.

Once decisions had been made on the approximate age of the stand to be thinned and the approach to be used, the proposal was discussed with the Ontario Ministry of Natural Resources (OMNR) at Chapleau. With their assistance a stand was chosen and a logging contractor was located. Eddy Forest Products Limited in Espanola, Ontario agreed to purchase approximately 7,250 cu. m (2,000 cords) of 2.54-m (100-in.) jack pine pulpwood. In October, 1970 a cutting authority was issued to the local contractor who, in turn, negotiated a contract with Eddy Forest Products Limited, and the trial was begun.

Description of Study Area and Stand

The study area is located near the west boundary of Nimitz Township in the Chapleau Administrative District. It is immediately north of Highway 129, approximately 18.0 km (11.2 miles) east of its junction with Highway 101.

The area is a flat to gently rolling plain, lacustrine in origin. The soil texture is variable, but is generally a silty to sandy loam overlying a coarser sandy gravel. The soil profile is in the Podzol Great Soil Group.

The specific stand involved is designated Stand 83 in the provincial forest inventory for Nimitz Township.[1] It falls within the Missinaibi—Cabonga Ecological Section of the Boreal Forest Region (Rowe 1972). The stand is even-aged, having originated from a wildfire that occurred some 45-50 years ago. In 1970, mean stand height of the dominant and codominant trees was 13.7 m (45 ft) and mean stand diameter 11.4 cm (4.5 in.). The area was classified as site class 2 (Plonski 1960). Species composition was 95 percent jack pine and 5 percent other species, principally black spruce (*Picea mariana* [Mill.] B.S.P.). The average stand basal area measured at breast height was 28.7 sq. m/ha (125 sq. ft/acre). Diameter distribution and gross merchantable volume of trees by diameter class (in 1970) are indicated in Table 1 (Plonski, n.d.).

Methodology

The design and layout of the area was the first operational consideration. Three baselines were established at 301.9-m (15-chain) intervals to provide initial ground control. These same lines were later cut and cleared by the contractor to a width of 20.1 m (1 chain) to accommodate strip roads. The 301.9-m interval between strip roads was considered to provide the maximum economic forwarding distance. Figure 1 shows the layout of the operating area.

Since only one thinning was to be made prior to final harvest, each cutting section consisted of one "cut" strip and one "leave" strip (Fig. 2). A nominal cut strip width of 4.6 m (15 ft) was selected to provide adequate room for felling and for manoeuvring of logging equipment.[2] A leave strip of 5.5 m (18 ft) was selected for convenience in strip layout and as a width that would result in reasonably full stocking at maturity. This prescription provided for removal of about 45% of the

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[1] Forest Stand Map, Nimitz Township, Forest Resources Inventory 1964, Chapleau District, OMNR.

[2] A post-cut survey showed that both "cut" and "leave" strips were somewhat wider than planned.

Table 1. Diameter distribution and yield of trees in Stand 83

Dbh class	No. of trees/acre	Distribution (%)	Gross merch. vol./acre[a] (cu. ft)[b]
1	36.9	3.3	--
2	82.0	7.3	--
3	206.4	18.4	81.11
4	342.0	30.5	271.35
5	241.9	21.6	514.29
6	130.9	11.7	486.55
7	52.4	4.7	290.40
8	19.6	1.8	146.55
9	3.6	0.3	33.70
10	2.2	0.2	24.94
11	1.8	0.2	23.21
Total	1,119.7	100.0	1,872.10

[a] The scale provided by OMNR revealed that the cull factor was approximately 2 percent.

[b] 1 cu. ft/acre = .07 cu. m/ha

stand volume in the thinning operation. The resultant stand structure was expected to be windfirm, and to permit faster growth of the trees along both edges of the residual strips (Fig. 3). A total area of approximately 51.84 ha (128 acres) was laid out, of which approximately 8.91 ha (22 acres) were needed for strip roads.

Only one side of each "cut" strip was painted. Painting required about 4.32 man-hours/ha (1.75 mh/acre), and used approximately 363.6 litres (80 gal) of mixed paint. Eventually the second side of each cut strip was flagged by the contractor to minimize overcutting of the strips. This additional work is not included in the foregoing labour figures but is included as part of the contractor's supervision costs. The flagging was done during slack periods in the foreman's working day.

Data collection consisted of three distinct operations: work studies of each of the felling and forwarding operations and a post-cut timber cruise. The methodology for each will be discussed briefly below. Cut wood was hauled by truck to the rail side at Nemegos some 24.1 km (15 miles) from the operating site. Cost figures for this part of the operation are included in the analysis.

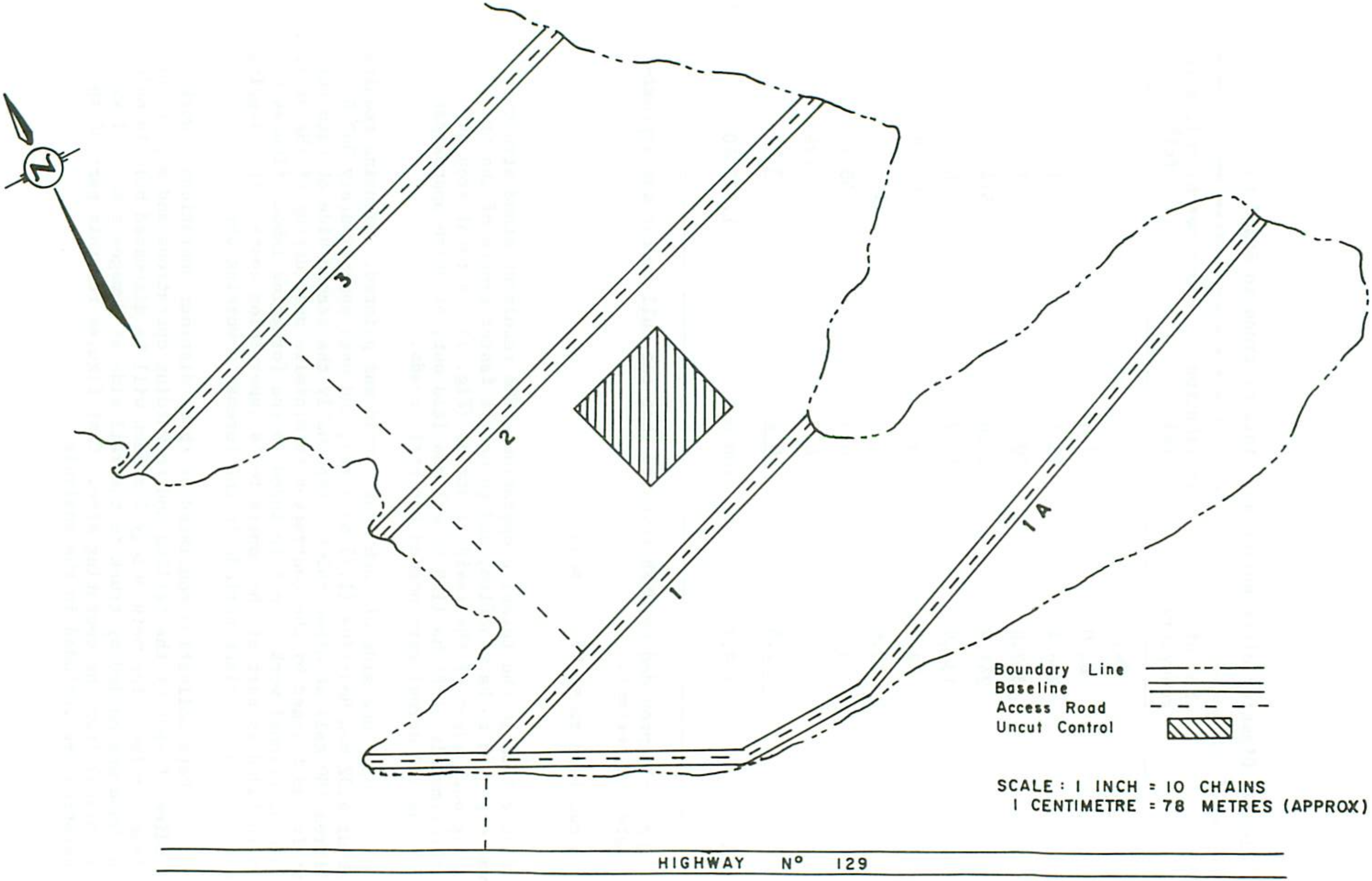

Figure 1. Schematic diagram showing the layout of strip cut area in Nimitz Township.

Figure 2. A view of "cut" and "leave" strips.

Figure 3. A view across residual strips.

Work Studies

In each of the work studies a time-point sampling technique (Nadler 1955) was used in which work elements were defined and tallied as they occurred at 15-second intervals. Of the 4524.88 cu. m (1901.21 cords) harvested during the trial, 41.55 cu. m (17.46 cords) were sampled for felling productivity and 176.48 cu. m (74.15 cords) for forwarding productivity. This represents a sampling intensity of 0.92 percent for felling and 3.90 percent for forwarding.

In the felling study, the following work elements were recognized: felling, bucking, limbing, piling, walking, other, nonproductive work, and nonproductive personal time. In the forwarding study each trip from the skidway on the strip road to the pile of 2.4-m (8-ft) wood on the strip and the return trip was timed according to the following work elements: travel empty, loading, manoeuvring, travel loaded, unloading. There was also an occasional need for hand-loading and straightening of bolts in the skidway. Such time was included in a miscellaneous category. Nonproductive time was also recognized and recorded in two subcategories--that caused by machine malfunction and that caused by the operator. The strip length over which forwarding took place was also measured and the average forwarding distance per trip calculated for each of the sampled strips.

Results

Figures 2 and 3 show the results of the thinning along and across the strips, respectively. Figure 2 also gives an impression of the pretreatment stand condition.

The post-cut cruise revealed that the average width of cut strip was 5.0 m (16.5 ft) and the leave strip was 6.3 m (20.5 ft). On the basis of these widths it is apparent that 44.5 percent of the area (excluding roadways) was harvested. From post-cut aerial photographs we determined that 19.1 ha (47.1 acres) were cut and 23.7 ha (58.6 acres) were left. There were also 9.0 ha (22.2 acres) of roadway harvested.

Out-of-pocket costs for the layout were approximately \$13.83/ha (\$5.60/acre) for labour[3] and \$5.63/ha (\$2.28/acre) for paint.

Although the general results of the post-cut cruise have been presented previously, there are several summary results which are of interest. The division of cruise data into three size classes in Table 2 emphasizes the problems associated with tree size distribution in a strip thinning operation. The live stems 2.54-7.62 cm (1-3 in.) dbh were too

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[3] A 1970 labour rate of \$3.20/hour was used in this calculation.

small to be utilized. Trees in this class constituted 29% of the live stems per acre, yet they contained only 4.3% of the total volume and none of the merchantable volume. Of course, both the larger size classes, "4-8" and "9+" were merchantable. Trees 22.86 cm (9 in.) and over were assumed to be residuals from a previous stand, as evidenced by the fact that most of them bore fire scars. In addition to the large number of undersized stems per acre, there were about 50 windthrown trees/ha (20 trees/acre) and 1,788 dead trees/ha (724 trees/acre). During harvest the standing portion of these unmerchantable stems, 2,590.9 trees/ha (1,049.3 trees/acre), should be felled so that they do not impede the progress of logging. This is especially critical for strip thinning because of the limited manoeuvring space afforded men and machinery.

Table 2. The relationship between diameter distribution and volume

Diameter class	No. of trees/acre[a]	Percent of total	Volume (cu. ft/acre)	Percent of total
1-3	325.3	29.0	81.11	4.3
4-8	786.8	70.3	1,709.14	91.3
9+	7.6	0.7	81.92	4.4
Total	1,119.7	100.0	1,872.17	100.0

[a] 1 acre = 0.41 ha.

The harvest of the area began in mid-October and was completed by mid-November. During this period 27 time-point samples of 1-hour duration were taken. Twenty of these samples applied to one man felling, limbing, and piling, and the remainder to two men performing these functions. The data were stratified on the basis of the two gang sizes and volume of trees felled per man-hour. In Table 3 the percentage of time spent in each of the work elements is presented for both of these strata. It is apparent that there were no meaningful differences between the two gang sizes. Note that without exception the more productive gangs spent a larger percentage of their time in productive activities.

The production classes presented in Table 3 are based solely on variation in the volume produced in trees felled. However, because each time study was conducted for a discrete period, i.e., 1 hour, it was seldom possible to follow the processing of all trees felled during each sampling period through to piling, the end point as far as this part of the work study was concerned. From Table 4 it can be determined that the higher the production class for both gang types, the greater was the

Table 3. Percentage breakdown of felling operation by work elements

Gang type	Production class	No. of trees	Productive time (%)							Nonproductive time (%)		
			Fell	Buck	Limb	Pile	Walk	Other	Total	Work	Personal	Total
One-man	20-40	111	11.3	12.6	17.5	23.2	3.1	7.7	75.4	14.5	10.1	24.6
	40-60	144	9.9	14.1	19.9	24.0	3.7	9.5	82.1	6.1	11.8	17.9
	60-80	34	10.8	14.1	18.9	33.8	3.2	5.9	86.7	12.0	1.3	13.3
	mean[a]	289[b]	10.6	13.5	18.8	25.5	3.4	8.4	80.2	10.0	9.8	19.8
Two-man[c]	20-40	117	12.4	13.9	14.6	25.0	3.3	7.2	76.5	13.8	9.7	23.5
	40-60	80	11.1	12.0	15.1	25.4	5.5	9.9	79.0	12.9	8.1	20.9
	mean	197[b]	11.9	13.2	14.8	25.2	4.1	8.2	77.4	13.4	9.1	22.6
Combined	20-40	228	12.0	13.4	15.8	24.2	3.2	7.4	76.0	14.1	9.9	24.0
	40-60	224	10.4	13.3	18.0	25.1	4.4	9.7	80.9	8.7	10.4	19.1
	60-80	34	10.8	14.1	18.9	33.8	3.2	5.9	86.7	12.0	1.3	13.3
	mean	486[b]	11.2	13.4	17.0	25.3	3.7	8.3	78.9	11.6	9.5	21.1

[a] This mean is derived by summing the time-points for each work element for each of the gang types and converting to percentages.

[b] These are totals, not means.

[c] These figures are the total of the time spent performing each of the work elements by both men in the crew, and are prorated on a per-man basis.

Table 4. Variation in productivity between one- and two-man gangs based on volume production, trees felled, and bolts piled

Gang type	Production class (gmcf/mh)[a]	No. of gangs/class	Trees felled/hr	Vol. per tree (gmcf)	No. bolts per tree	Bolts piled/hr
One-man	20-40	7	15.9	2.17	2.3	34.1
	40-60	9	16.0	3.98	2.9	42.0
	60-80	3	13.6	5.80	4.4	47.6
	mean		15.7	3.00	2.8	39.8
Two-man[b]	20-40	5	12.2	2.90	3.0	35.0
	40-60	3	14.3	3.16	3.2	50.8
	mean		13.0	3.00	3.1	39.1
Both gang types	20-40	12	13.4	2.63	2.7	34.7
	40-60	12	16.0	4.01	3.0	44.7
	60-80	3	13.6	5.80	4.4	47.6
All production classes		27	14.4	3.37	2.9	39.5

[a] Productivity is measured in gross merchantable cubic feet per man-hour (gmcf/mh). The cull factor is 2 percent. The production class is based only on the gross merchantable volume of trees felled in an hour.

[b] The two-man figures are the summed performance of both men prorated on a per-man basis.

tendency to fell more volume than reached the pile. Thus, overall productivity per gang, with the exception of both gang types in the 20-40 production class, was actually somewhat less than is apparent from felled tree volume, the reason being that if these gangs had been compelled to pile all the trees they felled they could not have felled as many trees. However, the reduction in felling production that would be involved is not large enough to move the gangs to a lower production class. The importance of this point is further reduced by the fact that the more productive gangs piled more bolts even though they did not pile their entire felling production. Note that if the definition of productivity had been based on the numbers of trees felled rather than the volume of wood in the trees felled, the gangs would have been ranked differently. This table also indicates the influence of tree size on the gangs' production. It is apparent that the volume per tree and the number of bolts per tree strongly influenced production and that larger trees enabled the workers to attain higher levels of production.

The forwarding study consisted of 16.56 hours of timing the transport of approximately 176.48 cu. m (74.15 cords) of pulpwood. The sample was drawn from 22 strips scattered throughout the harvested area. Two different sizes of front-end loaders were used in the forwarding of the wood to roadside: a Drott 175B and a Drott 250B. Time studies involving the Drott 175B consisted of timing the forwarding of logs from 17 strips over a total of 113 trips. Those involving the Drott 250B consisted of forwarding wood from five strips over 34 trips.

It was a two-part study. One part was a time-point sample of the forwarding operation which was divided into component work elements (Table 5). The brevity of the trial and the use of a spot sampling technique precluded determining a realistic figure for nonproductive work which was negligible in this case.

In order to obtain a full load it was sometimes necessary for the loaders to go to more than one pile. Thus two "load" elements are noted. The "miscellaneous" work element is basically a productive, nonforwarding element in which such actions as straightening piles at the landing and hand-loading individual bolts were tallied. There do not appear to be any obvious differences between the two machines in terms of the breakdown of time into work elements.

The second part of the study involved scaling the bolts forwarded during each trip and measuring the maximum forwarding distance on each of the sampled strips. The mean forwarding distance (Table 6) is a function of the maximum strip length over which piles were forwarded and the number of trips involved. It was determined on a strip-by-strip basis, and then each of these means was weighted by the number of trips to derive a mean for each forwarder. The larger forwarder travelled faster on the strips both empty and loaded. In Table 7 it becomes apparent that although machine cost per hour was higher for the 250B, the greater speed and the larger payload made it the cheaper forwarder in this particular situation.

Although the results presented previously are essential in describing the logging strategy and performance, the important result is the income statement. Table 8 reveals that the operator realized a healthy profit from this operation. It amounted to $2.35/cu. m

Table 5. Time and percent breakdown of work elements measured during forwarding

Work element	Drott 250B Time (seconds)	Drott 250B (%)	Drott 175B Time (seconds)	Drott 175B (%)
Travel road, empty	89.0	6.1	425.5	6.0
Travel strip, empty	378.7	26.1	1,573.5	22.1
Manoeuvre	57.5	4.0	279.6	3.9
Load, pile 1	79.3	5.5	500.2	7.0
Manoeuvre	82.8	5.7	464.5	6.5
Load, pile 2	23.0	1.6	124.7	1.7
Manoeuvre	7.8	0.5	28.8	0.4
Travel strip, loaded	339.4	23.3	1,686.2	23.7
Travel road, loaded	98.8	6.8	497.6	7.0
Manoeuvring	19.1	1.3	191.0	2.7
Unload	113.2	7.8	466.3	6.5
Miscellaneous	164.8	11.3	890.8	12.5
Total	1,453.4	100.0	7,128.7	100.0

Table 6. Comparison of two forwarders in terms of distances travelled and speeds

Parameters	Drott 250B	Drott 175B
Mean maximum strip length (ft)[a]	428.0	329.7
Number of trips sampled	35	113
Mean forwarding distance/return trip (ft)	490.9	423.8
Strip speed, empty (mph)[b]	3.9	2.4
Strip speed, loaded (mph)	4.4	2.3

[a] 1 ft = 0.31 m

[b] 1 mph = 1.61 km/hr

Table 7. Comparison of forwarders in terms of volumes forwarded and operating costs

Item	Drott 250B	Drott 175B
Total volume forwarded (cords)	19.28	54.86
Volume per trip (cords[a])	0.55	0.49
Total time spent forwarding (hours)	2.80	14.07
Volume forwarded per hour (cords)	6.89	3.90
Number of piles forwarded	41	131
Volume per pile (cords)	0.47	0.42
Machine cost per hour ($)	20.00	12.00
Machine cost per cord ($)	2.90	3.08
Total forwarding distance (miles[b])	3.25	9.07
Machine cost per mile ($)	17.23	18.62

[a] 1 cord = 3.63 cu. m

[b] 1 mile = 1.61 km

Table 8. 1970 income statement on the thinning operation

Gross sales 1,644.59 cunits @ $27.00			$44,403.93
Cost of stumpage 1,901.21 cords @ $2.00			-3,802.42
Scaling and forest management charges			-254.72
Net revenue			$40,346.79
Less: Operating Expenses			
felling		$15,209.68	
forwarding		2,740.00	
hauling		6,654.24	
Overhead			
Workmen's Compensation	$ 912.58		
Unemployment Insurance	158.47		
Canada Pension Plan	183.42		
office supervision	150.00		
bush supervision	2,095.00		
scaling	549.00		
half-ton rental	120.96		
float and truck transport	114.00		
road construction	700.00		
paint	60.00		
loss of van	66.35		
Total		5,109.78	
Total expenses			29,713.70
Net profit			$10,633.09

($5.59/cord) based on the OMNR stumpage scale. Note that there are actually three scales of the material involved. The scale by the purchaser--Eddy Forest Products--is the basis for the payment to the contractor and is reflected in the value of the gross sales. The scale by OMNR is the basis for the stumpage, scaling and forest management charges near the top of the income statement. The separate scaling cost, which is a part of the overhead cost, is a scale required by the contractor for payment of his felling crews. The cutters were paid $28.96/cu. m ($8.00 per cord). The hauling cost was relatively low because of the short distance involved--approximately 24.1 km (15 miles). The cost of layout and marking which was cited previously did not include any additional costs incurred by the contractor. Both a part of the cost denoted for bush supervision (where the foreman flagged and painted a part of the second side of the cut strip) and the cost of paint used would be additional layout and marking costs.

DISCUSSION

The main purpose of this trial was to determine whether a contractor could profitably strip-thin an overstocked stand using a conventional logging system. The income statement indicates that with a sale price of $9.64/cu. m ($27.00/cunit) for 243.84-cm (8-ft) wood delivered to the rail-side, the contractor was able to realize a net profit of $2.35/cu. m ($5.59/cord), OMNR scale. Consequently, it is possible to conclude, at least under conditions similar to these, that commercial thinning can be a profitable undertaking. This is important, since part of the reason commercial thinning is not applied more widely is the concern that it may not produce a net profit, in which case it might be necessary to subsidize the operation.

It is readily apparent that tree size had a marked effect on gang output. In this trial all trees in the cut strip were felled although only stems of commercial size were processed into bolts. Over 2,469 undersized, dead or windblown stems per hectare (1,000/acre) were unusable. The stand could have produced much more merchantable volume at time of thinning and at final harvest if the growth which went into the unmerchantable trees had been concentrated on the merchantable stems. Alternatively, the stand could have been thinned (and eventually harvested) at an earlier age. A large part of the growth potential of the site was wasted on small stems which could never be used and only served to impede operations. Biologically and probably economically (Cayford 1964, Riley 1973) this stand would have benefited from an early precommercial thinning. In general, stems would have been larger, fewer trees would have been handled and, in all likelihood, the stand would have reached merchantable size at an earlier age. The reduced cost of harvesting larger trees has been noted earlier and is well documented in the literature. There should be an even greater benefit with the introduction of mechanized thinning, which will likely be feasible in the next few years if tests just completed are as successful as preliminary results indicate.[4]

One aspect of the strip thinning which could be improved is the layout and marking of the area. It is to be hoped that the cost of both labour and materials could be reduced. The technique we used required 4.32 man-hours/hectare (1.75 mh/acre) of thinned area to lay out and mark. The cost in terms of out-of-pocket expenses was $19.46/hectare ($7.88/acre). Since the yield was 133.06 cu. m/hectare (14.85 cords/acre), this represents a cost of $0.22/cu. m ($0.53/cord). With the development of mechanical thinners it may be possible to reduce the amount of pre-marking by only marking a centre line or by instructing the operator to leave a strip of a certain width (e.g., four to five trees wide at least) and to cut only the minimum width required to move his machine through the stand while harvesting.

A comparison of the performance of the two forwarders shows that the larger unit--the 250B--was somewhat cheaper to operate owing to its ability to transport a larger payload and to travel faster. For no apparent reason it travelled faster loaded than empty, whereas the smaller unit travelled at virtually the same speed, loaded or empty.

That the contractor can realize a profit from such a thinning venture represents only a partial measure of success from the forest manager's point of view. Presumably the thinned stand will also demonstrate a satisfactory growth response. In order to evaluate this, there will be an assessment of survival and growth for at least two 5-year intervals after the thinning. The first assessment was conducted in 1975.

CONCLUSION

The trial clearly showed that commercial strip thinning by a conventional shortwood harvesting technique was profitable in this semi-mature stand of jack pine. It is probable that more fully mechanized thinning (e.g., with feller-bunchers and grapple skidders) will produce even more favourable results.

In addition to yielding an earlier return on investments in forest management, commercial strip thinning may also help the forest manager to adjust for an unbalanced age class structure. By supplementing the harvest of mature stands with thinning of semimature stands he may be able to avoid premature clear cutting.

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[4] GLFRC and Eaton Yale Limited conducted an operational thinning trial with the Timberjack RW-30 in a similar stand in the same general area. Results should be published in the near future.

Thinning increases stand yield by enabling the manager to salvage recent or potential mortality. It also allows the manager to manipulate the stand character in order to meet product and logging specifications.

In view of the increasing demand for forest products and the decreasing land base available for wood production, the role of thinning in forest management must become increasingly important.

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