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Evaluation of three brushcutters for semi-mechanized precommercial thinning in Quebec

Abstract

Mechanization of precommercial thinning has increased significantly in Quebec since 2003. The development of new machines designed specifically for semi-mechanized precommercial strip thinning has contributed greatly to the implementation of this new method. FERIC conducted studies to compare the productivity and treatment costs with three different machines. Our studies demonstrated the potential for a reduction in treatment cost under easy to moderate operating conditions. However, under difficult operating conditions, the treatment cost was slightly higher than the reimbursement rate.

Keywords:

Brushcutters, Precommercial thinning, Strip thinning, Motor manual method, Machine evaluation, Productivity, Costs, Eastern Canada.

Introduction

Currently, there is a shortage of workers to perform precommercial thinning, and the workforce is aging. Moreover, many workers are leaving the brushcutting profession for various reasons and there has been little succession. Contractors have thus been forced to look to mechanization to decrease the pressure on the existing workers by improving their working conditions and work environment.

The studies performed to date have shown that semi-mechanized strip thinning offers the greatest potential to reduce the cost of precommercial thinning and to obtain a treatment quality comparable to that of a fully manual operation (Ryans 1995; Sidders 1989; St-Amour 1998a, 1998b, 2000, 2004). This system combines systematic cutting of strips by a machine with a manual treatment using brush-saws in the leave strips to finalize the spacing and selection of future crop trees (Figure 1). The corridors cut by the machine facilitate access to the site for the workers and offer more space in which to fell cut stems to the ground, thereby making the work safer and less physically demanding. In addition, this system allows treatment of a larger area per year with the same number of workers. Planning and block layout for the motor-manual teams are also simplified.

Despite the advantages offered by strip thinning, most machines we have tested thus far have not been appropriate for this type of operation or for the terrain and stand conditions typically encountered in such operations (St-Amour 2006). Their main disadvantages were their cut width, which was larger than the desired 2-m spacing between future crop trees, as well as a lack of power. In addition, although the two-row

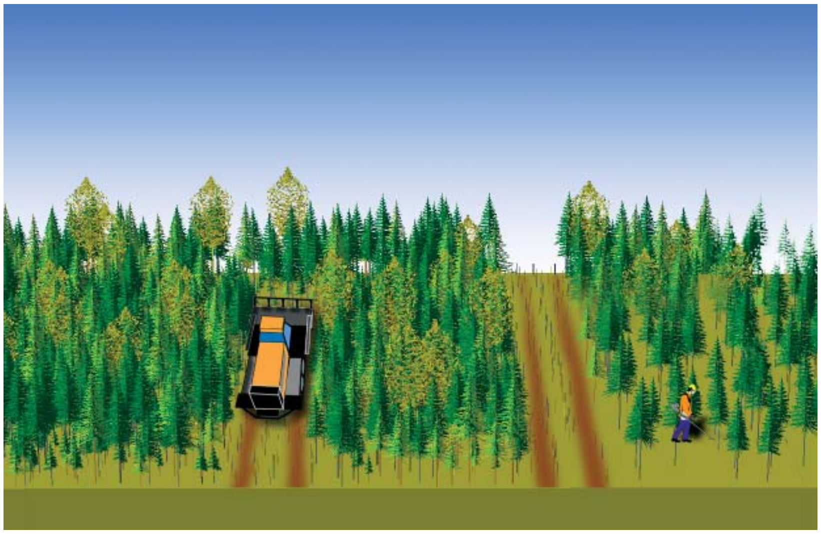

Figure 1. Schematic of a semi-mechanized strip-thinning operation (one-row method).

Nokamic brushcutter appeared capable of efficiently treating high-density stands (St-Amour 2004), it cannot be used in stands taller than 3 m because it must straddle the rows of trees.

Faced with this situation, several manufacturers have developed one-row brushcutters designed specifically for semi-mechanized precommercial thinning. These designs have addressed the basic criteria that must be met to produce a machine appropriate for treating most sites and stands, while still providing an acceptable quality of work (St-Amour 2006).

Since 2003, FERIC has been studying the productivity and work quality of the Forestrac, GyroTrac, and Nokamic brushcutters. The studies were performed as part of a joint research and development program between FERIC and Quebec's Ministère des Ressources Naturelles et de la Faune (MRNFQ). This report presents the results of studies of these machines under a range of operating conditions in Quebec.

Machine descriptions

The Forestrac, GyroTrac, and Nokamic brushcutters are illustrated and described in Table 1. The Forestrac and the GyroTrac are fixed-frame tracked machines. The Nokamic has an articulated frame and eight-wheel-drive tracked bogies. All three machines have horizontal-shaft cutting heads with fixed knives. More specific details on each machine are provided by St-Amour (2006).

All machines were equipped with a GPS-based navigation system. This system comprised a GPS receiver with a roof-mounted antenna at the center of the cab and a computer with a touch-screen inside the cab. This system helped to guide the operator, who could continuously determine the machine's position with respect to the block boundaries and previously treated strips; this helped operators to maintain constant spacing between strips without reducing the machine's travel speed.

Description of the study sites

The studies were performed under operating conditions ranging from easy to difficult in the Abitibi, Côte-Nord, and Lac St-Jean regions of Quebec (Table 2). The degree of difficulty of the study areas was defined based on the number of obstacles on the ground and on the slope. Despite the high density of the Abitibi stand (45 000 stem/ha), the level of difficulty of the site was judged to be easy because of the lower number of obstacles on the ground and the flat terrain. At Lac St-Jean, the number of obstacles on the ground was higher and the slopes were steeper than in the Abitibi stand,

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Table 1. Characteristics of the three machines

Forestrac 9060 brushcutter

- Manufactured by Cam-Trac Chicoutimi
- Fixed frame
- Steel tracks
- Width: 1.93 m
- Length: 4.62 m
- Ground clearance: 52 cm
- Power: 68 or 78 kW
- FAE cutting head
- Weight: 5680 kg
- Cost: $240 000

GyroTrac GT-13 brushcutter

- Manufactured by GyroTrac Inc.
- Fixed frame
- Rubber tracks with steel grousers
- Width: 1.85 m
- Length: 5.2 m
- Ground clearance: 36 cm
- Power: 93 kW
- Toma-Ax cutting head
- Weight: 5680 kg
- Cost: $200 000

Nokamic NP-8030 brushcutter

- Manufactured by Nokamic Inc.
- Articulated frame with central oscillation
- Eight-wheel-drive tracked bogies
- Width: 2.0 m
- Length: 7.9 m
- Ground clearance: 50 cm
- Power: 203 kW
- Nokamic cutting head
- Weight: 12 730 kg
- Cost: $380 000

Table 2. Characteristics of the study areas before treatment

Machine	**Forestrac**	**GyroTrac**		**Nokamic**	
Location	**Lac-St-Jean**	**Côte-Nord**	**Côte-Nord**	**Abitibi**	**Côte-Nord**
Level of difficulty	**Moderate**	**Moderate**	**Difficult**	**Easy**	**Very difficult**
Terrain					
CPPA classification	2.3.2	1.3.2(3)	1.3.3(4)	3.2.1	1.3.3(4)
- Soil bearing capacity	Good	Very good	Very good	Moderate	Very good
- Terrain roughness	Rough	Rough	Rough	Slightly rough	Rough
- Slope	Slight to moderate	Slight to moderate	Moderate to steep	Level	Moderate to steep
Obstacles on the ground					
Number/ha	1381	1565	1711	1037	1880
Average height (cm)	36	36	38	31	36
Mean slope (%)	11	14	21	0	19
Stand					
Density before treatment (stems/ha)					
Total density *	46 953	32 168	35 837	49 114	30 979
MRNFQ density **	23 846	22 597	20 466	35 459	17 528
Average height (m)	1.8	2.1	2.1	2.3	1.3

* Includes all stems taller than 15 cm.
** Based on the MRNFQ standard for calculating reimbursement rates; includes only softwoods taller than 1.2 m and hardwoods taller than 1.8 m.

and the stand density was 47 000 stems/ha. At the Côte-Nord sites, the operating conditions ranged from moderate to very difficult even though the stand densities were lower (between 31 000 and 36 000 stems/ha) because the numbers of obstacles and rocks were higher and the slopes were steeper. The site treated by the Nokamic was very difficult because of the combined effect of a very high number of rocks or boulders and steep slopes.

Results and discussion

Productivity

Table 3 presents the results of our time studies. For the studies as a whole, the effective productive time (time spent cutting strips) decreased as the level of difficulty increased. The slope, rocks, logging debris, and particularly downed trees slowed down the machines. On the more difficult sites, delays due to obstacles accounted for 17 to 19% of total productive time, versus 2 to 11% on easy to moderate sites.

The productivities of the Forestrac and GyroTrac were similar, and ranged between 0.17 and 0.19 net ha/PMH on moderate sites. (A "net hectare" corresponds to only the area occupied by the strips cut by the machine.) Although the obstacles were more numerous for the GyroTrac, the density of the treated stands was lower. The Forestrac's low incidence of delays due to obstacles indicated that the machine had less difficulty crossing obstacles due to its high ground clearance, and its steel tracks appeared to provide better traction. However, its high center of gravity sometimes required the operator to slow down while crossing obstacles or descending side slopes to avoid a rollover. In addition, the low engine power caused occasional delays and sometimes even com-

Table 3. Summary of the mechanized operations

Machine	Forestrac	GyroTrac		Nokamic	
Location	Lac-St-Jean	Côte-Nord	Côte-Nord	Abitibi	Côte-Nord
Level of difficulty	Moderate	Moderate	Difficult	Easy	Very difficult
Distribution of work cycle time elements (%)					
Effective productive time	81	82	68	86	65
Maneuvers	7	2	4	4	7
Delays due to obstacles	4	11	19	2	17
Reconnaissance	3	0	1	4	5
Travel	3	2	5	2	4
Mechanical delays		2	2		
Personal delays	2	1	1	2	2
Total (%)	**100**	**100**	**100**	**100**	**100**
Productive machine hours (PMH)	14.4	19.5	25.3	8.8	9.4
Average travel speed (m/min)	17.4	21.2	18.0	38.4	23.1
Average width of cut strips (m)	1.97	1.83	1.87	1.94	2.02
Area occupied by cut strips (net ha)	2.4	3.7	3.5	3.5	1.7
Total area (gross ha)	13.8	23.6	21.8	12.6	8.5
Treatment intensity (net/gross, %)	17	16	16	28	20
Productivity (net ha/PMH)	0.17	0.19	0.14	0.40	0.18

pletely stopped the machine when the stem density became too high.

Thanks to its more powerful engine, which facilitated mulching of the vegetation, and its superior stability, the GyroTrac was able to maintain a higher travel speed than the Forestrac. However, it was more sensitive to obstacles on the ground because of its low ground clearance, and its tracks appeared to be less aggressive, although the sites treated with the GyroTrac were also generally more difficult.

The Nokamic brushcutter was considerably more powerful than the two other machines and attained the highest travel speed and productivity. Its articulated frame and eight-wheel-drive bogies provided high stability and mobility, and it could maintain good travel speeds while crossing obstacles and steep slopes. Nevertheless, it still spent considerable time maneuvering and encountered many delays due to obstacles on the very difficult Côte-Nord site, which presented a high number of obstacles, rocks, and steep slopes. At the Abitibi site, its productivity was very high because of the easy operating conditions. Under these conditions, the Forestrac and GyroTrac brushcutters would also undoubtedly have attained higher productivities than what they attained under moderate operating conditions. In contrast, they would still have been limited by their lower ability to mulch the vegetation.

Treatment quality

Our evaluation of the treatment quality in the mechanized operations revealed that the difficulty of the site had a direct impact on treatment quality (Table 4). The rate of wounds to residual trees in the leave strips, the height of the stumps, and the number of stumps with live branches all increased with increasing site difficulty.

Wounded trees were found along the edges of the cut strips. The outer edges of the cutting head and of the carrier's tracks were the primary causes of wounds. Turns and maneuvers significantly increased the risk of wounds, since both involved sharp lateral movement of the cutting heads and tracks. The greater the number of obstacles on the ground and the steeper the slope, the more often the operator was forced to maneuver and turn to get around an obstacle; as a result, the number of wounds to trees along the edges of the cut strip increased.

In addition, more frequent and higher debris and rocks on the ground required the operator to lift the cutting head so as to minimize shocks and breakage of the cutting teeth. This prevented operators from keeping the cutting head close to the ground and cutting the trees at an acceptable height. On the very difficult Côte-Nord site, we observed a high frequency of stumps with live branches after the mechanized treatment. Rocks and boulders accounted for a much higher

Table 4. Evaluation of the quality of the mechanized treatments and overall treatment quality

Machine	Forestrac	GyroTrac		Nokamic	
Location	Lac-St-Jean	Côte-Nord	Côte-Nord	Abitibi	Côte-Nord
Level of difficulty	Moderate	Moderate	Difficult	Easy	Very difficult
After the mechanized treatment					
Damaged stems (% of residual trees)	2.6	2.9	2.9	1.6	4.2
Stump height (cm)	27	26	29	23	32
Stumps with live branches (no./ha)	373	415	848	305	2969
Average width of the cut strips (m)	1.97	1.83	1.87	1.94	2.02

proportion of the obstacles on the ground on this site than on the other sites.

The average width of the cut strips was lower with the GyroTrac (1.83 to 1.87 m) than with the Forestrac and Nokamic (1.94 to 2.02 m). This can be explained by the fact that the GyroTrac was the narrowest of the three machines. The width of the strips cut with the Nokamic was higher at the very difficult Côte-Nord site than at the easy Abitibi site despite using the same machine and operator. This difference mainly resulted from the many turns and maneuvers dictated by the greater number of obstacles on the ground and by the steep slopes.

Analysis of treatment costs

The hourly operating costs of the machines based on FERIC's standard method is estimated at $187, $179, and $251 per PMH for the Forestrac, GyroTrac, and Nokamic, respectively. This amount includes the purchase, repair, and operating costs of the machines, as well as the operator's wages and other related costs such as supervision, administrative costs, overhead, and profits. Our analysis assumed a machine utilization rate of 70% and a working life of 7 years.

The results of our analysis of treatment costs for the various studies are presented in Table 5. The total cost of the semi-mechanized operation was determined as follows:

- The cost of the mechanized treatment (in $/gross ha) was calculated based on the hourly cost of the machines, their productivity, and the treatment intensity.
- The cost of the manual follow-up after the mechanized treatment was calculated by multiplying the occupancy of the site by leave strips by the expected MRNFQ reimbursement rate for fully motor-manual operations.
- The total treatment cost equals the sum of the mechanized treatment cost and the motor-manual follow-up.

The results demonstrated that the three machines were all economical under conditions ranging from easy to moderate; that is, the total semi-mechanized treatment cost ($/gross ha) was lower than the reimbursement rate.

Table 5. Analysis of treatment costs in the semi-mechanized operations

Machine	Forestrac	GyroTrac		Nokamic	
Location	**Lac-St-Jean**	**Côte-Nord**	**Côte-Nord**	**Abitibi**	**Côte-Nord**
Level of difficulty	**Moderate**	**Moderate**	**Difficult**	**Easy**	**Very difficult**
Hourly cost of the machine ($/PMH)	187	179	179	251	251
Productivity of the machine (net ha/PMH)	0.166	0.193	0.136	0.402	0.182
Treatment intensity (%)	17	16	16	28	20
Mechanized treatment cost ($/net ha)	1124	928	1313	625	1379
Occupancy rate by leave strips (%)	83	84	84	72	80
Mechanized treatment cost ($/gross ha)	192	148	208	175	276
Cost of motor-manual follow-up ($/gross ha)	972	964	922	986	814
Total treatment cost ($/gross ha)	1164	1112	1130	1161	1090
MRNFQ reimbursement rate ($/ha)	1171	1145	1096	1370	1018
Difference with respect to reimbursement rate (%)	-1	-3	+3	-15	+7

As the Forestrac was barely economical under moderate conditions, we can assume that it would have been uneconomical under difficult conditions. In addition, compared with the GyroTrac, its hourly cost is higher and its lower power undoubtedly would slow it more.

Under difficult conditions, the semi-mechanized treatment cost with the GyroTrac was nearly comparable to the reimbursement rate and that would also likely be the case with the Nokamic. However, the risk of exceeding the reimbursement rate is relatively high when the machines operate under difficult conditions. The proof of this is that under the very difficult Côte-Nord conditions, the treatment cost with the Nokamic exceeded the reimbursement rate by 7%. However, it should be noted that the density and reimbursement rate for this site were lower. It is highly likely that the Forestrac and GyroTrac would be even less economical under such conditions given that their ability to cross obstacles and slopes is less than that of the Nokamic.

Implementation

The study demonstrated that it is possible to reduce treatment costs with the three machines under conditions ranging from easy to moderate. However, under difficult conditions, the semi-mechanized treatment cost exceeded the reimbursement rate. Debris on the ground, rocks, and slopes all had a greater impact than stand density on machine productivity.

Our analysis of treatment costs was based on a machine utilization rate of 70% and a working life of 7 years. Based on our observations, we estimate that the utilization rate was lower during the first years but that it should increase over time. We believe that the 70% rate is representative and applicable to the results of the present studies, in which the machines had been used for 3 years.

Careful planning of the mechanized work is desirable to improve the utilization rate of the machines. It's important to properly target the right sites to be treated so as to reduce the frequency of unproductive time. An increase in the scheduled hours of the machines would also reduce their operating costs, making it easier to treat sites with difficult operating conditions without exceeding the reimbursement rate.

Each machine had advantages and disadvantages. The Forestrac and GyroTrac cost less, but their power, stability, and mobility were lower than those of the Nokamic. They can be floated between sites on a trailer pulled by a pickup truck, whereas the Nokamic requires a float truck. The GyroTrac is less expensive, more powerful, and more stable than the Forestrac, but it is more sensitive to obstacles on the ground because of its low ground clearance.

The Nokamic offers more power, mobility, and stability (articulated frame, eight-wheel-drive tracked bogies). This type of carrier can thus treat a larger proportion of sites than the other machines and can maintain the desired treatment intensity because it is better able to cross obstacles in difficult terrain. However, it must be more productive to justify its higher purchase cost.

The presence of rocks appears to be the primary factor that influences work quality and productivity, and consequently the treatment cost for all three machines. Despite the robustness and effectiveness of the cutting heads, impacts with rocks and boulders still lead to rapid wear and breakage of the cutting teeth. Rocky terrain can thus lead to high repair and replacement costs, in addition to increasing the frequency of delays.

Although the machines were relatively new, their manufacturers have implemented many improvements to the carriers and cutting tools with the goal of increasing their effectiveness. Among the specific characteristics of the machines designed to improve treatment quality, the protective guarding added around the Forestrac proved very effective at limiting damage to future crop trees along the edges of the leave strips. This feature should thus be adopted by the other machines. Since the study took place, the manufacturer of the Forestrac has offered a more powerful model of the machine (78 kW). As well, GyroTrac expects to increase the power of the GT-13 model to 118 kW, and to increase its ground clearance.

This new approach to thinning requires a major investment by contractors, and the development of new work logistics. In addition, these machines are new and their reliability is not yet proven. In such a context, it's obvious that a learning period and some fine-tuning of operations will be unavoidable. It will also be necessary to develop mechanisms for longer-term contracts between the contractors and the forestry company to protect the contractor's investment.

The first users of this approach have already acquired considerable expertise with the system and have begun to perform this work on an operational scale. In 2005, around 13 machines were operating in eastern Canada, and treated around 10 000 ha.

In parallel with this study, FERIC compared the treatment quality in conventional thinning (a fully motor-manual operation) and semi-mechanized strip thinning. Our preliminary results demonstrate that it is possible to obtain treatment quality comparable to that of a fully motor-manual operation. A guide on the application approach and the limitations of semi-mechanized strip thinning is currently being prepared. It will present the criteria that must be met to satisfy provincial treatment standards and the objectives of the precommercial thinning.

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