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STRATEGIES FOR REDUCING THE COST OF MECHANIZED SELECTION HARVESTING IN HARDWOOD FORESTS

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Abstract

In an effort to optimize the use of mechanization in partial cutting, FERIC investigated alternatives to single-tree selection, including patch and shelterwood cuts. By targeting single-tree selection for daytime hours, and the latter two approaches for night work, the costs of mechanized felling (with a feller-buncher) could be decreased. However, achieving this result requires careful allocation of cutovers to the different treatments and times of year.

Introduction

In recent years, there has been a growing shortage of qualified workers for manual selection-cutting operations in the Laurentian and Ottawa Valley regions of eastern Canada (McNamara 1997), as well as in Ontario and the Maritimes. The workers currently doing this job are aging, and the potential for replacing them is low. Mechanization can provide a solution to this problem, since it offers the advantages of reduced physical effort and a controlled work environment. One option for mechanization would be the use of a feller-buncher such as the Timbco T-445 used by contractor H. Leggett and Sons Inc. (Namur, Que.). Selection harvesting with this equipment has already been studied by FERIC (Meek 1997).

To prove acceptable, mechanized harvesting should meet the conflicting criteria of quality and economics. In selection harvesting, the costs of harvesting with a feller-buncher, manual delimbing, and extraction, as well as the costs of meeting the required quality criteria, have been demonstrated to be similar to those with manual felling. However, the use of feller-bunchers has not yet been optimized since felling at night has proven nearly impossible (Meek 1997; McNamara 1997). The main problems involve the difficulty in seeing marking paint, the loss of depth perception caused by the artificial lighting, and a significant increase in wounding of residual stems. The hourly cost of using feller-bunchers thus remains high.

Recently, the new management guidelines for hardwood forests in Quebec have opened up new silvicultural treatment options. Instead of traditional single-tree selection cuts, it is now possible to perform selection cuts in many stands by means of patch cuts, small-area clearcuts, and shelterwood cuts. Trials were thus performed to evaluate whether it was possible to use a single machine for the harvesting phase by combining daytime single-tree selection with other prescriptions that can be performed efficiently at night. This project represents a cooperative study by FERIC and Groupe Forestier Intech Inc., a firm that specializes in the management of hardwood forests in the Ottawa Valley and the Laurentians.

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The objective of this study was thus to evaluate the feasibility of minimizing the cost of the feller-buncher through judicious use of single-tree selection during the day and other types of cut at night. The feasibility of working at night in tolerant hardwood forests was studied in terms of the operation's productivity and how well it complemented the daytime operations.

Study Methods

Night Work

The study was performed in the Papineau-Labelle wildlife reserve in the fall of 1998. The first step involved estimating the percentage of the operating area in which the contractor was working that would be suitable for night work. For this to be the case, the terrain had to have good trafficability, with a slope of less than 30% and low roughness. The second step was to assess the stands themselves in terms of their prescription. Stands suitable for single-tree selection were excluded from night work, and mixedwood stands with yellow birch were reserved for shelterwood cuts or patch cuts. Based on these criteria, 41% of the operating area was considered to be suitable for harvesting at night.

The number of hours available for daytime operations was also a limiting factor, since the areas chosen for single-tree selection had to be treated during the day. Environment Canada provided data on the number of hours between sunrise and sunset for this region over the course of the year. The period between mid-March and mid-May was ignored, since harvesting operations are usually suspended during the spring breakup. To account for the still-acceptable lighting conditions just before sunrise and after sunset, the number of daylight hours was increased by 2 hours per day. On this basis, 4202 hours of acceptable lighting were available, of which 1155 hours fell on weekends (Figure 1). On average, 13.6 hours per day were available for single-tree selection. Based on two shifts per day, for a total of 20 hours, an average of only 6.4 hours/day required night work (i.e., 32% of the available time).

Although the overall percentage of stands and terrain suitable for night work appears adequate for the night work required this may not be the case for specific operating areas. Thus, operational planning must consider both the percentage of the terrain that can be treated at night and the variation in the number of hours of daylight throughout the year for the locales where the work will be done. As much as possible, areas with a high percentage of sites suitable for night work should be harvested during the winter, since this is when the number of hours of sunlight are at a minimum. In summer, when the most daylight is available, operations should focus on areas with the highest proportion of single-tree selection.

The night work during FERIC's study mainly involved patch cuts and shelterwood cuts. Other work involving

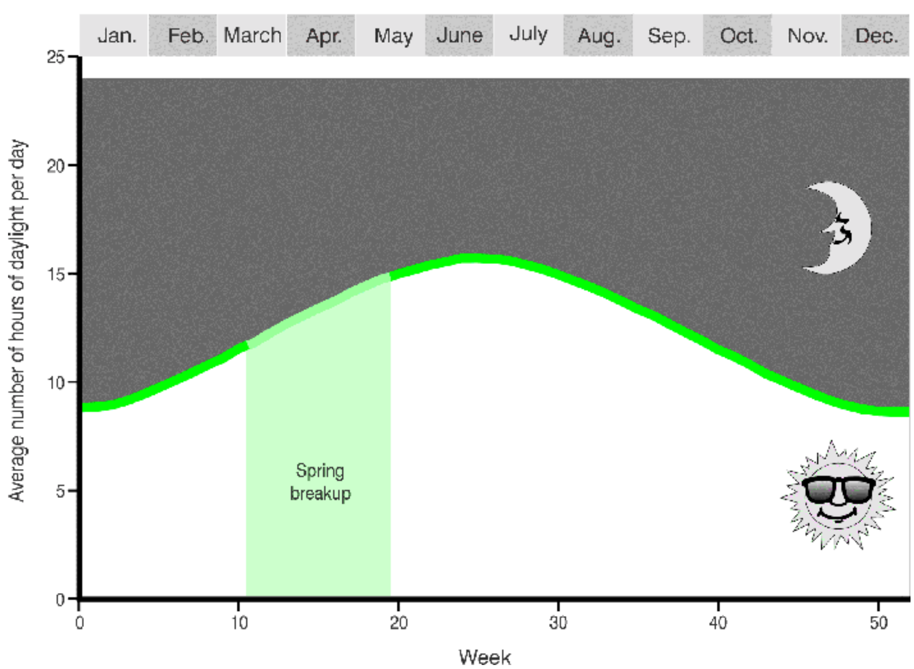

Figure 1. Annual distribution of daylight hours in the Ottawa Valley region.

clearcutting (e.g., harvesting with protection of regeneration and soils, cutting of road right-of-ways, harvesting main extraction trails) should also be considered for night work during the operational planning. This increases the proportion of work that can be performed at night and consequently increases the flexibility of planning. However, these other treatments were not considered in this analysis.

To measure the magnitude of the potential savings, FERIC compared three scenarios for managing the use of the feller-buncher. The first involved using only a single shift per day. The second defined the annual proportion of night work (32%) based on the number of daylight hours. The third scenario was instead based on the proportion of the terrain suitable for night work in the study area (41% of the operating area).

Description of the Harvesting Systems

The production of tree-length wood is the main approach used for harvesting hardwoods, whether by manual or mechanized means. The contractor in the present study produced tree-length wood using a Timbco T-445 feller-buncher followed by manual delimbing with a chain saw. Subsequent extraction with cable skidders occurred over distances of up to 600 m. The felling, delimbing, and extraction productivities during single-tree selection had been previously measured under various operating conditions in maple stands (Meek 1997).

Work Methods for the Feller-buncher at Night

Implementing various work patterns with mechanized felling at night as alternatives, to single-tree selection was the subject of careful analysis to identify approaches that would meet the silvicultural objectives. The usual work of the feller-buncher in single-tree selection cuts comprises the establishment of a network of main trails spaced 33 m apart, supplemented by additional secondary trails (inserts). This pattern was used as the starting point for designing selection cuts with patches and shelterwood patch cuts.

Figure 2 presents the work patterns used by the feller-buncher to create the patches. The selection-cutting approach used 500-m² patches, versus 1200-m² patches for the shelterwood cuts. The shape of the patches was determined by the reach of the boom and the width of the trails used by the feller-buncher. Harvesting the trees in these patches allowed good productivity because the work patterns were similar to those used in clearcuts. Single-tree selection with 15% basal area removal adjacent to the extraction trail and patches provided the stem selection between the patches, and both

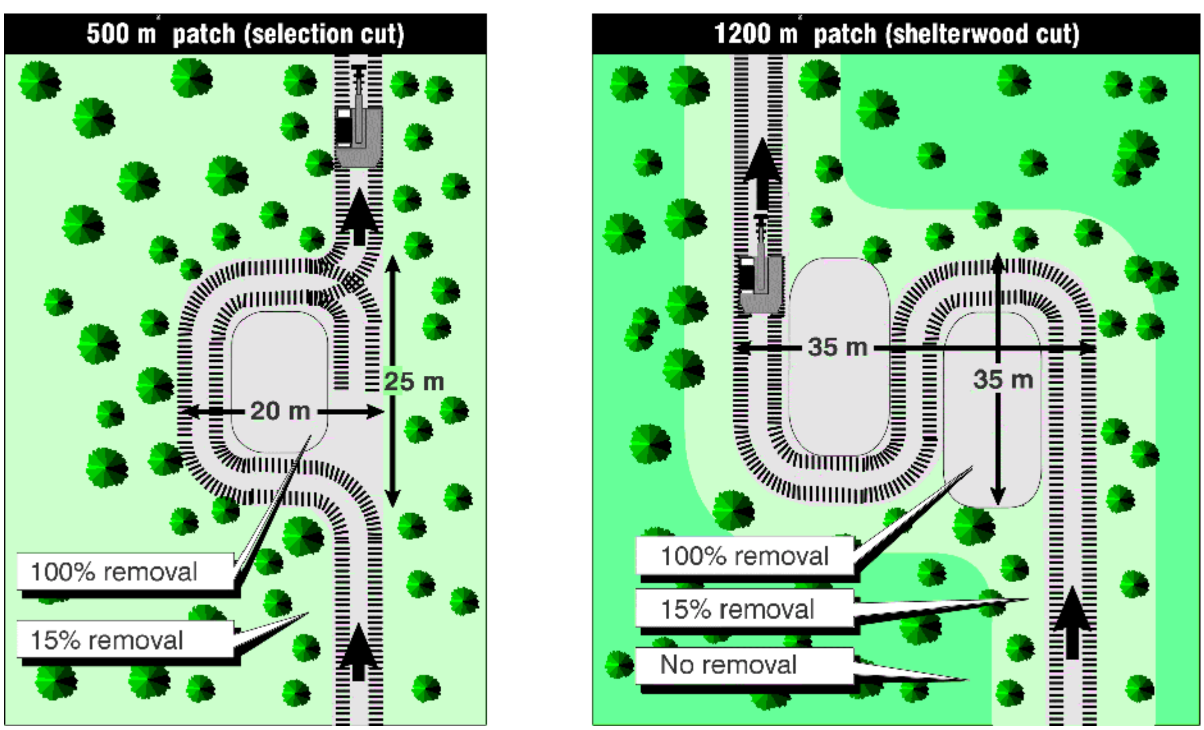

Figure 2. Work patterns used by the feller-buncher to create the two patch sizes used in the study.

improved the treatment quality and favored light penetration in the stand.

Figure 3 illustrates the work pattern proposed for the selection cuts with patches, in which trails dedicated to the 500-m² patches alternated with trails in which uniform removal was performed. This approach can be used if the trails with patches are harvested at night and the trails with uniform removal are left for harvesting during the day. To minimize the damage to residual stems, felled stems can be piled in the openings created by selection harvesting or in the patches themselves. With three patches per hectare, a removal intensity of 15% between the patches, and the clearcutting of trees in the trails, the overall removal level reaches around 37% of basal area with this setup.

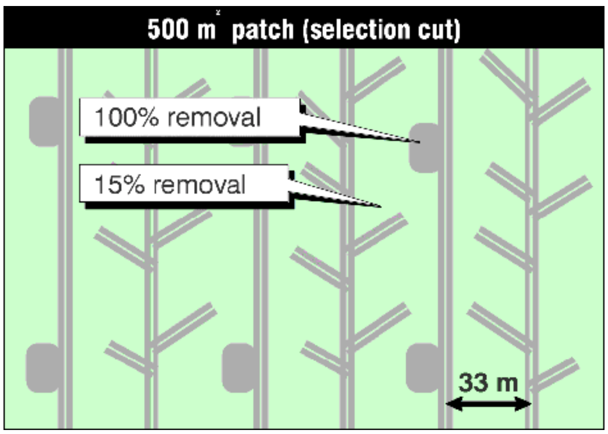

Figure 3. Distribution of trails (33-m spacing) and of 500-m² patches for the selection cut with patches.

Figure 4 presents the work pattern for the shelterwood cut with 1200-m² patches. The patches are staggered, and particular care is used to establish the trail positions so that machine travel in regenerating patches would not be required during the future (second) stand entry. Selective removal along the edges of the trails and patches also lets operators harvest high-value trees without additional cost so as to reduce the risks of quality losses between the two stand entries. This removal also releases the crowns of desired species to facilitate the dispersal of seeds into the openings. With two patches per hectare (at a 50-m trail spacing), the removal intensity would reach 34% of the volume; roughly three patches per ha (at a 33-m trail spacing) would be required to achieve a 51% removal intensity, which would be necessary to promote the establishment of species with moderate or low shade tolerance.

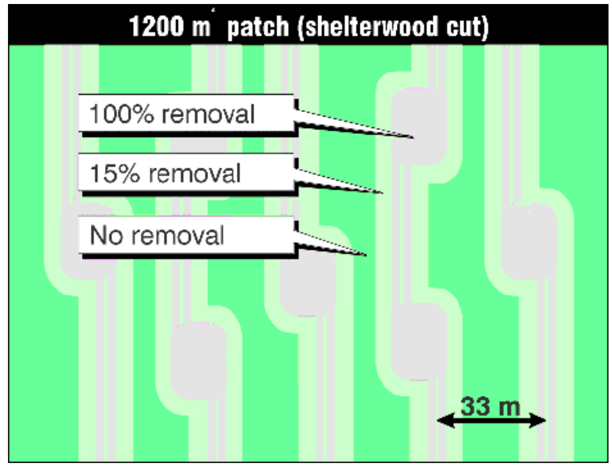

Figure 4. Pattern of trails with 1200-m² patches for shelterwood patch cuts and a removal intensity of 51% (the trails are 5 m wide, with a 33-m spacing).

Figure 5 presents the work pattern chosen for the uniform shelterwood cut. This pattern distributes the removal of trees without creating large patches, while maintaining good feller-buncher productivity. The 5-m-wide trails can accommodate the width of most machines and provide room for piling felled trees. Selective removal in the strips adjacent to the trails is done using the maximum reach of the feller-buncher's boom and increases light penetration into the leave strips. The untreated 5-m-wide strips will serve as extraction trails during the final harvest. The removal intensity for this pattern was 50%, but this could be increased or decreased by changing the widths of the various strips.

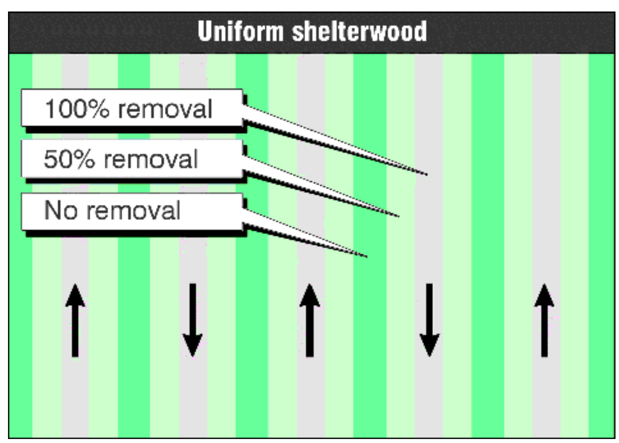

Figure 5. The pattern of trails for the uniform shelterwood cut with a 50% removal intensity (5-m-wide strips).

Treated Stands

The trials were conducted in mixedwood stands in which single-tree selection wasn't the preferred option. The creation of patches or of strips had the silvicultural goal of regenerating species with moderate shade tolerance, such as yellow birch. A second goal was to conserve the mixedwood stand structure over the long term. Table 1 presents the main characteristics of the stands treated during the trials.

Results

Evaluation of Productivity

FERIC performed short-term productivity studies of the feller-buncher for the three night operations (Table 2). Shift-level data were gathered using a vibration recorder installed on the feller-buncher. The felled stems were counted and a sample was scaled to determine the average volume per stem and the productivity.

Cost Analysis

Calculating hourly costs is an important part of analyzing the cost of the operation. The Appendix presents the assumptions used to calculate the direct hourly costs for the study based on one or two shifts per day. These costs are independent of the machine's productivity, and cover only the operating costs, excluding transport, supervision, profits, and other overhead. The two examples in the appendix are typical of the operating costs for a feller-buncher, but do not reflect the exact situation of the contractor (H. Leggett and Sons).

The difference in the hourly costs calculated for the two approaches depends on the assumptions used to calculate the ownership cost. This cost was calculated based on the machine's net cost (purchase price – resale price) and on the interest rate over the working life of the machine. The working life of the machine was 20 000 scheduled machine hours in both cases, but this would obviously be spread over twice as many years in the single-shift operation. The utilization rate of the machine was the same for both situations, since the mechanical availability and the operational effectiveness should not change significantly.

Table 1. Stand characteristics for the study treatments, and the associated removal intensities

	Night treatments			Daytime treatment
	Selection cuts with patches	Shelterwood patch cuts	Uniform shelterwood	Single-tree selection[a]
Stand composition	Mixedwood, with tolerant hardwoods and softwoods	Mixedwood, with tolerant hardwoods and softwoods	Mixedwood, with hemlock and yellow birch	Maple stand
Basal area (m^2/ha)	29.4	33.2	31.7	25.0
Volume (m^3/ha)	245	297	292	209
Average DBH (cm)	22	27	30	28
Stems/ha	793	599	454	492
Target removal intensity (%)	37	51	50	30

[a] Based on Meek (1997).

Table 2. Productivity of the four study treatments

	Night treatments			Daytime treatment
	Selection cuts with patches	Shelterwood patch cuts	Uniform shelterwood	Single-tree selection[a]
Study duration (PMH)	3.9	4.1	8.3	n.a.
Volume (m^3/stem)	0.547	0.594	0.627	0.810
Productivity				
Stems/PMH	81	93	92	43
m^3/PMH	44.3	55.2	57.7	34.8
Area harvested (ha/PMH)	0.51	0.37	0.40	0.56
Removal intensity (%)	37	51	50	30

[a] Based on Meek (1997).

The calculations presented in the Appendix raise the question of how relevant certain assumptions are. It appears unrealistic to think that a machine could work for 10 years (1 shift/day), since it risks becoming obsolete with the arrival of more productive machines on the market. This risk was not addressed in FERIC's analysis. The utilization rate used in both scenarios (85%) could also be considered optimistic for two shifts per day, since there would be less opportunity to maintain the machine between shifts. Several approaches to calculating direct costs were considered, including one in which the machine had a shorter working life. In the end, a conservative approach that minimized the difference in the results was used. The calculations demonstrated that the hourly cost of the Timbco T-445 feller-buncher would be nearly $14 per productive machine hour (PMH) lower (a difference of about 12%) when the machine works two shifts per day.

FERIC then studied the impact of assigning the feller-buncher to different treatments. Table 3 presents three different scenarios for using the feller-buncher. In the first scenario, the feller-buncher only operates during the day, whereas the two other scenarios assign different levels of night work to alternative silvicultural prescriptions. Scenario 2 is based on shelterwood cuts or selection cuts with patches for 32% of the scheduled *time*, which is the minimum required to account for the night periods in the operating season. Scenario 3 utilizes all the *area* suitable for night work in the study area, to a total of 41% of the overall area (equivalent to 38% of the operating *time* because of the feller-buncher's greater productivity in patch or shelterwood cuts).

The hourly cost for two shifts per day was used to determine the costs of scenarios 2 and 3. The productivity for single-tree selection from Meek (1997) was used, and an average productivity of 52.5 m³/PMH was used for the "other" silvicultural prescriptions in the table. The latter figure is based on the assumption that the harvest area was divided so that equal amounts of time were dedicated to shelterwood patch cuts, uniform shelterwood cuts, and selection cuts with patches (i.e., one-third for each).

Compared with the felling cost in Scenario 1 (single-tree selection, one shift/day), the calculated felling costs were 21 and 23% lower in scenarios 2 and 3, respectively. The different scenarios should have little effect on the subsequent delimbing and extraction costs, since productivity decreases caused by the lower average volume per stem in the patch and shelterwood cuts would be compensated for by greater concentration of the felled trees.

The total harvesting costs for the scenarios with two shifts per day, based on a delimbing and extraction cost of $5.44/m³, were $8.20 and $8.13 per m³, respectively; this is around 9% lower than in the scenario with one shift per day ($8.94/m³), with traditional single-tree selection performed during the day alone.

Table 3. Calculation of the felling cost for three usage scenarios for the feller-buncher

	Scenario 1: one shift per day	Scenario 2: two shifts/day with the minimum night work		Scenario 3: two shifts/day with the maximum night work	
Scheduled machine hours (SMH)/year	2000	4000		4000	
Prescription	Single-tree selection	Single-tree selection	Other	Single-tree selection	Other
Proportion (% of time)	100	68	32	62	38
Proportion (% of the area)	100	66	34	59	41
Felling					
Direct hourly cost ($/PMH)	121.68	107.57	107.57	107.57	107.57
Productivity (m³/PMH)	35.0	35.0	52.5	35.0	52.5
Direct cost ($/m³)[a]	3.50	3.09	2.05	3.09	2.05
Weighted mean felling cost ($/m³)	3.50	2.76		2.69	
Difference ($/m³)		–0.74 (–21%)		–0.81 (–23%)	

[a] These costs cover only direct operating costs, excluding transport costs, camp costs, etc., as well as profits and overhead.

Discussion

Based on the analysis in the previous section, the use of two shifts and the alternative silvicultural treatments permitted direct harvesting cost savings of 9% at roadside. A 20% decrease in felling cost was made possible in equal measure by the decreased hourly cost and by the increased productivity permitted by the alternative silvicultural prescriptions. This is an impressive result provided that all the assumptions used to calculate the costs are realistic and that implementation of the alternative approaches can be done efficiently. Certain cost savings are even possible in single-shift operations by using the alternative prescriptions during the day, as the improved productivity would reduce the felling cost by 12% compared with the traditional approach. However, since the alternative treatments can be performed at night, it would be logical to consider using two shifts per day to obtain additional savings.

The more that harvesting areas are dispersed, the lower the flexibility for planners. Scattered cutblocks make it difficult to fully utilize the night hours (a minimum of 32% of total time) that are available within two-shift operations. As mentioned previously, there is a minimum level of terrain available for night work required to maximize the use of the feller-buncher; it is easy to find these sites in large operating areas, but more difficult to find them among the blocks at individual locales.

As an example, let's assume that a working area that will be harvested over the course of a year is divided into three blocks of equal area, but in which the proportions of sites suitable for night work are 60, 25, and 15%. Taken as a whole, these blocks provide 33% of the overall area that is suitable for night work. However, managers must ensure that the 15% block is treated in the summer, when there are the fewest night hours; that the 25% block is treated in the fall; and that the 60% block is treated during the winter, when operators face the greatest number of hours with no light. What would happen if the 15% block can only be treated in the winter because of accessibility problems? This example shows that the harvesting time for each block must be matched to the spatial distribution of areas suitable for night work in each block; if not, the feller-buncher's utilization rate will decrease. This highlights the need for good planning and careful control of the operations.

The greater the range of silvicultural alternatives to single-tree selection, the greater the number of treatments that can be carried out at night. This also increases the chances of reaching the critical area threshold required for night work (32%) to optimize the use of the feller-buncher. It also increases the flexibility of planning, because with more silvicultural prescriptions available, it becomes easier to find blocks suitable for night work near those that will be harvested during the day, thereby decreasing machine travel time between the blocks. The alternative treatments that could be done at night also include cutting road right-of-ways, harvesting main extraction trails, and clearcutting.

For a harvesting contractor, an operation with two shifts per day would produce a greater volume of wood per year than with a single shift. As in any production system, increasing the volume produced does not necessarily lead to a proportional increase in fixed, management, planning, and other costs. Double-shifting thus becomes attractive for contractors, who can offer their services to harvest additional volumes.

Conclusions

FERIC's study revealed that the costs of mechanized felling could be decreased by around 20% by using two shifts per day combined with an appropriate selection of alternative silvicultural prescriptions for part of the operating area. However, a large part of the work during the second shift would have to be done at night. To work effectively at night, there must be a sufficient quantity of suitable terrain. In addition, since single-tree selection is difficult to perform at night, alternative silvicultural treatments must be considered, such as shelterwood cuts and selection cuts with patches or small-area clearcuts; various clearcutting applications could also be considered for night work, such as cutting road right-of-ways, harvesting the main extraction trails, and clearcutting softwood patches (with protection of regeneration and soils). These options could let hardwood contractors consider mechanization with more peace of mind.

FERIC is continuing trials to determine how to facilitate the work of feller-buncher operators during the night. For example, modifications to the lighting system (e.g., the use of xenon lights) as well as the use of reflective paint can improve the operator's ability to detect marked stems. FERIC is also participating in the development of a GPS-based navigation system with real-time correction; the applications in selection harvesting at night have been analyzed, and the preliminary results appear promising.

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Disclaimer

Appendix

Assumptions and Calculations Used to Determine the Hourly Cost of the Timbco T-445 Feller-buncher

	One shift/day	Two shifts/day
Assumptions		
Working life of the machine (years)	10	5
Scheduled machine hours (SMH)/year	2000	4000
Purchase price ($)	450 000	450 000
Resale price ($)	45 000	45 000
Licensing ($/year)	500	500
Insurance ($/year)	18 000	18 000
Interest rate (%)	10	10
Utilization rate (%)	85	85
Lifetime repair cost ($)	450 000	450 000
Fuel consumption (L/PMH)	25	25
Fuel cost ($/L)	0.50	0.50
Oil and lubricant cost ($/PMH)	1.00	1.00
Operator cost ($/SMH)	25.00	25.00
Fixed costs		
Cost/PMH ($)	52.30	38.18
Cost/SMH ($)	44.46	32.46
Variable costs		
Cost/PMH ($)	39.97	39.97
Cost/SMH ($)	33.98	33.98
Operator costs		
Cost/PMH ($)	29.41	29.41
Cost/SMH ($)	25.00	25.00
Total cost		
Grand total per PMH ($)	121.68	107.57
Grand total per SMH ($)	103.43	91.43