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Contents

An implementation guide for mechanized single-tree selection using 33-m trail spacing

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Abstract

Harvesting with 33-m trail spacing was proposed by FERIC as a way to meet the quality criteria for single-tree selection in hardwood forests in Quebec's public forests. The approach is, however, applicable to any partial-cutting treatment in hardwood forests, and the method was studied in 16 operations in 2003–2004. The approach represents an acceptable compromise between protection of the residual stand and operating costs, as the productivity of the feller-bunchers using this method decreased only slightly as a result of increased travel. The operations that FERIC studied did not all meet the target quality criteria, but provided an adequate level of protection of residual stems. The method requires a certain degree of control to limit the felling of non-marked stems, and the use of evaluation criteria specially adapted to this method would facilitate its implementation.

Keywords:

Skid trails, Feller-bunchers, Single-tree selection, Mechanical method, Productivity, Hardwoods, Tree-length systems, Delimbing, Cable skidders.

Introduction

An increasing scarcity of workers with experience in manual felling and related safety concerns have led to increased mechanization of hardwood and mixedwood operations. Currently, single-tree selection in hardwood forests is often performed using felling equipment, most commonly with tracked feller-bunchers (Figure 1). Meek (1997) described several aspects of mechanized single-tree selection, and the costs of some variations on this method. Even then, an approach based on harvesting with 33-m trail spacing appeared to be the most effective at meeting the quality criteria established for single-tree selection cuts in Quebec's public forests. This method adopts one of the main characteristics of partial cuts conducted

Figure 1. A feller-buncher working in single-tree selection.

in European countries, where cut blocks are harvested with wide spacing between permanently established trails to reduce damage to the stands. Trail spacings of up to 45 m are used in Germany's Black Forest as part of their uneven-aged management strategies.

In eastern Canada, the increasing use of mechanization has coincided with increasing difficulty meeting the quality criteria for selection cuts. The ideal stand conditions for such operations are becoming rarer and the forests that must be treated often originated from poorly controlled partial cuts during the 1960s and 1970s.

Effective protection of the residual stand and control of the removal intensity depends heavily on training of the forestry staff involved in the harvest—the machine operators and their supervisors. The method based on 33-m trail spacing facilitates this training because it provides a systematic approach to the work. Machine traffic is planned independently of the distribution of the marked stems, and allows a reasonable proportion of unplanned felling, thereby reducing the amount of wounding caused by extraction of the felled stems. The operating parameters are also easy to define and the results are easily evaluated. Although the method was originally developed for tree-length harvesting with mechanized felling, the same approach could be used with feller-directors, with manual felling, or with cut-to-length harvesting, although no formal studies of the latter systems have yet been performed. The current report describes the implementation of this method and presents the results of observations in eastern Canada, particularly those conducted in Quebec in 2003–2004.

Description of harvesting with 33-m trail spacing

Harvesting with 33-m trail spacing is illustrated in Figure 2 (see page 6).

The use of this method does not guarantee that the operation will meet the criteria for protection of the residual stand that are currently in effect in eastern Canada because machine operators must still maneuver carefully to limit stem damage. In general, operators must avoid all contacts between the equipment and residual stems as well as between harvested stems and the residual stems. The basic method involves the creation of wide trails (5 m) to facilitate maneuvering and the handling of harvested stems. The use of 5-m-wide trails in tolerant hardwood forests facilitates rotation of the feller-buncher's upper structure because relatively few trees border on the trails. However, the operator must still pay careful attention when maneuvering near these trees.

In some cases, the work techniques must be adapted to local conditions. For example, the basic method involves a double pass by the feller-buncher within each trail. The trail is created while traveling towards the back of the cut block on sites where the density of trees to be felled is high (more than 5 m^2/ha, for example) and is designed to provide maneuvering room around the trail. Thereafter, operators complete the felling of the trees between the trails during their return to roadside along the same trail. In low-density stands, the felling of all marked trees in and along the trail in a single pass is justified, so long as access to the trees to be felled remains easy.

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To guide operators who have not yet mastered the application of this method, flagging of trails before harvesting could be necessary to provide the consistent spacing between trails that is essential to limit felling of unmarked trees. The use of navigation tools such as GPS may help to attain this objective at lower cost.

In easy terrain, the operation targets a regular network of parallel trails. In more difficult terrain, it's better to establish trails that concentrate machine traffic in areas with the most accessible terrain rather than strictly following the desired spacing. In this case, managers must accept greater coverage of the site by trails to maintain the equipment's mobility or avoid excessive soil disturbance.

Extraction trails should be as straight as possible because skidders with a load can be 15 to 20 m long and are thus difficult to maneuver around turns. A sharp curve can easily cause the trail to widen to an excessive width of 7 to 8 m.

When the feller-buncher works during its return to roadside, the operator fells marked trees while working from secondary trails if the trees to be felled are located beyond the reach of the boom. Only the feller-buncher travels in these trails, whose length can reach up to 10 m. The cut stems are returned to the edge of the extraction trail for subsequent delimbing and extraction. The secondary trails should be established so as to minimize the felling of unmarked trees and regeneration. The angle between the extraction trail and the secondary trail can vary if necessary to avoid felling a future crop tree. However, a 45° angle such as the one illustrated in step 6 of Figure 2 (see page 6) is preferable because it facilitates the extraction of stems and minimizes the risk of wounding trees at the edge of the trails.

In Figure 2 (see page 6), the shaded area in dark grey will experience no machine travel, and covers roughly 40% of the area. The area in light grey sustains all machine traffic and becomes a regeneration zone because of the seedbeds created by the machine traffic. The trails for the subsequent harvest will likely be located in the dark grey zone so as to protect the developing regeneration in the light gray area.

Once the trees have been felled, delimbing (using chainsaws) can be done simultaneously with extraction or in a separate operation. Figure 3 (see page 8) illustrates this step for an operation in which delimbing is integrated with extraction. However, to avoid immobilizing a skidder during the long interval required for the operator to complete the delimbing, complete or partial delimbing can performed by a different worker who performs this task immediately after the felling has been done. The trees can also be partially topped by the feller-buncher after they have been placed on the ground. The delimbing is thereafter completed by the skidder operator once the trees have been pulled onto the extraction trail.

Productivity studies

Previous studies of the method with wide trail spacing (Meek 1997) demonstrated that the felling costs would be affected more than the extraction and delimbing costs. Our analysis in the present report thus focused primarily on the feller-buncher's work.

In 2003–2004, FERIC evaluated harvesting with 33-m trail spacing in several harvesting operations in Quebec's public forests. Data were gathered for 16 selection-cut operations with marking of trees, with each block covering 6 to 10 ha. The removal intensity ranged from 20 to 40% of basal area in maple and yellow birch hardwood stands or mixedwood stands dominated by hardwoods. After a short training period, felling began using the method with 33-m trail spacing. In each study block, we performed a detailed time study of the feller-buncher's productivity.

Figure 4 (see page 9) presents the 2003–2004 observations combined with the results of previous observations of this method. In the operations that we studied, the relationship between the mean volume of the harvested stems and the productivity of the feller-bunchers was not statistically significant. This is unlike what is typically observed in clearcutting. In single-tree selection cuts, the distance between the stems to be harvested increases with increasing stem volume, as does the duration of the work cycle, and the handling time for high-volume stems is also longer. Thus, mean stem volume is not a major factor in explaining variations in the feller-buncher's productivity. Moreover, no other variable describing the operating conditions was significantly related to the feller-buncher's productivity. For example, productivity was not significantly related to the basal area harvested nor to the initial stand density.

The operations with a 33-m trail spacing permitted a higher feller-buncher productivity (37 m³/PMH) than in previous FERIC studies at tighter trail spacing (less than 25 m; around 30 m³/PMH). This productivity difference is difficult to explain, since the additional maneuvering by the feller-buncher at the wider trail spacing should have decreased its productivity. We suspect that the older studies at narrower trail spacing may have involved less-experienced machine operators.

To evaluate the impact of the 33-m spacing on productivity more closely, we performed a more detailed analysis of the feller-buncher's work cycle. Figure 5 (see page 9) illustrates the mean distribution of work cycle time elements for this method.

The time distribution in Figure 5 illustrates the importance of the travel component that is typical of the work cycle during single-tree selection. In these operations, the trees to be cut are relatively far apart, thus it takes longer to travel between them so as to cover the area of the stand to be treated. The previous report (Meek 1997), which compared methods with 33-m and tighter trail spacing, revealed that the travel time was independent of the trail spacing itself. Whether the travel took place only in the extraction trail or also in secondary trails, the brushing, felling, and piling times were similar. In contrast, the work cycle element travel for bunching (12% of the time in Figure 5) was exclusive to the method with 33-m trail spacing. This represents the time required to move the harvested stem from the back of the secondary trail towards a more convenient location at the edge of the extraction trail (Figure 6, page 9). FERIC's productivity database indicates that felling without the use of secondary trails (as in clearcutting of softwoods, for example) can result in 10% shorter cycle times since the travel-to-bunch time is minimal. This behavior should also apply to single-tree selection with narrow trail spacing, where less effort is spent to group the trees. We can thus assume that the method with 33-m trail spacing requires a work cycle that is roughly 10% longer.

This result is comparable to the differences observed in previous comparative studies in Quebec (Meek 1997) and Ontario (Meek, unpublished data). Table 1 summarizes the impact on the total direct cost at roadside ($/m³) of using the approach with wide trail spacing, which is around 4% higher (excluding the costs of any additional supervision). It was assumed that the spacing of the extraction trails had no effect on the delimbing and extraction phases.

Table 1. Estimated mean direct costs ($/m³) for harvesting with two different trail spacings

	Felling	Delimbing	Extraction	Total
Harvesting with narrow trail spacing	4.20	1.28	4.90	10.38
Harvesting with 33-m trail spacing	4.62	1.28	4.90	10.80
Cost increase (%)	10	0	0	4

Table 2. Proportion of the operations studied by FERIC that met the quality criteria for the treatment (see Appendix 1 for details)

Criteria	Proportion of compliant operations (%)
Minimum felling level (>90% of the marked basal area)	75
Maximum felling level (<110% of the marked basal area)	38
Increase in the proportion of sawlog-quality stems	68
Protection of stems between 10 and 22 cm in DBH (75% of the initial density)	81
Wounds (maximum of 10%)	94

Effects on the residual stand

To describe the effects of harvesting on the treated stands, we performed a detailed inventory before and after harvesting in the operations studied in 2003–2004. Sample plots were surveyed following FERIC's standard techniques and classification of the stems was performed based on the guidelines provided by Quebec's Ministère des Ressources Naturelles et de la Faune (MRNFQ) that were applicable in 2003–2004. After harvesting, we described the network of trails in terms of mean trail width and spacing. We also surveyed the trees and stumps in the residual stand with respect to the trails to determine whether any unplanned felling was used to create the network of extraction trails.

Table 2 summarizes our observations of the harvesting operations in terms of their compliance with the MRNFQ criteria for management of single-tree selection.

The results demonstrate that some of the operations that used the 33-m trail spacing did not fully comply with these guidelines. In several cases, unfavorable terrain conditions restricted access to marked stems. In particular, the reduced visibility caused by the large amounts of foliage in the understory led to harvesting of less than 90% of the basal area of marked stems in some operations. The method with 33-m trail spacing requires particular attention under these conditions. For example, such areas should be harvested during the winter or late in the fall after the leaves have fallen. It is also possible to increase supervision of the operators to detect missed stems before the extraction phase is complete.

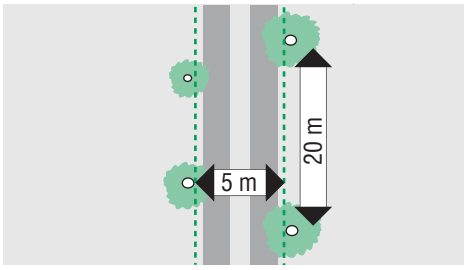
The difficulty in respecting the selection of marked trees is highlighted by the fact that the majority of the operations harvested an excessive proportion of stems larger than 24 cm in DBH that had not been marked (more than 110% of the marked basal area). The method with 33-m trail spacing involves the felling of unmarked stems in the trails, and the proportion of these stems appears to have been higher in operations with a low removal intensity. As well, the excessive felling detected in most operations often led to deficiencies in meeting the objectives for maintaining vigorous stems and an acceptable proportion of small stems. However, only one of the 16 operations that FERIC evaluated caused excessive wounding of the residual trees. This is one of the desired benefits of using a wide trail spacing.

❶ Layout and creation of trails:

- Creation of the trail is done by felling only a few trees to reduce encumbrance of the site.
- The feller-buncher travels towards the back of the block following as straight a line as possible, taking advantage of references such as flagging.
- Gentle curves are permitted to allow operators to travel on the most appropriate terrain.
- The operator plans the felling and determines the location of the secondary trails.

❷ Limitations on the width of the extraction trails:

- The extraction trail is defined by the total area available for travel of a loaded skidder and will be used for at least two passes by the skidder.
- The width is defined as the distance perpendicular to the direction of travel, measured between two lines drawn at a tangent to the trees that define the edges of the trail.
- The trees used for this measurement can have a very small diameter (1 cm) and can be as much as 20 m apart (roughly the length of a loaded skidder).



❸ Measurement of trail spacing:

- The spacing between trails is measured perpendicular to the trail direction, and represents the distance between two lines that represents the corresponding sides (i.e., left or right) of two adjacent trails.

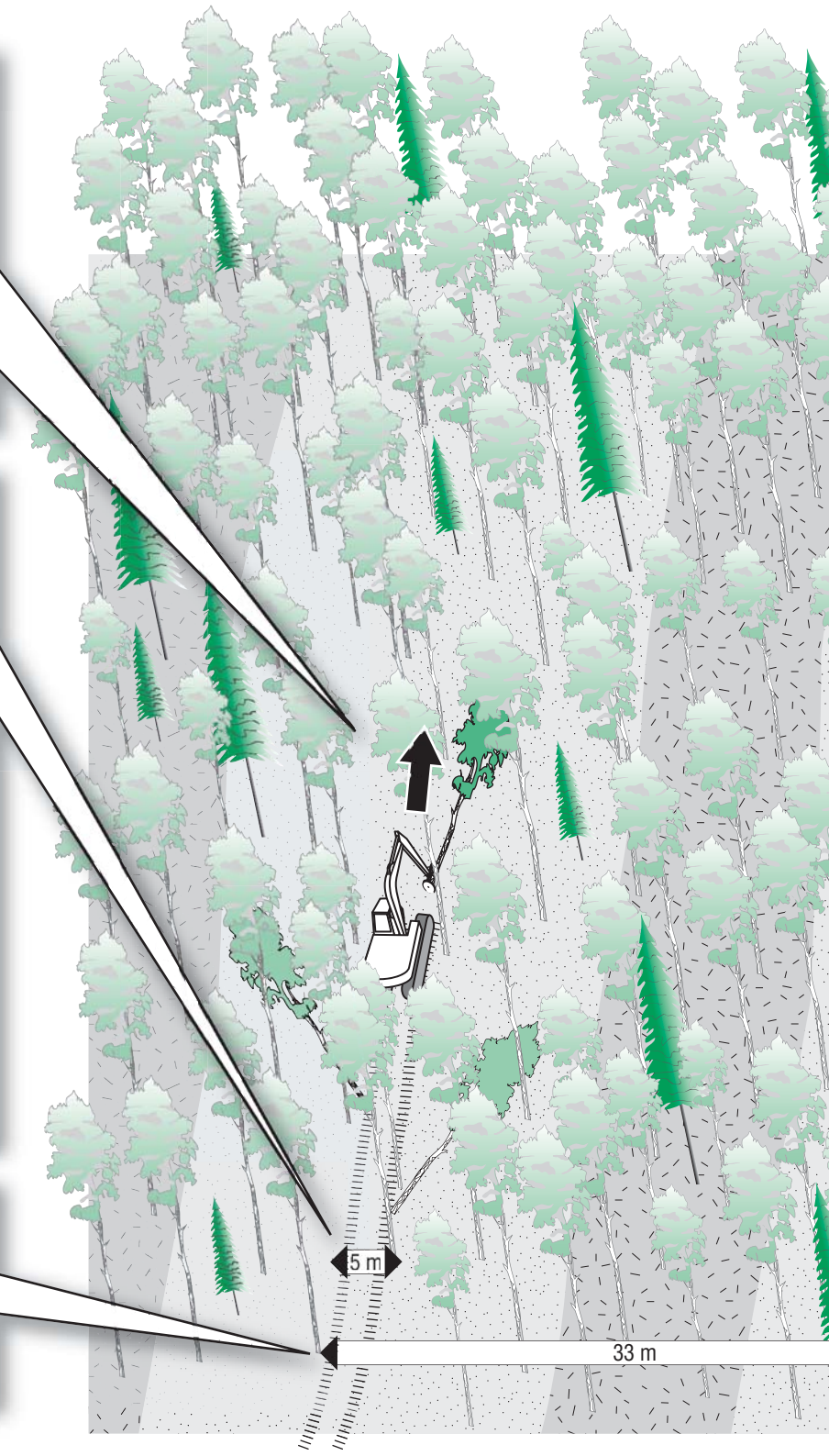
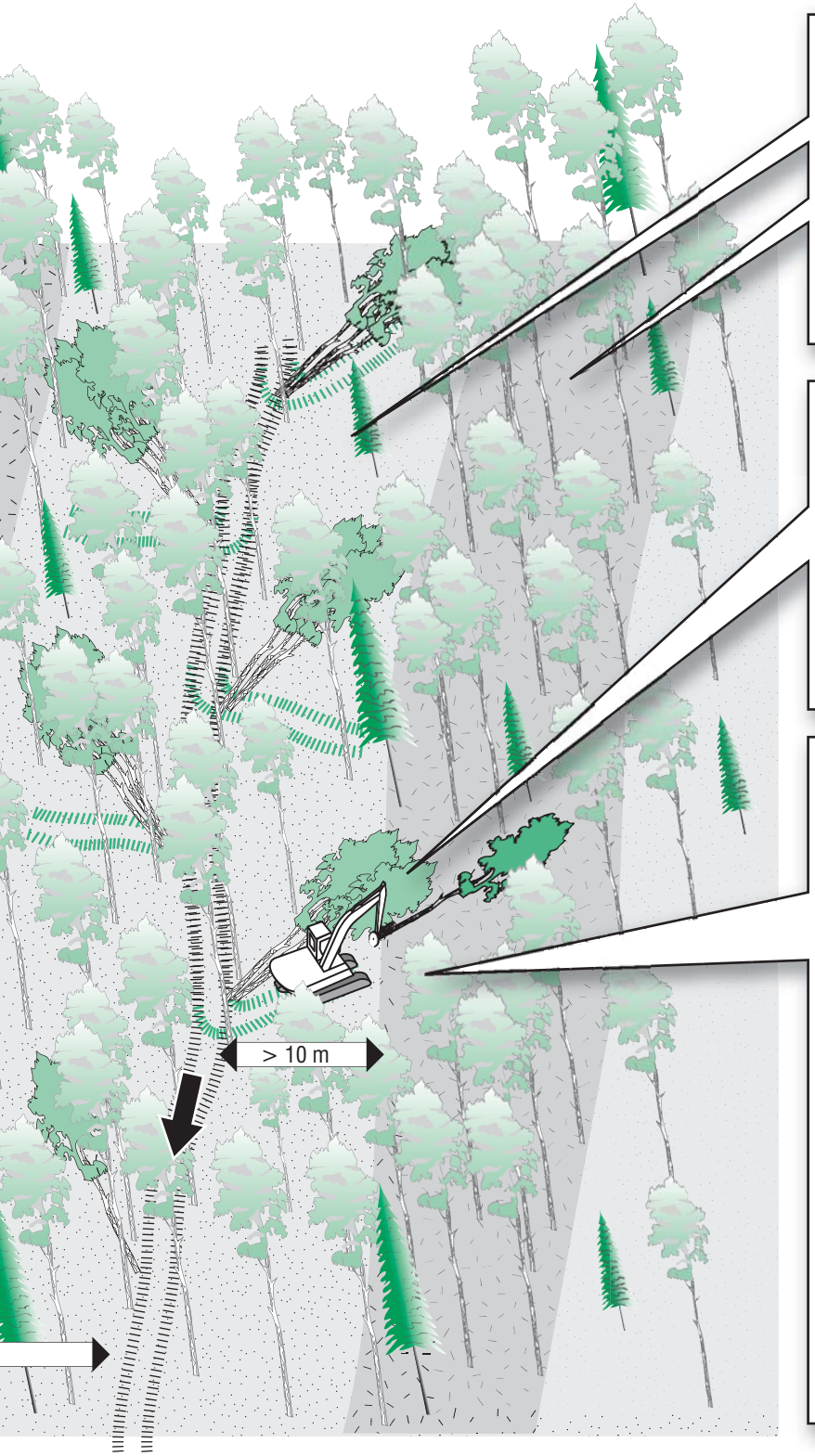


Figure 2. A guide for the implementation of harvesting with 33-m trail spacing.

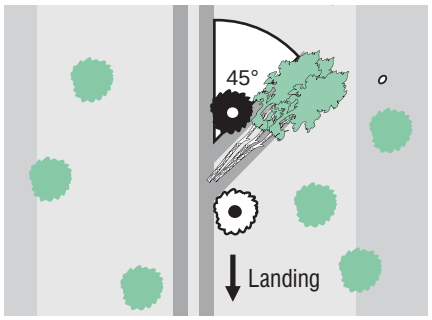


❹ Clearcutting of the trail and selection cutting:

- While returning to the landing, the feller-buncher fells any trees that remain on the extraction trail and trees within the reach of the boom (light-grey areas).
- Trees located beyond the reach of the boom (dark-grey areas) are felled while working from secondary trails.
- This area remains free from extraction trails.

❺ Felling from within the secondary trails:

- The secondary trail is slightly wider than the feller-buncher.
- The length of a secondary trail should not exceed 10 m except where spacing of the extraction trails is uneven.
- Secondary trails should be positioned so that marked trees can be felled without damaging any future crop trees.



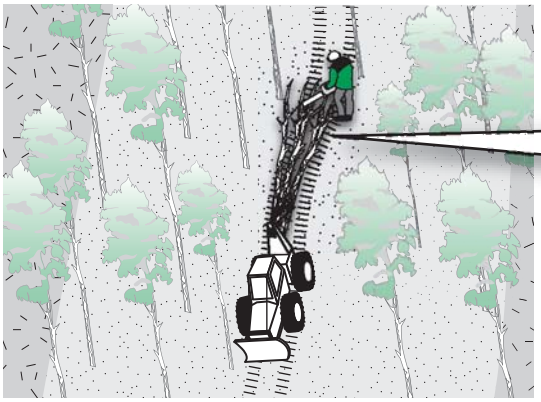
❻ Controlled piling of felled trees:

- Felled trees are piled by the side of the extraction trail, taking advantage of the gaps created by the secondary trails.
- Extraction is facilitated by maintaining an angle of 45° or less between the piles and the extraction trail.
- Each pile should be created as far as possible from the tree on the side of the pile nearest to the landing (shown in white in the illustration above).
- The number of trees in the pile should be limited and their arrangement should be designed to facilitate delimbing.

❶ Partial delimbing:
- Delimbing of the piled trees is performed in the secondary trail to leave as many branches as possible in that trail.

❷ Winching of the felled trees:
- The trees are winched with great care to avoid damaging the tree nearest to the landing (shown in dark green in this illustration).

❸ Delimbing of trees in a second pile:
- Delimbing of the first pile is completed after winching and skidder travel for a short distance so that difficult-to-reach branches become more accessible.
- Delimbing of trees from the second pile is also performed in the secondary trail.
- The trees from the first pile can be used as a counterweight during winching of trees from the second pile.



❹ Final delimbing:
- The previous steps are repeated until the skidder has acquired a load equal to its capacity and final delimbing can occur.

Figure 3. The various steps in a delimbing operation integrated with the extraction phase.

The quality criteria used in Quebec relating to the felling of unmarked stems in the trails are problematic because they assume that the space required for travel by the harvesting equipment will be sufficient after felling only the marked trees. Unfortunately, this may only apply to very good stand conditions that are rarely encountered these days. The method with 33-m trail spacing permits the implementation of a trail network that accepts a certain proportion of unplanned felling.

In the 16 operations studied, the trails had an average width of 5.5 m and an average spacing of more than 30 m. These results, which are not quite perfect due to a lack of experience with this approach, produce an average of 18% coverage of the site by trails. However, the basal area felled for the creation of the extraction trails was only 13%. The majority of this felling (60%) targeted marked stems because the operators had a natural tendency to direct the trails towards the marked trees. Flagging of the trails only served as a guide to help operators confirm the trail spacing.

Table 3 shows that the widely spaced trails provided good protection of the residual stand based on a new set of criteria proposed by FERIC. This analysis assumes that the creation of extraction trails is inevitable. The evaluation proposed by these criteria thus focuses on protection of the residual stand between the trails. The felling of unmarked stems between the trails was clearly lower than that suggested by Table 2. Only 6% of the basal area of harvested stems comprised unmarked trees, and these were often small trees located between the extraction trail and a marked tree. We recorded an average of only two unmarked large trees per hectare (DBH ≥ 24 cm) felled between the trails. The wide trails permitted efficient maneuvering, since serious wounds only affected 5% of the trees between the trails.

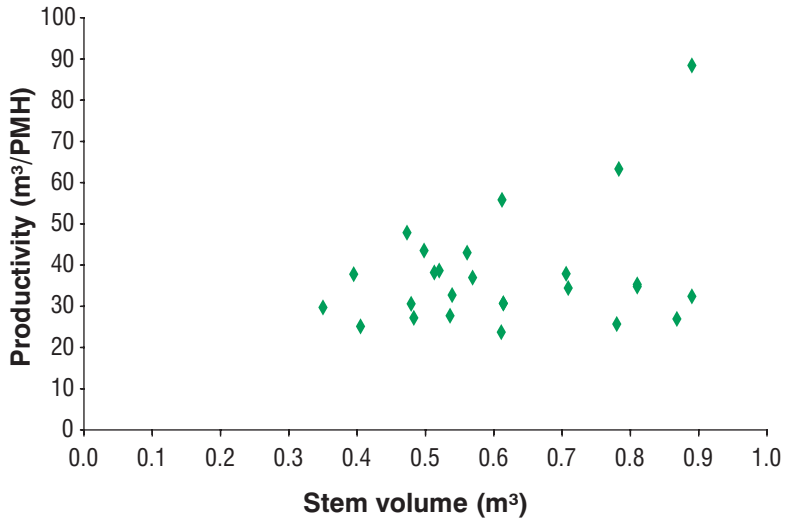


Figure 4. Productivity of feller-bunchers as a function of mean stem volume (33-m trail spacing).

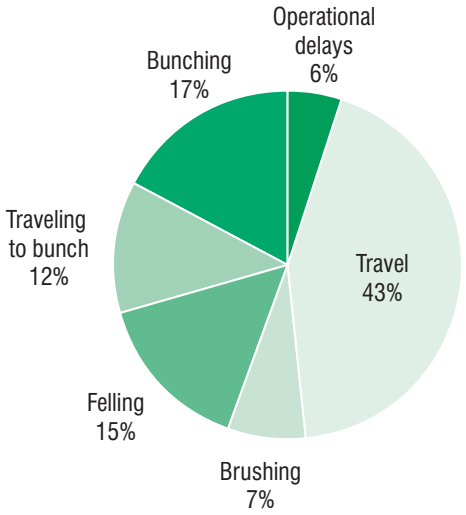


Figure 5. Mean distribution of work cycle time elements for feller-bunchers in the method with 33-m trail spacing.

Figure 6. Maneuvering to place a felled stem near the edge of the extraction trail after felling in the secondary trail.

Table 3. Mean characteristics of the treated stands

Description of the extraction trails	
Mean width (m)	5.5
Mean spacing (m)	30.7
Mean coverage of the site by trails (%)	18
Removal outside the extraction trail	
$\frac{\text{Basal area of unmarked harvested stems}}{\text{Basal area of harvested stems}}$	6%
Unmarked stems ≥ 24 cm in DBH that were felled (stems/ha)	2
Trees with wounds >100 cm^2	5%
Decrease in the proportion of vigorous stems attributable to harvesting, excluding stems on the extraction trail (% of basal area)	8%
Proportions of released stems (≥ 50% of the crown exposed)	
Before treatment	33%
After treatment	56%

Overall, the proportion of vigorous high-quality stems only decreased by 8% if we exclude the felling required to create the extraction trails. The creation of straight trails did not necessarily lead to an inadequate concentration of stem removal. The proportion of stems in the stand that had at least 50% of their crown released increased from 33% before the harvesting to 56% afterwards. Thus, more than half of the residual stems had the desired growth conditions and could benefit from the edge effects created by the extraction trails or by felling of a marked stem.

FERIC recommends more widespread use of the 33-m spacing method for selection treatments in hardwood forest wherever the terrain permits.

Implementation

Mechanized single-tree selection with 33-m trail spacing can improve protection of the residual stand compared with an approach based on narrow trail spacing. This approach represents an acceptable compromise between implementation costs and the required level of protection of the residual stand, particularly if the financial penalties for failure to comply with provincial guidelines are significant.

The method described in this report was developed for use in a semi-mechanized tree-length system, but the general principles also apply to other harvesting systems. For a mechanized full-tree system, trail width could be increased to 6 m and trail spacing could be increased to 40 m. For a system with manual felling followed by extraction with a cable skidder, the secondary trails can be lengthened and oriented so as to permit complete loading of the skidder from the secondary trail. In a cut-to-length system, the trails do not have to be as straight because forwarders can more easily navigate around good future crop trees. In every case, definition of the target quality criteria, including those related to the residual growing stock, must account for unplanned felling to leave room for operators to maneuver under more difficult conditions.

The use of 33-m trail spacing offers excellent opportunities to improve the control and supervision of harvesting teams. To the extent that the harvesting method is based on operational parameters (e.g., trail width and spacing), it is possible to control the operation by measuring these parameters continuously. Often, the traditional control

procedure is based on a network of semi-permanent sample plots that are remeasured after harvesting by a technical team that is independent of the harvesting team. The resulting delay and separation of responsibility makes it difficult to detect any deviations from the plan and take appropriate corrective measures.

In particular, measuring trail width and spacing can be done using temporary sample plots. These plots are rectangular and their sides coincide with the centers of two adjacent trails. Thus, the parameters of the trail network are measured directly and this sample provides an immediate estimate of the degree of control. Other parameters useful for the management of the treatment can also be measured in these plots. The plots thus permit control throughout the site at any time after the felling. Even informal measurements of the spacing of trails by the machine operators and the frontline supervisors can provide an approximation of the quality of the implementation that can later be measured more formally using the temporary sample plots. A supervisor could thus expect that the results of measuring trail widths and spacings several times per week would be subsequently validated by formal measurements of the sample plots. This ongoing sampling makes it possible to react rapidly if significant deviations are detected, thereby preventing the harvesting of several hectares in an unacceptable manner.

The implementation of 33-m trail spacing avoids the problem of post-harvest monitoring by proposing direct measurement of control parameters.

A survey of damage to the residual stems and an estimate with respect to the removal of marked trees between the trails should suffice to complete the evaluation procedure. The number of serious wounds to a predetermined number of residual trees and the inspection of stumps between adjacent trails would provide rapid, objective information. The managers of these operations could then define critical thresholds for conformity of the work with the management objectives and local conditions.

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Reference

Meek, P. 1997. Mechanized selection cutting in hardwoods with a Timbco T-445. For. Eng. Res. Inst. Can. (FERIC), Pointe-Claire, QC. Tech. Note TN-265. 12 p.

Appendix 1
Definitions of the criteria for evaluating treatment quality*

Minimum level of felling: the harvest should focus on marked stems comprising more than 90% of the marked basal area.

Maximum level of felling: the harvest should focus on marked stems comprising less than 110% of the marked basal area, including unmarked trees (with a DBH ≥ 24 cm) knocked down or felled.

Increase in the proportion of lumber-quality stems: the proportion of stems of the target species and of quality class 1 should increase after harvesting in a proportion related to the maximum theoretical increase. This theoretical proportion is determined by calculating the proportion of vigorous stems if the entire removal had focused on stems with low vigor. The thresholds to be attained at the time of the observations were 35 or 60%, depending on the extent of the selection by marking. The mechanized felling should, however, avoid excessive wounding or felling of vigorous stems to ensure compliance with these guidelines.

Protection of stems 10 to 22 cm in DBH: the number of unmarked stems that are cut or knocked down should not exceed 25% of the total number of stems (before harvesting) in the diameter classes from 10 to 22 cm (inclusive).

Wounds: the trees of quality level 1 that are wounded during harvesting (≥100 cm^2 on the trunk) fall into a lower class. Fewer than 10% of the stems in lower quality classes should be wounded.

* As defined in the MRNFQ's "INSTRUCTIONS RELATIVES À L'APPLICATION DU RÈGLEMENT SUR LA VALEUR DES TRAITEMENTS SYLVICOLES ADMISSIBLES EN PAIEMENT DES DROITS, EXERCICE 2003-04".