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Author
Luc Desrochers
Eastern Region

Mechanized harvesting in riparian zones using a long-reach single-grip harvester

Abstract

Two single-grip harvesters with a long reach were evaluated in partial-cutting operations in riparian zones in the Lac Saint-Jean region of Quebec. During the first study, the harvester remained outside the reserve, and some of the trees remained beyond its reach. The following year, an experimental trial tested the possibility of using the harvester to make small inserts into the riparian zone to reach a larger proportion of the trees. In both studies, harvesting productivities were comparable to those of single-grip harvesters used in other typical harvesting regimes in eastern Canada. The harvester's entry into the 20-m reserve caused no notable soil disturbance.

Keywords:

Riparian zones, Buffer strips, Single-grip harvesters, Long-reach booms, Telescopic booms, Shortwood forwarder, Cut-to-length harvesting systems, Productivity, Soil disturbance.

Introduction

The logistics of semi-mechanized harvesting (with manual felling) in riparian zones often prove difficult: the operation is isolated, only part of the stand is harvested, winching and extraction distances are long, frequent machine travel is required, there is a risk of accidents, insurance and liability costs are high, and so on. On the other hand, regulations prevent forestry machines from traveling in riparian zones and the limited reach of harvester booms make a mechanized approach impractical with conventional equipment. As a result, most forestry companies have avoided or have abandoned harvesting in these reserves. However, in Quebec, the harvest volumes available in riparian zones will be included in the allowable cut starting in 2008, increasing interest in harvesting in these zones.

In 2002, Wajax-Hydrofor, an equipment manufacturer in the Lac Saint-Jean region of Quebec proposed a solution: installation of a single-grip head at the end of a stroke delimber boom, thereby creating a harvester with a 17-m reach. Starting in 2002, the machine was used for partial cutting in 20-m riparian zones on the limits of Bowater Canadian Forest Products Inc. A second machine was added in 2003.

An initial evaluation by FERIC in the fall of 2003 revealed that the riparian zones averaged 23.4 m in depth and that the proportion of the reserves beyond the reach of the harvester was around 27%. One

possible solution was to make inserts into the riparian zone with the harvester to provide access to the full width of the strip. In the fall of 2004, FERIC performed a second trial to test a harvest layout that included short inserts into the riparian zones. This report presents the results of FERIC's two studies.

Description of the equipment and operations

Camp Rivière Bureau operation

The first operation was observed in late September 2003 near Bowater-Mistassini's Rivière Bureau camp in the Lac Saint-Jean region of Quebec. The harvester, owned by Forestier Marcel Tremblay Enr., was a tracked 1996-model Kobelco 220, equipped with a Denis DT 3000 telescopic-boom stroke delimber boom with a 1995-model FMG 746 single-grip head mounted at its end. The harvester's reach was 16.9 m from its tracks to the felling head. A six-wheeled 1996-model Timberjack 1010B forwarder with a 10-t load capacity extracted the wood.

Figure 1. A long-reach single-grip harvester using a telescopic delimber boom.

The harvester was dedicated to partial cutting of riparian zones and certain inaccessible areas such as steep slopes. In the riparian zones, the operator only harvested trees in areas with sufficient stem density and stem volume. Areas that were too steep, too soft, or that had too-low volume were excluded. No strict guidelines were established for the length of segments that should be harvested or excluded. The objective was to obtain a residual density of 500 stems/ha in the treated areas.

The harvester was studied while working on sites that had been harvested 1 or 2 years earlier. The stands comprised black spruce (59%) and balsam fir (41%) with mean volumes of 0.13 m^3 per tree and 184 m^3 per ha. The width of the riparian zones ranged from 20 to 27 m, and averaged 23.4 m. Abundant, tall regeneration created poor visibility inside the strip. The slope ranged from low (0 to 5%) to steep (15%). The operators monitored their work quality using circular, 5.64-m-radius sample plots.

The harvester remained outside the riparian zone and piled processed wood on both sides of the extraction trail (Figure 2). When the operators could not see the base of a tree, they grasped the stem where visible with the head, and then moved the head down to the base of the tree.

Camp Daniel operation

The second study was carried out in early November 2004 near Bowater-Mistassini's Daniel camp. The machines belonged to the contractor Lucien Tremblay. The harvester was a tracked 1996-model Kobelco M19 220 with a Denis telescoping delimber boom and a 2004-model Waratah 450 head. The machine's reach was 17.5 m between the tracks and the felling head.

During the study, a six-wheeled Valmet 646 forwarder with a 12-t load capacity worked with the harvester.

Harvesting of the adjacent block ended 1 week before the study. The width of the riparian zone ranged from 20 to 32 m, and averaged 24.7 m. The stand comprised mature black spruce with mean volumes of 0.12 m^3 per tree and 137 m^3 per ha. The low regeneration permitted good visibility of the interior of the reserve. The slope ranged from nil to low. During the study, the soil was partially frozen and was covered with a few centimeters of snow.

The trials were experimental. The harvesting pattern, which entailed inserts into the reserve, was developed by the machine operators. As in the previous study, the treatment objective was to leave between 500 and 600 merchantable stems per hectare and harvest the largest trees. Areas that were too wet or that had low-density stands were avoided.

The harvester penetrated an average of 4 m (ranging from 1 to 9 m) into the riparian zone. The operator felled the trees and piled them in front of the harvester, backed out of the reserve, then processed one stem at a time (Figure 3). Delimbing debris was left in the extraction trail and logs were piled on the opposite side of the trail from the reserve.

Figure 2. Felling from outside the riparian zone.

Figure 3. Felling from an insert in the riparian zone.

Study results

Table 1 presents the results of the time studies of the harvesters.

At Rivière Bureau, the harvester felled 84 stems/PMH, for a productivity of 19.0 m³/PMH (Table 1). The harvester treated an average of 131 m of reserve per PMH.

At Daniel, the harvester was much faster, felling an average of 146 stems/PMH. Flat terrain, better visibility, smaller trees, and a faster single-grip head explain this difference. Extension of the boom and positioning of the head on the stem took only half as long as in the Rivière Bureau operation. Harvester travel between treated areas was less frequent (due to the presence of contiguous harvestable areas), but the progression along the reserve was slower (84 m/PMH) because of the need to make the inserts and harvest trees in a larger proportion of the riparian zone. The mean volume per harvested tree was smaller at Daniel (0.141 m³/stem), thus the average productivity in m³/PMH was comparable to that at Rivière Bureau.

Forwarder productivity

At Rivière Bureau (nine extraction cycles), the forwarder completed a round trip (cycle) in an average of 25 min. The mean extraction distance was 177 m (ranging from 70 to 400 m), which is short for this type of operation. The volume per load averaged 10.7 m³ (ranging from 4 to 15 m³), for a mean productivity of 26 m³/PMH. This productivity was high because of the short extraction distance, which will not normally be the case because riparian zones are often located at the far end of the harvest blocks.

At Daniel (seven extraction cycles), the mean time per trip was 45 min over an average extraction distance of 450 m (ranging from 275 to 900 m), which is a more typical distance for this type of operation. The volume per load averaged 12.6 m³ (ranging from 12 to 14 m³), for a productivity of 16.8 m³/PMH. This was lower than the harvester's productivity. However, on a regular basis, an eight-wheeled Valmet 850 forwarder with a 15-t capacity normally accompanied the harvester.

Table 1. Productivity and work cycle time elements for the harvesters

Study	Rivière Bureau	Daniel
Harvester head	**FMG 746**	**Waratah 450**
Productive machine hours (PMH)	5.2	11.5
Trees/PMH	84	146
Mean volume per harvested stem (m³)	0.226	0.141
Mean number of logs/stem	2.31	1.91
Volume/PMH (m³)	19.0	20.6
Length of reserve treated per PMH (m)	131	84
Time elements	**Min/cycle**	**Min/cycle**
Travel	0.11	0.05
Boom extension/positioning of head	0.24	0.12
Felling	0.09	0.07
Processing	0.22	0.16
Operational delays	0.08	< 0.01
Total cycle time	0.74	0.41

Treatment quality

Pre- and post-harvesting stand characteristics

To evaluate the characteristics of the riparian zone throughout its depth, we used 10-m-wide rectangular sample plots that extended across the entire reserve (20 m or more). At Rivière Bureau, 12 plots were measured in four different harvest blocks. At Daniel, 11 plots were measured in a contiguous riparian zone. Table 2 summarizes the stand characteristics in the riparian zone before and after harvesting.

Camp Rivière Bureau

The reserve averaged 23.4 m in depth before harvesting and 22.2 m afterwards. On average, 26% of the stems and 46% of the stand volume were harvested. The number of residual stems remained relatively high (1120 stems/ha), in large part because of the harvester's limited boom reach (17 m).

Figure 3 presents the proportion of stems harvested within five 5-m bands away from the edge of the stream. A very small proportion of the trees was harvested between 0 and 10 m (the portion of the strip farthest from the harvester), and only 33% of the stems were harvested between 10 and 20 m from the river, leaving an average of 900 trees/ha in this section. Wounding of residual trees was negligible, with only 2.4% of the stems having wounds larger than 50 cm².

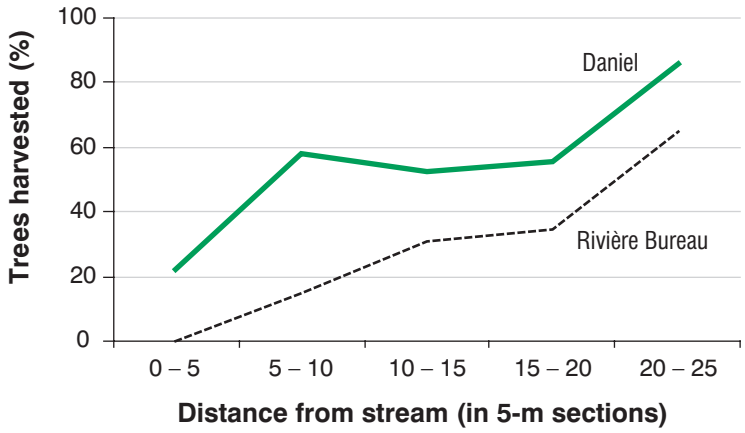

Figure 3. Percentage of trees harvested per 5-m section away from the stream.

Table 2. Stand characteristics before and after harvesting

	Rivière Bureau			Daniel		
Stand	**Before**	**Harvested**	**Residual**	**Before**	**Harvested**	**Residual**
Average width of the reserve (m)	23.4		22.2	24.7		22.7
Basal area/ha	30.8	12.3	19.5*	23.7	14.6	9.1*
Merchantable trees/ha	1441	381	1120*	1155	635	574*
Stems/ha (% of total)	100	26	74	100	55	45
Mean DBH (cm)	15.5	19.2	14.2	15.5	17.0	13.8
Volume/ha (m^3)	184	85	105*	137	94	47*
Volume/ha (% of total)	100	46	54	100	69	31
Mean volume/stem (m^3)	0.128	0.226	0.093	0.118	0.149	0.082
Damage to residual stems (% of stems)			**2.4**			**5.2**

* Based on residual area.

Camp Daniel

The riparian zone averaged 24.7 m in depth before harvesting and 22.7 m afterwards. On average, 55% of the stems and 69% of the volume were harvested, a clearly higher harvesting intensity than in the Rivière Bureau operation. Slightly more than 20% of the stems were harvested between 0 and 5 m from the stream (leaving a residual density of 875 trees/ha), versus 55% of the stems between 5 and 20 m from the stream (leaving a residual density of 525 stems/ha, which is close to the target density of 500 stems/ha). The mean volume per tree decreased from 0.118 m^3 to 0.082 m^3, leaving a residual merchantable volume of 47 m^3/ha. Because of the inserts, wounding of residual trees was higher (5.2%).

Frequency and length of inserts

Over 1.8 km of contiguous riparian zone, 1.5 km (83%) were treated and 48 inserts were cut. Table 3 summarizes the frequency and length of the inserts.

The distance between the inserts ranged from as little as 4 m to more than 106 m, and averaged 28 m. The harvester entered the riparian zone at a mean angle of 56° to minimize turning maneuvers and the resulting soil disturbance. The length of the inserts ranged from 1 to 9.4 m, and averaged 4.5 m. After correcting for the angle of the inserts with respect to the face of the riparian zone, the depth of penetration of the inserts ranged from 0.6 to 9.1 m, and averaged 3.7 m. The width of the riparian reserve ranged from 20 to 32 m, so only 45% of the inserts (2.1 m on average) actually encroached on the 20-m zone, amounting to 0.8% of the total area. In some cases, the extraction trail encroached 1 to 2.5 m into the 20-m zone, accounting for 4.5% of the total area.

Table 3. Frequency and length of the inserts

Inserts	
Mean distance between inserts (min - max)	28 m (4 - 106)
Mean length of the inserts (min - max)	4.5 m (1.0 - 9.4)
Mean angle of the inserts[a] (min - max)	56 ° (15 ° - 100 °)
Mean depth of the inserts[b] (min - max)	3.7 m (0.6 - 9.1)
Impact of the inserts within the 20-m zone	
Percentage of inserts penetrating the 20-m zone	45
Mean penetration of the inserts into this zone (m)	2.1 (0.6 – 6.4)
Occupancy of the inserts within the 20-m zone (% of total area)	0.8
Occupancy of extraction trails (% of total area)	4.5
Total occupancy within the 20-m zone (% of total area)	5.3

[a] Angle between travel along the face of the riparian zone and the inserts.
[b] Depth of the insert measured at 90° to the face of the riparian zone.

Soil disturbance

At Rivière Bureau, no significant soil disturbance such as exposed mineral soil was observed within the riparian zone. At Daniel, the harvester left an imprint 5 to 10 cm deep and inverted the humus at some locations, but no exposed mineral soil was found. The primary disturbances were caused by the forwarder traveling along the edge of the reserve. Ruts deeper than 20 cm covered only 0.13% of the area of the riparian zones.

Discussion and implementation

The observed productivities of the long-reach single-grip harvesters treating the riparian zones compared favorably with the mean productivities of conventional single-grip harvesters working in more typical operations (Table 4). Note that the results are presented per PMH and that the utilization rate of the machines (PMH/SMH) will normally be lower in the reserves because of their discontinuous nature and the increased travel required to fully treat the strips.

Harvesting of riparian zones offers certain advantages: only dense stands are harvested, and the harvesting targets large-diameter stems. However, the productivity of the machines will be affected by the long travel distances and the dispersion of suitable sites. The logistics for hauling wood will also be affected when harvesting of the reserves does not coincide with harvesting of the adjacent block.

Despite the harvester's long reach, part of the riparian zone remains inaccessible. By penetrating slightly into the riparian zone, it becomes possible to perform partial cutting throughout the depth of the reserve. During FERIC's trials, the inserts cut into the 20-m zone amounted to less than 1% of the total area and created no significant soil disturbance. The only disturbance that we observed was caused by the forwarder, and occurred at the outer edge of the 20-m zone.

Quebec forestry regulations forbid travel by forestry machines in the 20-m zone. Given the low impact observed during our studies, it appears reasonable to review these regulations to permit travel by machinery in part of the reserve (between 15 and 20 m from the stream), subject to limitations on the type of machine (i.e., only

Table 4. Mean productivities of single-grip harvesters in eastern Canada[a]

Volume/harvested tree (m^3)	Productivities observed	Mean productivities for various types of harvesting in eastern Canada		
	Riparian zone (m^3/PMH)	Commercial thinning (m^3/PMH)	Partial cutting (m^3/PMH)	HPRS (m^3/PMH)
0.141	20.6	11.3	14.9	16.4
0.226	19.0	18.3	21.1	23.1

[a] Calculated using FERIC's Interface software and the equations in Meek (2000) for equivalent volume/tree.

the harvester) and the type of entry (short inserts cut perpendicular to the border of the reserve or at an angle) and provided that soil disturbance caused by machine travel is not permitted.

In 2006, three long-reach single-grip harvesters were used in Bowater-Mistassini's operations to harvest trees in reserves. As prescribed by the regulations, the machines remained outside the 20-m strip. However, the operators carefully delineated the 20-m zone and harvested all parts of the stand outside this boundary, thereby minimizing the part of the zone beyond the harvester's reach.

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Find us online! www.feric.ca

Eastern Region
580 boul. St-Jean
Pointe-Claire, QC, H9R 3J9
(514) 694–1140
(514) 694–4351
admin@mtl.feric.ca

Western Region
2601 East Mall
Vancouver, BC, V6T 1Z4
(604) 228–1555
(604) 228–0999
admin@vcr.feric.ca

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