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Contents

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Impact of harvesting sound deadwood on harvesting productivity and costs

Abstract

Harvesting of the sound deadwood in an overmature stand reduced machine productivity and increased harvesting costs by nearly 12% in a cut-to-length system and by nearly 9% with a full-tree system. The need for operators to handle dry wood, which is more subject to breakage and thus to volume losses, increased handling times. Moreover, although only 15% of the deadwood present in the overmature stand before harvesting was classed as sound, over 55% of all deadwood was recovered. As a result, harvesting deadwood may potentially introduce a significant amount of undesirable decayed wood into the system.

Keywords:

Deadwood, Harvesting, Harvesting with protection of regeneration and soils, Productivity, Costs, Fiber recovery.

Introduction

With increasing fiber shortages and a reduction of nearly 20% in the annual harvest volumes allocated by Quebec's Ministère des Ressources Naturelles et Faune (MRNF), Quebec's forestry companies are increasingly being forced to turn to alternative sources of fiber. Among these, sound deadwood (described below) represents a significant volume of fiber in some forests, and the instructions provided by MRNF dictate that this wood should be harvested whenever it meets certain characteristics. However, harvesting and handling this volume becomes increasingly expensive as the proportion of sound deadwood increases because of the higher likelihood of breakage. To quantify the impact of harvesting this type of wood on machine productivity and harvesting costs, FERIC conducted a study with Produits Forestiers Arbec Inc. in the summer of 2005 in a region containing adjacent stands of mature and overmature forests.

Study sites and methodology

The two study sites were a mature spruce stand 70 to 90 years old (Figure 1, up) and an overmature uneven-aged spruce stand older than 120 years (Figure 1, low), both in the Lac Saint-Jean region of Quebec.

The terrain was relatively homogeneous, with the same bearing capacity and slope at both sites (CPPA classification 3.2.2). The weather conditions during the operations were relatively constant, and the same machine operators worked in both stands.

A study area was established in each stand. The site in the mature stand was divided into four 4-ha blocks; that in the overmature stand was subdivided into four 3-ha blocks. These blocks were harvested using two harvesting systems (full-tree and cut-to-length), with a replication for each system to let us confirm our results and compensate for any losses of data. The

Figure 1. A mature stand with only a small volume of sound deadwood (upper), and an overmature stand with a high proportion of sound deadwood (lower).

harvesting followed the standard approach used for harvesting with protection of regeneration and soils (HPRS).

In each of the two forests, 400-m² circular sample plots were established to permit pre- and post-harvest inventories; these plots were randomly located, at an intensity of one sample plot per hectare. Machine productivity in the two systems was determined using detailed time studies that let us assess the results based on the characteristics of the two stands.

Characterization of decayed wood and of sound deadwood

Characterization of decayed wood and of sound deadwood was based on the document Estimation des volumes de bois affectés par les opérations de récolte ("*estimation of wood volumes attributed to harvesting operations*") published by Quebec's Ministère des Ressources Naturelles, de la Faune et des Parcs (MRNFP, 2004).

Deadwood is considered sound if it meets the following criteria:

- The fiber is dry and difficult to break when a sample around 2.5 cm thick, removed with a hatchet, is subjected to medium pressure in the assessor's hands.
- The wood shows no discoloration even if the bark is missing or detaches easily.
- There is no moss growing on the top of the log if it is resting on the ground.

Dead, decayed wood can be distinguished from sound deadwood using the following criteria:

- There is a fringe of friable (crumbly) wood either completely or partially surrounding the log.
- There is discoloration of the wood where the bark is missing.

Based on MRNFP's guidelines, the stand inventory must account for the volume of sound dead trees and parts of dead trees left on the cutover. However, this material can be omitted from the inventory if at least one defect (continuous or discontinuous) can be found over more than one-third of the stem's length.

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Stand characteristics

The merchantable fiber available at the study sites included both live trees and sound deadwood. However, the proportion of deadwood was very different: the mature stand contained primarily live wood, whereas in the overmature stand, nearly 50% of the wood was dead. Table 1 summarizes the stand characteristics.

The total merchantable volumes available for harvesting, including the live trees and the sound deadwood, were comparable: 137.2 m³/ha in the mature stand and 135.6 m³/ha in the overmature stand. However, the sound deadwood represented 1 and 15% of these volumes, respectively. In addition, the mean volume per stem or per piece of stem was higher in the overmature stand, irrespective of the species and the nature of the wood, both for the live trees and the dead wood. The values in Table 1 represent averages per block, but the actual volumes of the stems harvested during our observations may have differed slightly from these values in some cases as a result of micro-variation within the stand.

Table 1. Volumes of wood available in the two study stands

	Mature stand	Overmature stand
Standing live trees		
Stand density (stems/ha)	1560	800
Merchantable volume (m³/ha)	**135.7**	**115.3**
Species distribution (% of volume)		
- Black spruce	92.4	52.1
- Balsam fir	7.0	46.1
- Other	0.6	1.8
Mean merchantable volume per stem (m³/stem)		
- Black spruce	0.090	0.287
- Balsam fir	0.060	0.092
Deadwood (standing or on the ground)		
Density (pieces/ha)*	55	730
Volume available (m³/ha)		
- Dry and sound	1.5	20.3
- Decayed	1.1	89.7
- Total (dead)	**2.6**	**110.0**
Total, merchantable volume available (living + sound deadwood)	**137.2**	**135.6**

* Includes stems or parts of stems at least 2.5 m (8 ft) long, both standing and on the ground.

Impact of harvesting sound deadwood on machine productivity

Cut-to-length system

A Timberjack 608 single-grip harvester and a Timberjack 1010B forwarder were used in the cut-to-length system. The products were 5-m (16-ft) logs plus variable length top logs. Table 2 summarizes the productivities for the single-grip harvester in both stands, as well as standardized productivities based on a mean volume of 0.150 m³/stem. The high gross productivity was attributable to the high degree of operator skill and the short study duration.

Table 2 demonstrates that the *gross* productivity in the overmature uneven-aged stand was greater than that in the mature stand. However, this result does not reflect the difference between the mean stem volumes in each stand. Standardizing the values using the productivity curves in FERIC's *Interface* software (Figure 2) revealed that productivity in the mature stand was actually more than 20% greater than that in the overmature stand.

This productivity gap can be explained primarily by the fact that the many dead stems or pieces of deadwood in the overmature stand, even though they were classified as "sound", were not strong enough to sustain handling by the machine and thus provided much less merchantable volume.

A detailed analysis of the productivity in the overmature stand as a function of the nature of the wood appears in Table 3. The results show, in particular, the large impact of fallen deadwood on productivity.

Table 4 summarizes the productivities observed for the forwarder in the two stands.

Standardized for an extraction distance of 150 m, the forwarder's productivities were comparable in the two stands. Thus, the forwarder's productivity was not greatly affected by the sound deadwood in the overmature stand.

Table 2. Productivity of the single-grip harvester

	Mature stand	Overmature stand
Mean volume of harvested stems (m³)	0.35	0.215
Productivity (stems/PMH)	183	130
Productivity (m³/PMH)	24.8	28.1
Productivity standardized for a volume of 0.150 m³/stem (m³/PMH)	**26.7**	**22.0**

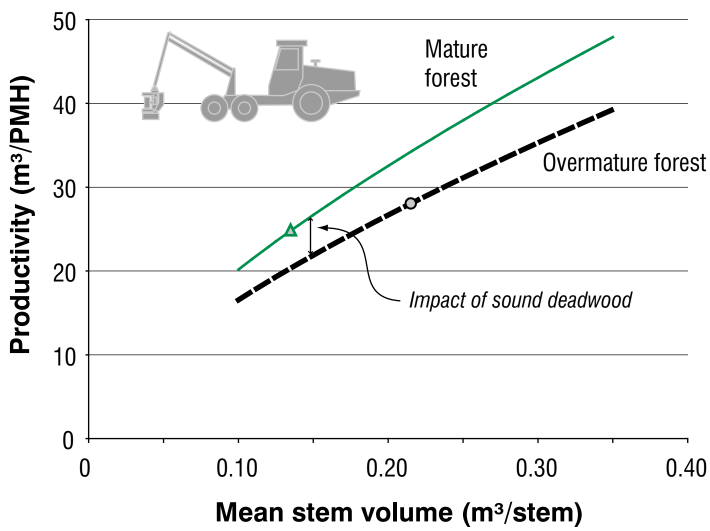

Figure 2. Standardized productivity curves for the single-grip harvester.

Full-tree system

A Timberjack 618 feller-buncher and a Lokomo 933 clambunk skidder were used, with roadside delimbing performed by a Samsung 120LC delimber equipped with a Denharco DT 3500 boom.

Table 3. Detailed breakdown of the single-grip harvester's productivity in the overmature stand

	Live trees	Standing sound deadwood	Sound deadwood on the ground
Mean volume of harvested stems (m^3)	0.225	0.138	0.194
Productivity (stems/PMH)	132	147	108
Productivity (m^3/PMH)	29.6	20.3	21.0
Productivity standardized for a volume of 0.150 m^3/stem	**22.5**	**21.5**	**17.6**

Table 4. Productivity of the forwarder

	Mature stand	Overmature stand
Mean volume per log (m^3)	0.059	0.121
Average extraction distance (m)	190	222
Productivity (m^3/PMH)	22.7	22.2
Productivity standardized for a 150-m extraction distance (m^3/PMH)	**25.2**	**26.3**

Table 5. Productivity of the feller-buncher

	Mature stand	Overmature stand
Mean stem volume (m^3)	0.162	0.202
Productivity (stems/PMH)	348	246
Productivity (m^3/PMH)	56.4	49.7
Productivity standardized for a volume of 0.150 m^3/stem (m^3/PMH)	**52.5**	**38.4**

Table 5 summarizes the feller-buncher's productivities in the two stands.

After standardization to a mean volume of 0.150 m^3/stem, the productivity in the overmature stand was nearly 27% lower than that in the mature stand (Figure 3).

Rough handling of the deadwood by the feller-buncher broke stems and made them unusable, thereby reducing the number of stems produced per PMH. This phenomenon was observed in more than 8% of the work cycles. As a result, the feller-buncher in the overmature stand was only able to collect an average of 3.0 trees (0.61 m^3) per bunching cycle versus 4.9 trees (0.79 m^3) per bunching cycle in the mature stand.

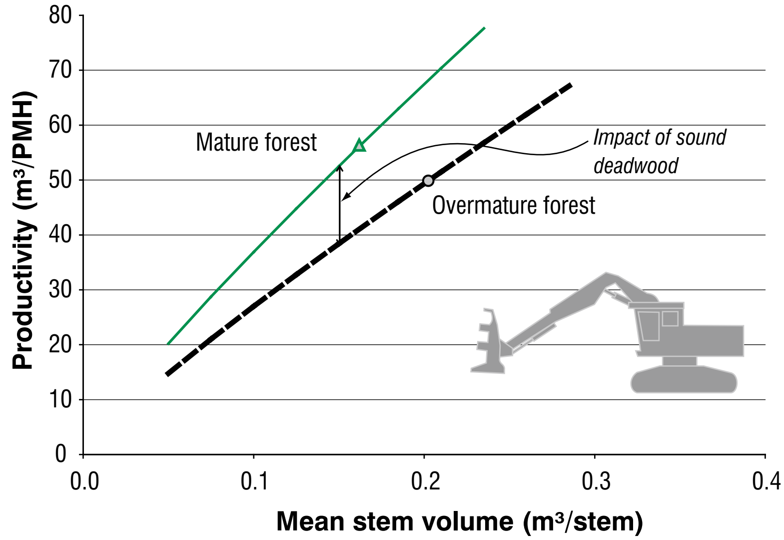

Figure 3. Standardized productivity curves for the feller-buncher.

During extraction, the clambunk skidder was not affected by the nature of the fiber, and its productivity depended primarily on terrain conditions and on the locations and sizes of the bunches. Table 6 summarizes the productivities for the clambunk skidder in the two stands.

Standardizing the extraction distance at 150 m and the mean stem volume at 0.150 m^3/stem revealed that the productivities were essentially equal in the mature and overmature stands.

For the delimber, factors known to affect its productivity include stem size and branchiness. In addition, handling of deadwood, whether decayed or dry and sound, can also decrease its productivity because of stem breakage. However, our studies did not let us detect measurable effects of sound deadwood on the delimber productivity.

Impact of harvesting sound deadwood on the fiber recovery rate

To evaluate the fiber recovery rate in the two harvesting systems, we performed a post-harvest inventory at the same sampling intensity used in the pre-harvest inventory. The same scaling equations and evaluation criteria were used in both inventories.

Recovery rate for green fiber

Table 7 summarizes the recovery rate for live merchantable stems. Harvesting of live trees by the feller-buncher left less than 1 m^3/ha of merchantable volume on the site in both stands, including live standing stems and green wood on the ground, for a recovery rate greater than 99%. In contrast, the single-grip harvester left much larger residual volumes (1.7 and 5.1 m^3/ha, respectively, in the mature and overmature stands), for recovery rates of 98.8 and 95.6%, respectively.

Recovery rate for deadwood

In the overmature stand, the deadwood left standing after harvesting primarily represented decayed wood that was intentionally left behind. The high volume of deadwood on the ground after harvesting was largely deadwood that was already on the ground before harvesting and dead standing wood that was broken during handling. Table 8 summarizes the volumes of deadwood longer than 2.5 m (8 ft) measured before and after harvesting.

In the mature stand, the volume of deadwood left on the ground after harvesting was greater than or equal to the initial amount of deadwood, but generally

Table 6. Productivity of the clambunk skidder in the two stands

	Mature stand	Overmature stand
Mean stem volume (m^3)	0.165	0.206
Average extraction distance (m)	91	301
Productivity (stems/PMH)	345	202
Productivity (m^3/PMH)	56.9	41.6
Productivity standardized for a 150-m extraction distance (m^3/PMH)	**48.0**	**48.3**

remained very low. In the overmature stand, the recovery rate for standing and fallen deadwood exceeded 55% for both harvesting systems. However, since only 18% of the pre-harvest volume of deadwood was classed as sound, this suggests that a large quantity of decayed wood entered the system.

Table 7. Recovery rate for live stems

	Mature stand		Overmature stand	
	Standing	On the ground	Standing	On the ground
Pre-harvest volume (m³/ha)	135.7	0	115.3	0
Residual volume (m³/ha)				
- Cut-to-length	1.1	0.6	1.9	3.2
- Full-tree	0.7	0	0.7	0
Recovery rate (%)				
- Cut-to-length	98.8		95.6	
- Full-tree	99.5		99.4	

Table 8. Recovery rate for deadwood

	Mature stand	Overmature stand
Pre-harvest volume (m³/ha)	2.6	110.0
Residual volume (m³/ha)		
- Cut-to-length	3.2	45.5
- Full-tree	2.6	47.0
Recovery rate (%)		
- Cut-to-length	0	58.7
- Full-tree	0	57.3

Impact of harvesting sound deadwood on operating costs

By affecting machine productivity, harvesting sound deadwood will also directly affect the operating cost to various extents, depending on the equipment used and the type of harvesting system chosen. The estimated direct hourly costs for the machines used in this study were calculated using FERIC's standard method and thus may not necessarily represent the real costs a contractor will encounter:

Cut-to-length system:

- Single-grip harvester: ..$160/PMH
- Forwarder: $120/PMH

Full-tree system:

- Feller-buncher: $150/PMH
- Clambunk skidder: $180/PMH
- Delimber: $130/PMH

Based on the productivities observed during our study and standardized for a stem volume of 0.150 m³, operating costs for the cut-to-length system were nearly 12% greater in the overmature stand than in the mature stand free of deadwood. For the full-tree system, this difference was around 9%.

Implementation

Harvesting sound deadwood is now required under the harvesting and forest management agreements signed in Quebec, since this increases the volume of fiber harvested per hectare. However, the operating costs measured during our trial in the overmature forest were nearly 12% greater than in the mature forest using the cut-to-length system and nearly 9% greater using the full-tree system. The handling of significant volumes of deadwood will lead to losses of time related to the facts that this material is more fragile and thus, that not all of this volume will be recovered.

The recovery of the broken sections of stems should be easier with a shortwood forwarder than with the skidders used in the full-tree system, even though there was not a large difference during this trial. It's important to note that the results described in this report are specific to the study conditions, and should thus only be used as indications of relative performance.

The increased recovery of deadwood will increase the proportion of potentially decayed wood hauled to the mill. It is thus important to carefully define the parameters for sound wood so that machine operators can avoid introducing unusable fiber into the system. In addition, processing a significant volume of deadwood at the mill will undoubtedly lead to additional costs, but the analysis of these costs is beyond the scope of the current project and should become the subject of a future study.

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