Advantage

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Contents

Butt damage associated with high-speed circular saws in winter operations

Abstract

The Forest Engineering Research Institute of Canada (FERIC) examined the level of butt damage from felling with high-speed circular saws in three winter harvesting operations in Alberta and British Columbia. The location and extent of the butt damage on each damaged stem were recorded, and the impact of the butt damage in terms of loss of sawlog volume available for lumber manufacturing was projected. Factors influencing butt damage are discussed, and recommendations to reduce wood losses are made.

Keywords

Butt damage, Felling, Fibre loss, Feller-bunchers, High-speed circular saws.

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Introduction

In the early 1980s, FERIC conducted a series of studies examining the butt damage resulting from felling with various types of tree shears and non-shear devices. The results showed volume losses of 3.5 to 4.5% for felling machines with tree shears, while the volume losses for non-shear machines ranged from 0.1 to 1.9% (McMorland and Guimier 1984). As various types of saw heads were developed and improved, they replaced tree shears. With this change, butt damage was reduced considerably and generally stopped being an issue in timber harvesting. However, in recent years, sawmill operators have reported end-splits on sawn lumber typically associated with butt damage from felling operations. In response to these reports, FERIC initiated a study to examine butt damage from felling with high-speed circular saws in winter conditions. This is one of several FERIC studies focusing on mechanical wood damage associated with harvesting and wood handling operations, and strategies to maximize the value and volume of marketable fibre from the forest.

Study objectives

The overall goal of the study was to evaluate the butt damage associated with feller-bunchers equipped with high-speed circular saws in winter operations. The specific objectives were to:

- Record butt damage from feller-bunchers in winter operations.
- Determine the impact of stem diameter size, multiple-stem felling,[1] and tooth sharpness on butt damage.
- Recommend strategies for reducing butt damage.

Description of studies

The project consisted of three studies conducted in cooperation with Manning Diversified Forest Products Ltd. in Manning, Alberta (Studies 1 and 2), and with Abitibi-Consolidated Inc. in Mackenzie, British Columbia (Study 3). The field data were collected in January 2001 and January 2002

[1] Multiple-stem felling refers to the operating technique of cutting the trees one by one, but accumulating two or more of them in the felling head before bunching.

on regular harvesting operations that used feller-bunchers equipped with high-speed circular saws to fell and bunch the wood (Figure 1). The machines in the study included carriers, felling heads, and saws from different manufacturers (Appendix I).

The operating conditions also varied between studies. The sites in Study 1 and 2 were flat to gently rolling and snow-covered (<0.3 m depth). Stand composition varied from overmature conifer to mature aspen/spruce mixtures, with average tree size ranging from 0.2 to 0.5 m^3. Ambient temperature ranged from -20° to -5°C. The sites in Study 3 were on 5 to 30% slopes with the occasional steeper grade, and snow-covered (0.5 to 1.0 m depth). The stands were mixtures of mature white spruce, lodgepole pine and subalpine fir, with average tree size ranging from 0.3 to 0.5 m^3. Ambient temperature ranged from -10° to 0°C.

About 1200 full-tree conifer stems were examined on 12 different felling sites prior to skidding. The stems were randomly selected from sound stems located on top of the bunches and accessible for measuring. The diameters at the butt, as well as at 1 and 5 m from the butt, were recorded for each selected stem. A 5-cm-thick cookie, assumed to represent the normal end-trimming of logs in sawmills, was cut from the butt of each selected stem. The exposed butt surface was then examined for visual damage. If there was no visual damage, then a second cookie about 3 cm thick was cut and examined to ensure that the butt surface was free from hairline cracks. If butt damage was present, the type (split or torn piece), its location on the butt surface, and its length were recorded (Figure 2). Additional cookies were cut from stems with end splits, and each new butt

Figure 1. Feller-buncher in Study 2 at Manning.

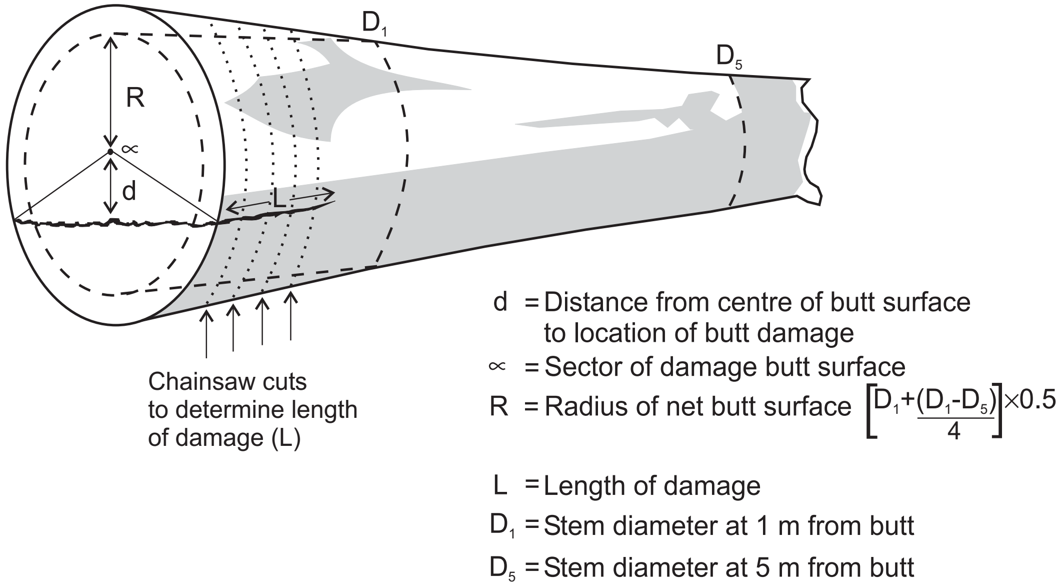

Figure 2. Measurements recorded on damaged logs.

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surface was examined for damage until the remaining stem was free from butt damage. The length of the damage was measured by totalling the thickness of the cut-off cookies and adding 0.75 cm kerf for each chainsaw cut made.

All butt logs were assumed to be cut 5 m long and without butt flare. The log's net butt diameter (butt diameter without flare) was calculated by projecting the log's taper between the l-m to 5-m section to the butt end.[2] The sawlog volume of the butt log was calculated using Smalian's formula, and the total merchantable sawlog volume of the stem was obtained from data on the volume relationship between 5-m butt logs and the merchantable stem determined in prior studies.[3]

Only damage that occurred within the net butt diameter was assumed to affect lumber recovery from the log. The loss of sawlog volume available for lumber manufacturing was calculated using the same method as in prior studies to quantify wood damage in terms of volume loss (Andersson et al. 2002). However, the volume loss calculated with this method (Figure 3) does not necessarily correspond to an equal percentage reduction in lumber recovery. Instead, the results should be seen as indices of wood loss associated with butt damage from different causes.

Results

In the initial analysis, FERIC compiled the butt damage and operating conditions for each of the 12 sites to determine common factors and/or trends (Appendix I). The results showed that the butt damage varied with stem diameter, felling technique (single-stem versus multiple-stem), and condition of the cutting teeth (old versus new). Although these factors did not explain all the variations in butt damage, no other measurable factors (e.g., number of teeth per saw, or operator experience in years) could be correlated to the recorded butt damage. Thus, the data from some sites were combined and analyzed for a particular treatment (Table 1).

The frequency of stems with damaged butts ranged by treatment from 9 to 53%. However, some of the stems were only damaged outside the net butt diameter and thus the damage was assumed to have no effect on lumber recovery. Excluding this damage, the frequency of damaged butts with loss of sawlog volume ranged from 8 to 33%.

[2] If the projected (calculated) butt diameter was larger than the measured butt diameter, the latter was used as the butt's net diameter.

[3] Tree-length volume data for Studies 1 and 2 were obtained from a stem breakage study in High Level (200 km north of Manning), and for Study 3 these data were obtained from a stem breakage study in Mackenzie.

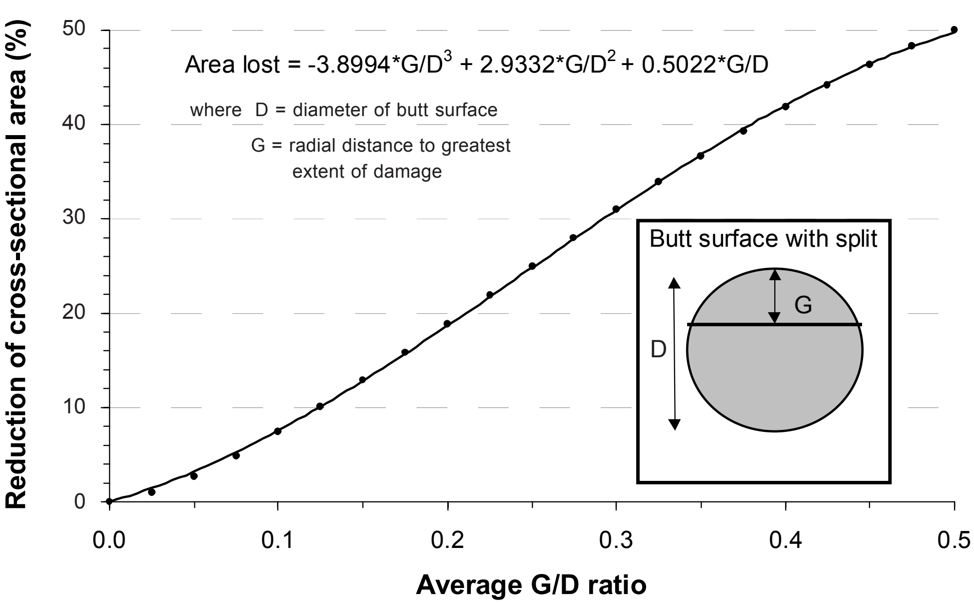

Figure 3. Projected reduction of butt surface available for lumber manufacturing, due to butt damage.

Treatment Study sites	Normal operation 2001 1–4	Single-stem felling 5–7	Multiple-stem felling 5–7	Normal operation 2002 8	Old cutting teeth 9–11	New cutting teeth 12
Total stems (no.)	350	127	206	119	190	209
damaged with no volume loss (%)	20.3	1.6	6.8	0.8	23.7	5.7
damaged with volume loss (%)	32.9	8.7	12.1	8.4	29.5	9.1
Location of damage on butt surface [a]						
<0.24R (% of all stems)	5.7	0.0	2.9	1.7	3.7	0.5
0.25–0.49R (% of all stems)	4.6	1.6	1.4	0.0	3.1	0.5
0.50–0.74R (% of all stems)	7.7	1.6	3.4	1.7	5.3	1.9
≥0.75R (% of all stems)	14.9	5.5	4.4	5.0	17.4	6.2
Length of damage						
≤30 cm (% of all stems)	20.9	7.1	9.7	6.7	18.4	7.1
31–60 cm (% of all stems)	8.6	1.6	1.0	0.8	7.9	0.5
61–120 cm (% of all stems)	2.6	-	1.4	0.0	2.6	1.0
>120 cm (% of all stems)	0.8	-	-	0.8	0.5	0.5
Projected loss of sawlog volume						
% of 5-m butt log volume	0.90	0.09	0.33	0.21	0.70	0.12
% of merchantable stem volume	0.48	0.04	0.16	0.09	0.35	0.06

Table 1. Summary of results

[a] R = net radius of butt surface.

Most of the damage consisted of a single split or a piece torn from the side of the butt, but a few stems had multiple occurrences. Typically, the majority of the damage was located in the outer quarter section[4] of the net butt surface. The length of the damage on individual stems ranged from 4 to 280 cm, but most of the damage was confined to within the first 30 cm of the stem length. Overall, less than 2% of the 1200 stems had damage that extended more than 60 cm from the butt.

The projected loss of sawlog volume from the butt damage, expressed as percentages of the volume of 5-m butt logs and of merchantable stem, ranged on the 12 study sites from 0.1 to 1.5% and from 0.04 to 0.8%, respectively (Appendix I).

The butt damage was generally more extensive among small-diameter stems than among larger-diameter stems. Results from Study 1 (Figure 4) showed the damage frequency for stems with dbh ≤20 cm was double compared to stems with dbh >30 cm, and projected loss of sawlog volume was nearly five times higher. Similar trends were also recorded in the other treatments, although the differences varied in magnitude (Figure 5).

The volume loss among multiple-felled stems was four times that of the single-felled ones. This was due in part to the higher overall damage frequency, but mainly due to the damage being more extensive among the multiple-felled group. The difference in volume loss between the two groups decreased with an increase in stem diameter.

The sharpness of the cutting teeth influenced the severity of butt damage. Cutting teeth that had been in use for about 150–200 hours caused more butt damage in terms of frequency and loss of sawlog volume than teeth that had been in use for about 20 hours.[5] Overall, 30% of trees felled with old teeth were damaged compared with 10% of the trees felled with new teeth. The

[4] Measured from the centre of the butt surface.

[5] The life of the teeth was estimated based on the approximate number of shifts and the shift hours the machine had been scheduled to work since new teeth were mounted on the disc. The teeth had also been turned once or twice during their use.

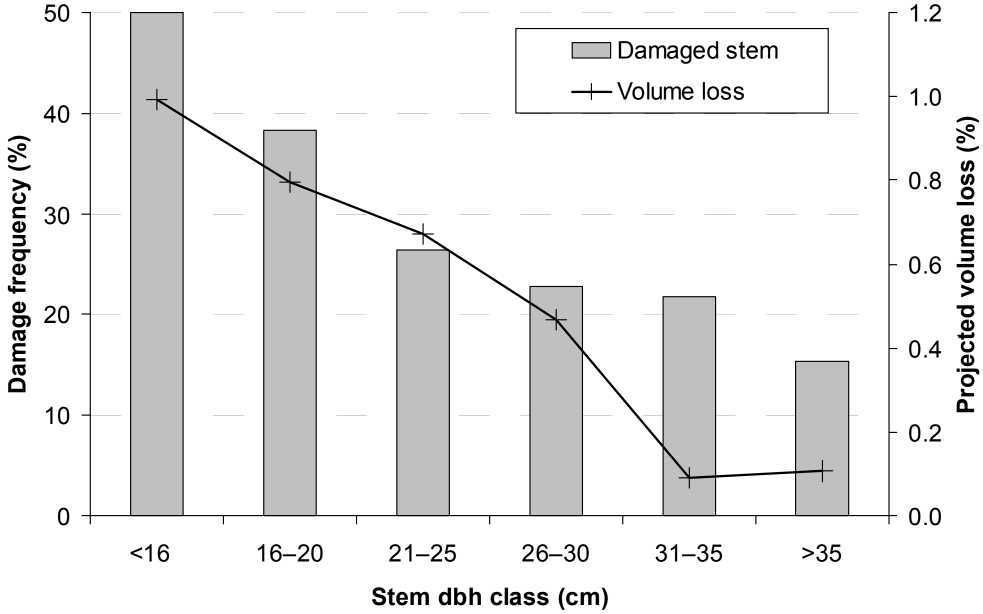

Figure 4. The extent of butt damage by diameter class in Study 1.

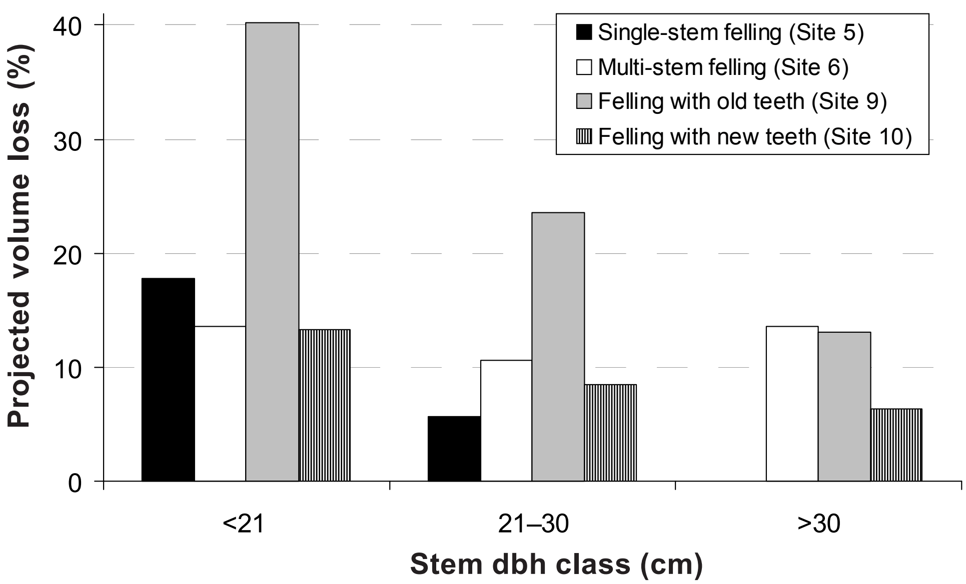

Figure 5. Damage frequency by treatment and stem dbh class.

difference in damage frequency was higher for small-diameter stems than for larger-diameter stems.

The volume loss among the stems felled with old teeth was found to be nearly six times that of stems felled with new teeth (Table 1). The volume loss also decreased with an increase in stem diameter, but the decrease was proportionally less for dull teeth than for sharp teeth (Figure 6).

Discussion

As one of the underlying causes of butt damage is the bending force applied to the tree at the time of felling (McMorland 1985), a key to preventing butt damage is the operator's ability to position the felling head and sever the stem completely without subjecting it to bending forces (Figure 7). However, this is not always possible as trees may be subjected to natural bending forces (e.g., wind or snow) or may be leaning in a direction that makes it difficult to position the felling head squarely against the stem. Under such conditions, the cut must be done quickly to minimize the risk of end splitting (Helgesson 1997). Hence, having sharp cutting teeth and positioning the felling head

Figure 6. Loss of sawlog volume by diameter class and treatment.

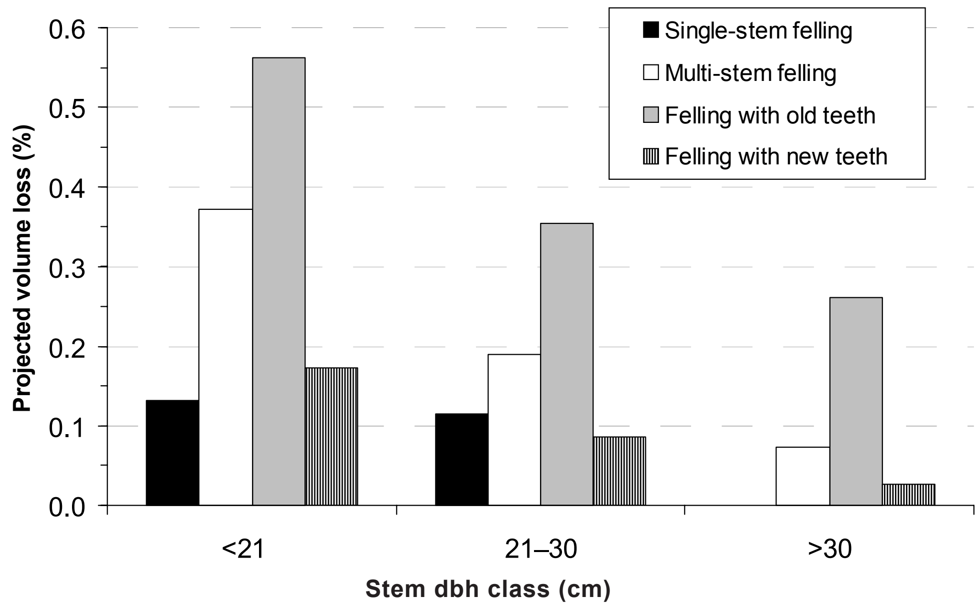

Figure 7. Bending forces applied to tree during felling.

to make a clean cut through the stem would contribute to reduced butt damage under less advantageous felling conditions.

Multiple-stem felling. The risk of subjecting trees to bending forces is increased because the crowns of trees accumulated in the felling head often will push on the crown of the next tree being cut. Accumulated stems may also impair the view for the operator, thus making it more difficult to position the felling head properly for a clean cut. Only trees felled following the first one in each felling cycle will potentially be subjected to bending forces associated with multiple-stem felling, therefore a decrease in the number of trees per felling cycle results in proportionally fewer trees being affected. However, eliminating multiple-stem felling will reduce machine productivity, and the gain in revenue from less butt damage may not offset the reduction in productivity.[6] Yet, at some point, additional accumulation of trees in the felling head will likely cause more revenue losses from butt damage than is gained in reduced harvesting cost. As stand conditions in this study did not allow for examining butt damage for different levels of multiple-stem felling, this issue could not be addressed.

Tooth sharpness. The studies comparing the influence of tooth sharpness were done under normal operating conditions involving different machines, operators, and site conditions. Thus, factors other than the condition of the teeth could have influenced the results. The condition of the teeth may also have varied, as "hours-in-use" are not necessarily good indicators of sharpness. However, the large difference in the incidence of butt damage of trees cut with old and new saw teeth shows that the sharpness of teeth had a considerable impact on butt damage. Operators also reported improved productivity with sharp teeth.

Human factors. Differences in stem size, tooth sharpness, and multi-stem felling did not explain all the variations in the recorded butt damage. For example, the butt damage in Study 2 was considerably less than in Study 1 even though both studies were done

[6] While no machine productivity data were collected in this study, it was obvious from observing the machines that their production rate was considerably lower while single-stem felling compared to multiple-stem felling.

in the same general operating area and with the same group of logging contractors, but conducted a year apart. This difference had also been noticed at the cooperating company's sawmill. Some of the logging contractors believed that this reduction was associated with trees on some sites being more susceptible to felling damage. Unfortunately, this theory could neither be substantiated nor discarded. On the other hand, the company had strengthened its wood quality program prior to Study 2 in an attempt to reduce the butt damage experienced during the previous harvesting season (when Study 1 was conducted). The impact of human factors coupled with regular quality checks and feedback to operators (now part of the wood quality program) have been shown to greatly influence wood quality issues. Thus, some of the reduction in butt damage was most likely attributable to the changes made in the company's wood quality program.

Volume loss and lumber recovery. While it is easy to accurately measure the occurrence and physical extent of butt damage in the studies, the actual impact of butt damage on lumber recovery is more difficult to assess without a mill study. The loss of sawlog volume used in this report to quantify butt damage does not necessarily correspond to an equal percentage reduction in lumber recovery. The actual impact on lumber recovery would depend on factors such as the type of sawmill equipment, products sawn, position of the log during the breakdown process, and the presence of other log defects. Instead, the results in this report should be seen as indices for comparing the butt damage associated with different felling practices.

Butt damage was also recorded and analyzed with the Bicycle-Wheel Method developed by FERIC in the 1980s for comparing butt damage between different felling alternatives (Guimier and McMorland 1981). This method can also be used to predict the effect of butt damage when different lumber dimensions are manufactured. Compared to the method used in this study, the Bicycle-Wheel Method projected a higher wood loss (Figure 8). The difference in predicted wood loss between the two methods was most pronounced for butt damage that had occurred in the outer two-thirds of the butt surface.

Conclusions

The frequency of stems with damaged butts causing loss of volume for lumber manufacturing ranged from 8 to 33%. The damage was typically located in the outer

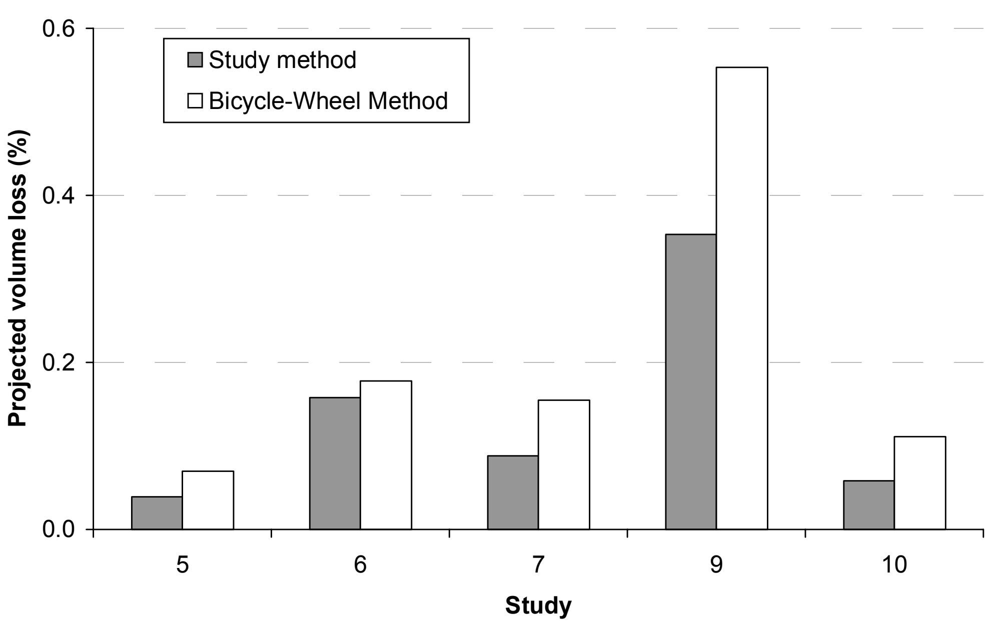

Figure 8. Comparison of projected loss of sawlog volume between assessment methods.

quarter-section of the butt surface, and confined to the first 30 cm of the stem length. The projected loss of sawlog volume from the butt damage in the 12 individual studies, expressed as percentages of the merchantable stem volume, ranged from 0.04 to 0.8%.

The frequency of butt damage and the loss of sawlog volume associated with butt damage were found to decrease with increasing stem diameter. Multiple-stem felling was also found to cause more butt damage than single-stem felling, although the difference was less noticeable for butt damage frequency than for loss of sawlog volume. Overall, 9% of the single-felled stems were damaged compared to 12% for the multiple-felled stems, and the loss of sawlog volume among the multiple-felled stems was four times that of the single-felled ones. The difference in volume loss between the two groups decreased with increasing stem diameter size.

The sharpness of the cutting teeth was also found to influence the level of butt damage. Cutting teeth that had been in use for 150–200 hours caused more butt damage, in terms of both frequency and loss of sawlog volume, than teeth that had been in use for about 20 hours. Overall, 30% of trees felled with old teeth were damaged compared with 10% of the trees felled with new teeth. The difference in damage frequency was somewhat higher for small-diameter stems than for larger-diameter stems.

The volume loss among the trees felled with old teeth was found to be nearly six times that of trees felled with new teeth. The volume loss also decreased with an increase in tree size, but the decrease was less pronounced for dull teeth compared to that of the sharp teeth.

Differences in stem size, tooth sharpness, and multi-stem felling did not explain all the variations in butt damage recorded in the studies. Logging contractors attributed differences in the butt damage between the studies conducted to conditions that made trees on some sites more susceptible to felling damage. However, this theory could neither be substantiated nor discarded. On the other hand, changes in the company's wood quality program may have influenced the results, as more emphasis is now being placed on reducing butt damage.

Implementation

As one of the underlying causes of butt damage is bending forces applied to the tree at the time of felling, a key to preventing butt damage is the ability of the operator to position the felling head and sever the tree completely without subjecting it to bending forces. Therefore, a program aimed at reducing butt damage should include educating operators on the impact of butt damage on sawmill revenue, and assisting operators to develop felling techniques that minimize the bending forces exerted on trees during felling. A useful tool to convey such information is an 8-minute long presentation developed by FERIC, and available for downloading on FERIC's website.[7]

The selection and maintenance of equipment can also impact the level of butt damage. Feller-bunchers equipped with head rotate and tilt will make it easier for the operator to position the felling head at the stem with minimum or no bending forces when on uneven terrain. Grapple and accumulator arms need to be kept in good operating condition. Cutting teeth must be kept as sharp as possible and in good operating condition. The machine's maintenance schedule should include a component to check the teeth, and rotate or replace them when necessary.

FERIC also recommends that a wood quality program be implemented. Ideally, it should be an all-inclusive program from stump to mill that includes regularly conducted quality checks and with feedback to all involved in the operations.[8]

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7 "Reducing damage during felling: a best practices guide for feller-buncher operators" can be downloaded at http://www.feric.ca/en/ed/html/breakage_during_felling.htm.

8 FERIC Wood Quality Workshop, November 2001. Unpublished presentations.

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Appendix I

Machine and site description for Study 1 in Manning, January 2001

Site	1	2	3	4
Machine	1999 Timberjack 850 with 20-tooth 18" Gilbertech saw on a Koehring head	Timberjack 850 with 30-tooth 24" Gilbertech saw on a Koehring head	Timberjack 628 with 24-tooth 22" Gilbertech saw on a Koehring head	1999 Timberjack 850 with 18-tooth 22" Koehring saw on a Koehring head
Operator experience	4 years	1 month	4 years	2 years
Stand description	Overmature pine/ spruce/fir stand on gently rolling terrain	Scattered mature and understorey spruce in a mature aspen stand on flat terrain	Mature and under-storey spruce mixed with scattered aspen on gently rolling terrain	Scattered mature and understorey spruce in a mature aspen stand on flat terrain
Avg. dbh (cm)	21	19	25	20
Avg. vol/tree (m^3)	0.26	0.21	0.48	0.26
Total stems (no.)	100	100	100	50
damaged without loss (%)	21	23	24	6
damaged with loss (%)	29	37	32	34
Loss of sawlog volume				
% of 5–m butt log	0.49	0.63	1.13	1.46
% of merchantable stem	0.28	0.40	0.53	0.84

Machine and site description for Study 2 in Manning, January 2002

Site	5	6	7	8
Machine	1999 Timberjack 850 with 20-tooth 18" Gilbertech saw on a Koehring head	1998 Caterpillar 1100 TK with 18-tooth 22" Rotosaw head	1999 Timberjack 628 with 20-tooth 18" Gilbertech saw on a Koehring head	1998 Caterpillar 1100 TK with 18-tooth 22" Rotosaw head
Operator experience	3 years	2 years	5 years	8 years
Stand description	Mature white spruce/trembling aspen mix on flat terrain	Overmature white spruce on flat terrain	Overmature pine/ white spruce mixed on flat terrain	Mature white spruce on gently rolling terrain
Avg. dbh (cm)	26	22	25	24
Avg. vol/tree (m^3)	0.54	0.33	0.50	0.49
Total stems (no.)	109	102	122	119
damaged without loss (%)	1	8	6	1
damaged with loss (%)	17	6	9	8
Loss of sawlog volume				
% of 5-m butt log	0.46	0.11	0.08	0.20
% of merchantable stem	0.20	0.06	0.04	0.09

Machine and site description for Study 3 in Mackenzie, January 2002				
Site	9	10	11	12
Machine	1993 Prentice with 18-tooth 22” Koehring saw on a Koehring head	1996 Madill 3200B with 20-tooth 24” Koehring saw on a Koehring head	1998 Prentice with 18-tooth 20” Koehring saw on a Koehring head	Timberjack 950 with 20-tooth 24” Koehring saw on a Koehring head
Operator experience	15 years	10 years	n.a.	5 years
Stand description	Mature spruce/fir stand on 20% slope	Mature spruce/pine stand on 30% slope	Mature spruce/pine stand on gentle slope	Mature white spruce/fir/pine stand on 30% slope
Avg. dbh (cm)	22	24	24	26
Avg. vol/tree (m^3) [a]	0.31	0.39	0.42	0.47
Total stems (no.)	100	100	100	99 [a]
damaged without loss (%)	27	19	6	5
damaged with loss (%)	23	27	14	11 [a]
Loss of sawlog volume				
% of 5-m butt log	0.24	0.31	0.74	0.19 [a]
% of merchantable stem	0.13	0.15	0.34	0.09 [a]

[a] Excludes a 51-cm-dbh tree that was partially out of reach and thus not completely severed when felled. If included: damage with loss is 12% and loss of sawlog volume is 0.61% of 5-m butt log and 0.29% of merchantable stem.