Advantage

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Contents

Butt damage and machine productivity with various degrees of multiple-tree felling: a case study

Abstract

The Forest Engineering Research Institute of Canada (FERIC) examined the level of butt damage from felling with a high-speed circular-saw felling head when a feller-buncher accumulated from one to five trees per cycle. The machine's productivity for the different number of trees per cycle was recorded, and the impact of factors such as terrain and stand conditions on wood damage is discussed.

Keywords

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

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Introduction

In January 2001 and 2002, FERIC examined the butt damage associated with feller-bunchers equipped with high-speed felling heads at 12 different felling sites. FERIC found that 8–33% of the examined stems per site had damaged butts, and projected the loss of sawlog volume due to the damage to be 0.04–0.48% of the gross merchantable tree volume (Andersson 2003). The variations in the observed butt damage were attributed to differences in tree sizes, condition of the cutting teeth, multi-tree felling,[1] and human factors. For example, the volume loss among multiple-felled stems was four times that of single-felled ones. However, the study did not address the issue of how butt damage might change with various degrees of multiple-tree felling. Such information could provide feller-buncher operators with guidelines on how many trees could be accumulated in the felling head while maintaining productivity and minimizing butt damage. To address this issue, FERIC, in cooperation with Canadian Forest Products Ltd. (Canfor) and I & B Contracting, conducted a study on multiple-tree felling in January 2004 at a harvesting operation near Hines Creek, Alberta.

Study objectives

The overall objective of the study was to evaluate the relationship between butt damage, machine productivity, and the number of trees per felling cycle for a feller-buncher equipped with a high-speed circular saw felling head. The specific objectives of the study were to:

- Record the frequency and the extent of butt damage for five different levels of multiple-tree felling.
- Record the time of each felling cycle for the five different levels of multiple-tree felling.
- Provide recommendations on the level of multiple-tree felling that is most beneficial considering both felling productivity and the loss of merchantable volume from butt damage.

[1] Multiple-tree 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.

- Determine if additional butt damage studies in different stand types are required.

Study description

Field data were collected during a 5-day period when the feller-buncher felled a mature lodgepole pine stand. The majority of trees had a diameter at breast height (dbh) between 16 and 25 cm and a total height between 18 and 22 m (Table 1). Most trees had a small crown with the lower 5–8 m part of the stem free from branches. The terrain was flat or gently undulating, and had a snow cover of less than 30 cm. The air temperature during the study was just below 0ºC. The trees were cut with a Timberjack 850 feller-buncher equipped with a Koehring 22-in., 18-tooth high-speed saw head in good condition. New teeth had been installed shortly before the start of the study. The operator was considered to be experienced.

The machine operated along the edge of standing timber and placed the bunches on the cutover (Figure 1). In each of the five treatments, the operator tried to accumulate the targeted number of trees in each felling cycle, but could bunch fewer trees when the targeted number of trees could not be accumulated safely. FERIC recorded the time and the actual number of trees of each felling cycle.

Figure 1. Feller-buncher operating on the study site.

Study method

From each treatment, FERIC randomly selected 87–115 stems with sound butts located on top of the bunches and accessible for measuring. Diameters were recorded at the butt and at 1.1 m and 5 m from the butt (Figure 2). A 5-cm-thick cookie was cut from the butt, and the new exposed butt surface was examined for damage. If there was no visual damage, a second 3-cm-thick cookie

Table 1. Average stem characteristics by treatment

	Target trees per felling cycle (no.)				
	1	2	3	4	5
Stems sampled (no.)	87	115	115	112	110
Average dbh (cm)	23.1	22.6	21.3	19.7	20.0
Diameter distribution (%)					
10–15 cm	7	7	11	10	13
16–20 cm	25	32	43	51	44
21–25 cm	33	33	27	29	34
26–30 cm	28	22	14	9	8
31–35 cm	7	5	4	1	0
>35 cm	0	1	1	0	1
Average total height (m)	21.1	21.0	20.5	19.9	20.0
Average volume/stem (m^3)	0.41	0.38	0.33	0.26	0.27

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Figure 2. Full-tree stems selected for butt damage inspection. Note the branch-free lower portion of the stems.

was cut and examined to ensure that the butt surface was free from hairline cracks. If butt damage was present, the type and its location on the butt surface were recorded. The length of the damage[2] was determined by successively cutting cookies off the stem until no more damage could be detected (Figure 3). The butt damage was also recorded using the Bicycle-Wheel method developed and used by FERIC in butt damage studies in the 1980s (Guimier and McMorland 1981).

Only damage that occurred within the net butt diameter[3] was assumed to affect lumber recovery from the log. The loss of sawlog volume was calculated using the method developed by FERIC that converts physical damage data into a quantitative measure of the damage's impact on sawmilling (Andersson et al. 2002). The calculated volume loss does not necessarily correspond to an equal percentage reduction in lumber recovery. Rather, these numbers should be regarded as wood loss indices, and used only to compare the differences in wood damage between different harvesting and wood handling practices.

Results

Stem damage and volume loss

The anticipated increase in butt damage with an increase in the number of trees accumulated in the felling head did not materialize in this study. The frequency of damaged stems for single-tree felling (one tree per cycle) was lower than for multiple-tree felling, but was only statistically different from the two trees per cycle treatment and not from the three-to-five trees per cycle treatments (Table 2). None of the multiple-tree treatments were statistically different from each other.

The percentage of damaged stems varied within the 5-cm dbh classes and treatments, but there was no trend to suggest that the

[2] Measured from the butt after the first 5-cm cookie (assumed to represent the normal end trimming in sawmills) had been cut.

[3] The log's net butt diameter was calculated by projecting the log's taper between the 1.1-m to 5.0-m section to the butt end. If that diameter was smaller than the measured butt diameter, it was considered as the true butt diameter (i.e., with no butt flare).

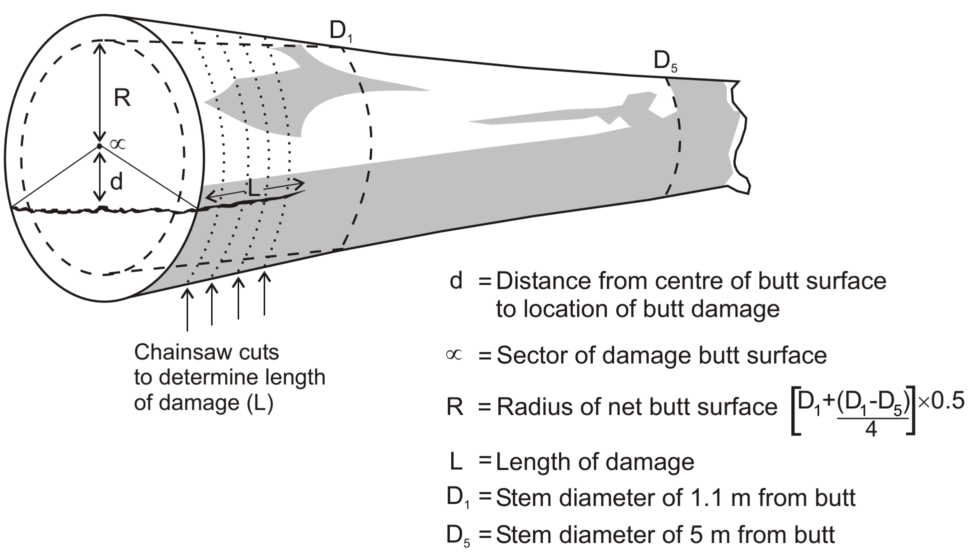

Figure 3. Measurements recorded on stems with butt damage.

Table 2. Summary of butt damage by treatment

	Target trees per felling cycle (no.)					
	1	2	3	4	5	All
Merchantable stem volume (m^3)	35.49	44.24	38.47	29.27	30.22	177.69
Stems sampled (no.)	87	115	115	112	110	539
Damaged butts (no.)	3	14	8	11	7	43
Volume loss (dm^3) [a]	64	109	93	41	18	325
Trees with dbh ≤15 cm						
Merchantable stem volume (m^3)	0.50	0.93	1.50	1.26	1.56	5.75
Stems sampled (no.)	6	8	13	11	14	52
Damaged butts (no.)	0	0	0	3	2	5
Volume loss (dm^3)	0	0	0	6	4	10
Trees with dbh 16–20 cm						
Merchantable stem volume (m^3)	4.29	7.32	10.99	10.84	9.54	42.98
Stems sampled (no.)	22	37	49	57	49	214
Damaged butts (no.)	1	6	2	3	3	15
Volume loss (dm^3)	49	39	14	9	10	121
Trees with dbh 21–25 cm						
Merchantable stem volume (m^3)	10.41	14.33	11.27	10.95	12.92	59.88
Stems sampled (no.)	29	38	31	33	37	168
Damaged butts (no.)	2	6	2	4	1	15
Volume loss (dm^3)	15	45	16	21	1	98
Trees with dbh 26–30 cm						
Merchantable stem volume (m^3)	14.95	14.95	9.81	5.38	4.99	50.08
Stems sampled (no.)	24	25	16	10	9	84
Damaged butts (no.)	0	2	3	1	1	7
Volume loss (dm^3)	0	25	44	5	3	77
Trees with dbh >30 cm						
Merchantable stem volume (m^3)	5.36	6.91	5.99	0.84	1.22	20.32
Stems sampled (no.)	6	7	6	1	1	21
Damaged butts (no.)	0	0	1	0	0	1
Volume loss (dm^3)	0	0	19	0	0	19

[a] Volume loss expressed in dm^3 (1 dm^3 = 0.001 m^3) because of its small amount.

damage was dependent on the tree size. Overall (all treatments combined), the percentage of damaged trees was relatively similar (range from 7.0 to 9.6%) among the trees in the four dbh classes up to 30 cm.

The length of splits among the 43 damaged stems ranged from 3 to 160 cm, with 77% of them having splits of 30 cm or less. Only one of the stems had a split longer than 60 cm.

The projected volume loss from butt damage in the five treatments ranged from 0.06 to 0.25% of the merchantable stem volume.[4] There was no indication to suggest that the volume loss increased or decreased with either the number of trees accumulated in the felling head or with the dbh classes.

Impact on productivity

The short-term detailed-timing study showed a considerable increase in the machine productivity with an increase in the number of trees per felling cycle. The feller-buncher achieved its highest productivity when four trees were accumulated in each felling cycle

[4] Merchantable stem volume calculated assuming a 20-cm stump and a stem topping diameter of 10 cm.

(Table 3). Because the amount of time spent moving and doing work other than felling and bunching may be more dependent on localized terrain conditions than on the number of trees accumulated per cycle, FERIC also calculated an adjusted productivity[5] for each treatment. The adjusted productivity also increased with an increase in the number of trees per cycle up to four trees, but at a somewhat flatter rate (Figure 4).

As there was little difference in the projected volume loss from butt damage between the different treatments, incorporating the loss of merchantable volume from butt damage would not in this case alter the number of trees per felling cycle that would optimize the operation.

Discussion

The results from this study did not support the perception that butt damage from mechanical felling increases with increased stem accumulation. Perhaps this is because butt damage from felling is affected more by poor felling practices and a poorly maintained felling head than by the number of trees accumulated in the felling head. Also, the stand conditions during the study were favourable for multiple-tree felling as the

[5] The adjusted productivity was based on the observed felling and bunching cycle times for each treatment, but assumed that the time of all other work elements, expressed in minutes per tree, were independent (constant) of trees in the felling cycle. It also included a 9% minor delay time (5 minutes per working hour).

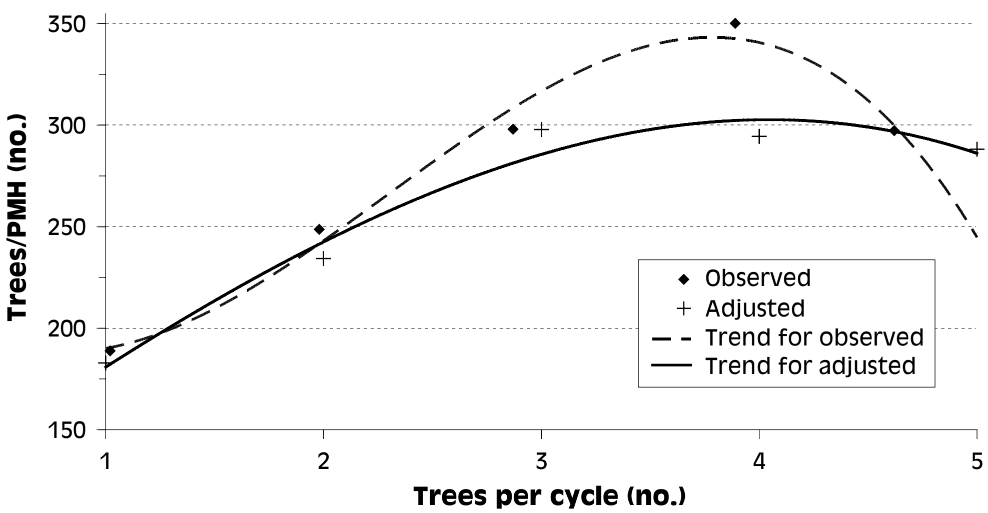

Figure 4. Projected productivity as a function of trees per cycle.

Table 3. Recorded times from detailed-timing study

	Target trees per felling cycle (no.)				
	1	2	3	4	5
Total cycles (no.)	200	128	109	80	80
Total trees felled (no.)	203	254	313	311	370
Average trees/cycle (no.)	1.02	1.98	2.87	3.89	4.62
Average volume/tree (m^3)	0.41	0.38	0.33	0.26	0.27
Work elements					
Fell & bunch (min.)	52.68	47.73	51.49	48.54	65.16
Move in stand (min.)	5.53	3.87	6.00	2.78	4.79
Clear debris (min.)	3.30	6.98	3.90	0.48	1.42
Other work (min.)	1.48	1.25	0.15	0.23	1.54
Delays (min.)	1.51	1.44	1.48	1.25	1.75
Total observed time (min.)	64.50	61.27	63.02	53.28	74.66

trees had small crowns and relatively branch-free lower stem sections. This gave the operator good visibility when grabbing the stems, and as long as the trees accumulated in the felling head were held vertically, their crowns appeared to exert little bending force on the tree being cut.

There is no doubt that multiple-tree felling may increase the risk of butt damage, but it also has a favourable impact on machine productivity. The optimum number of trees to collect in multiple-tree felling may not only depend on the tree diameter, but also on branchiness and the lean of the tree. Terrain conditions, such as steep slope and rough ground, may also increase the risk of damage from multiple-tree felling, as it is more challenging for the operator to grab trees without exerting bending forces on the stem, and to sever the trees completely before lifting the stems of the stumps. Therefore, the scope of this study was too limited to recommend specific numbers of stems that feller-buncher operators should accumulate in the felling head to give the best combination of good machine productivity and low level of butt damage. Factors such as the condition of the felling teeth (sharp or dull) and the aptitude of the operator would likely also affect the impact of multiple-tree felling on wood damage and machine productivity.

Conclusion

While the frequency of butt damage was higher among multiple-felled trees than among single-felled trees, the difference was not statistically significant. The perception that butt damage will increase with an increase in the number of trees accumulated in the felling head for each felling cycle was not realized in this study. The work habits of the feller-buncher operator and favourable stand conditions for multiple-tree felling may have contributed to the results.

The frequency of butt damage ranged from 3.4% to 12.2%, and the projected loss of sawlog volume was projected to range from 0.06–0.25% of the merchantable stem volume. FERIC found no trends that suggested butt damage varied with stem diameter.

Implementation

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 to have the operator position the felling head and sever the tree completely without subjecting it to bending forces. In multiple-tree felling, the operator must therefore try to keep the trees already accumulated in the felling head from pushing on the tree to be cut. This may be more difficult to do in stands where the trees have large branches, are of poor tree form (e.g., sweep, leaning), or when the machine is operating on sloped or uneven ground. Under such conditions, the operator may have to reduce the number of trees accumulated in the felling head to reduce the risk of butt damage. By periodically checking the butts of felled trees for damage, the operator can determine if the felling technique results in excessive butt damage.

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