Zero Waste Residue Piling and Transportation Trial

Technical report no. 40 - March 2018

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ABSTRACT

FPInnovations followed two fibre streams for the reclamation of residuals from the processing stage of the primary harvest through to the transport of the residuals to the chipper. A quality assessment for chips from the two streams was also performed. The results indicated that residuals from oriented piles were much cheaper to handle and transport than residuals from burn piles.

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Table of contents

1. INTRODUCTION

The allowable annual cut (AAC) in British Columbia will likely be reduced as a result of the high rate of harvest attributed to mountain pine beetle salvage. A large portion of the residual fibre from logging and sawmilling operations in the southern interior of B.C. is currently transported to coastal B.C. where it is valued for its high quality and low moisture content. The drop in AAC for interior timber supply areas means that other sources of fibre must be located.

One of the sources that have historically been passed over by the pulp industry can be found in the form of primary harvest residues. These residues have typically been considered too contaminated (rocks, sand, plastic, bark, and metal) and too costly to pursue. As a result, the piles are usually burned, at roadside, as a fire hazard abatement practice.

Until recently, little research had been performed in B.C. to analyze the productivity, yield, and chip quality derived from the chipping of logging residuals. However, in 2015–2016, FPInnovations performed trial work with a residual chipping operation on Vancouver Island in which the productivity results were promising. The current study (2017–2018) followed two fibre streams for the reclamation of residues from the processing stage of the primary harvest through to the transport of the residues to the chipper. A quality assessment for chips from the two streams was also performed.

2. OBJECTIVE

The objectives of the study were to determine and quantify the differences in productivity and cost between the recoveries of residues from two fibre streams:

1. Residues that have been designated for biomass recovery and handled as a biomass product
2. Residues that have been piled for burning, but later designated for biomass recovery and handled as a biomass product

The following phases of residue handling and extraction were analyzed:

- Management of residues in the processing phase (piling versus flinging)
- Handling of residues, including loader-forwarding (hoe-chucking) and loading at roadside
- Hauling of residues from roadside to a local sortyard
- Quality assessment of the chips collected from the predetermined chip streams

3. METHODOLOGY

Site descriptions

In-wood location

The harvest site where the stems were processed and piled was located approximately 10 km west of Port Alberni. The second-growth stand consisted of predominately 70-year-old Douglas-fir with a minor component of western hemlock and western red cedar (Figure 1).

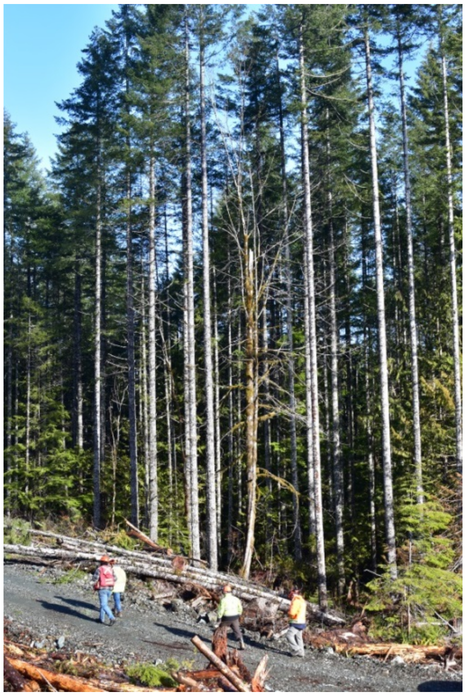

Figure 1. Adjacent stand beside trial location.

Chipping site

The chipping site was located at Island Timberlands' Canal West dryland sort, approximately 7 km from the cutblock (Figure 2).

Figure 2. Canal West dryland sort.

Equipment

Processing

A Link-Belt 350 with a Waratah 624C processing head was used to process stems for the duration of the trial (Figure 3).

Figure 3. Link-Belt 350 processor (left) with Waratah 624C processing head (right).

Piling and transport

A John Deere 230LC excavator with a saw-equipped power grapple was used to pile, unpile, forward, and load residues (Figure 4).

Figure 4. John Deere 230LC excavator pulling a residue pile apart.

Three different-sized bins and trailers were used to transport residues to the sortyard:

- 34.4 m^3 bin on a tandem-drive truck (Figure 5, left)
- 45.9 m^3 bin on a tridem-drive truck (Figure 5, right)
- 6.4 m long roll-off bunk (Figure 6, left) on a tridem truck with a tri-axle full trailer (Figure 6, right) towed behind it.

Figure 5. A 34.4 m^3 bin on tandem drive truck being unloaded (left) and a 45.9 m^3 bin being loaded (right).

Figure 6. A 6.4 m long roll-off bunk (left) and a tri-axle trailer (right).

The trailer portion of the roll-off bunk and trailer was unloaded by a Volvo EC210BLC excavator with a bucket and thumb attachment (Figure 7).

Figure 7. Volvo EC210BLC excavator with a bucket and thumb attachment.

Nomenclature

New practices or systems can often be difficult to describe as there is no common set of nomenclature to describe actions or results. Figure 8 outlines the processes in which the residues have been handled in the two fibre streams and the resulting pile types (oriented and burn piles).

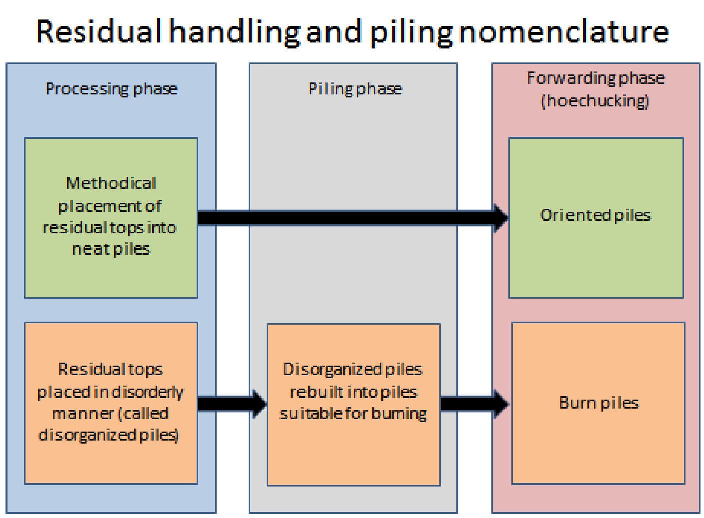

Figure 8. Residue handling and piling nomenclature.

Other terminology used in this report that may be unclear or confusing is in reference to primary harvesting and secondary harvesting. Primary harvesting can be defined as the phase that involves the harvest of traditionally merchantable trees.

Secondary harvesting can defined as the phase that involves the harvest of the residues or waste from the primary harvest. This typically includes grinding, chipping, and transport of uncomminuted materials.

Processing

The processing phase was designed to investigate whether handling the residual tops in a deliberate manner after the merchantable stems were processed incurred a cost in the form of reduced productivity. The processor was monitored for 2.5 days where the operator methodically laid tops in a deck-like formation so that they were roughly parallel (Figure 9, left) and 2.5 days where the operator handled the tops in a disorderly manner (Figure 9, right). The processed volume was recorded by the processor's on-board computer at the end of each day (or half day). Average piece size was also recorded by the on-board computer so that productivity could be compared if piece size changed over the course of the trial.

Figure 9. Methodically piled residues (left) and disorderly residues (right).

Piling and transport phase

After the processing phase of the initial harvest, the operator forwarded the methodically piled residual tops, or "oriented piles," to roadside for the loading phase (Figure 10). The forwarding time for each oriented pile was recorded.

Figure 10. Loader forwarding residual tops to roadside from an oriented pile.

The disorganized tops were built into piles suitable for burning (Figure 11). After building the "burn piles", the operator pulled the piles apart and forwarded the tops to roadside. The piling and loader forwarding times were recorded.

Figure 11. Loader building a burn pile from residual tops.

The operator loaded the bins and trailers at roadside and the residues were transported to the sortyard where they were unloaded by the excavator (Figure 12). The loading times, truck cycle times, and unloading times were recorded.

Figure 12. Excavator unloading residual tops from a tri-axle trailer.

Post-secondary harvest evaluation

A visual estimate of the residues that could potentially be chipped and the plantability of the pile sites were determined after loader-forwarding (Figure 13). Island Timberlands staff also participated in the assessment.

Figure 13. Residues after secondary harvest of an oriented pile (left) and a burn pile (right).

Chip quality assessment

Upon receipt, moisture content was determined for each of the samples (sample list provided in Table 1) with the oven-dry method and the remaining sample was frozen (-20°C). Thawed, well mixed, room temperature samples were coned and quartered to produce representative sample replicates for testing. A Wennberg chip classifier, fitted with 2, 4, 6, and 8 mm bar screens was used to determine chip thickness distributions. Chip basic density was determined by PAPTAC method A.8P. Loose chip packing density was determined using a method described by Hatton (1979). Samples were hand-sorted to determine percentage of bark, contaminants, and rot (TAPPI T 265 cm-09).

Table 1. Samples tested for chip quality are referred to as Oriented or Burn; average values will reflect the number of replicates for each sample type.

Pile type	Load number	Number of replicates per load
Oriented A Piled by the processor	1 & 2	3
Oriented B Not recorded in the processor phase	3 & 4	3
Burn	5	6

4. RESULTS AND DISCUSSION

Residue handling

The residue handling phase of the trial included assessing the handling of the residual tops by the processor during the primary harvest, piling the residues from half of the residue accumulations (disorganized piles) into piles designed for burning, and then forwarding all of the residual tops (both fibre streams) to roadside.

Processing

Residual tops were either dropped methodically into place (oriented piles) or flung out from the processor in a disorderly manner. Processor productivity was 43.2 m^3/PMH when creating oriented piles, and 38.2 m^3/PMH when handling tops in a disorderly manner. However, the average piece size handled during the two activities was significantly different at 0.69 m^3/stem and 0.55 m^3/stem, respectively (Table 2).

Table 2. Processor productivity by residue handling method

	Processor productivity	
Pile type	m^3/PMH	m^3/stem
Oriented	43.2	0.69
Disorganized	38.2	0.55

PMH: productive machine hours

Although the productivities and piece sizes were different for the handling methods, when placed onto a processor productivity curve (McMorland, 2007), the productivities can be considered equivalent, i.e., for their individual piece size, they occupy similar positions relative to the curve (Figure 14). Cost analysis during the processor phase was not performed as part of the trial because the productivities for the two handling methods were considered equivalent.

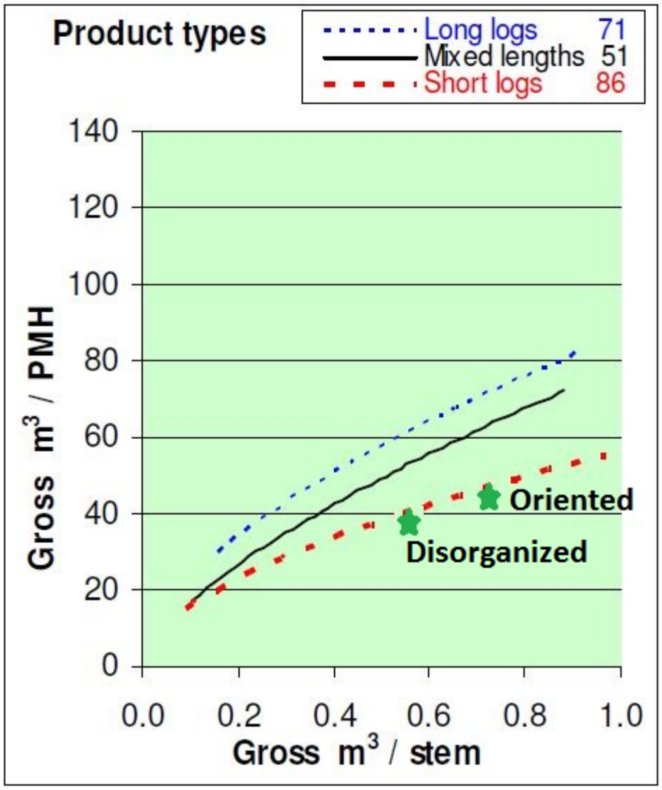

Figure 14. Processor productivity comparison of historic versus trial results.

Piling

Two of the accumulations of disorganized tops were built into piles designed for burning (Piles 7 and 8). The average productivity associated with building these piles was 92 m^3/SMH (Table 3). The average cost to build the piles was $1.27/$m^3$ or $2.92/ODT.

Table 3. Productivity and cost of piling residuals into burn piles

	Productivity	Cost	
Pile	m3/SMH	$/m3	$/ODT
7	85.2	1.36	3.14
8	98.8	1.18	2.71
Average	92.0	1.27	2.92

ODT: oven dried tonnes

SMH: scheduled machine hours

Hourly costs for the loader were derived using FPInnovations' costing methodology and are presented in Appendix I. All costs and productivities for the loader are based on a utilization value of 80%. Utilization is derived by dividing productive machine hours (PMH) by scheduled machine hours (SMH).

Loader-forwarding

All of the residual tops created during the processing phase of the trial, from both burn and oriented piles, were forwarded to roadside.

Productivity (and therefore cost) differences of forwarding the two pile types were significant. Oriented piles were very easily moved by the loader at a rate of 129.8 m^3/SMH and a cost of \$1.15/m^3 or \$2.65/ODT (Table 4).

The burn piles were, by a large margin, the least productive and most expensive pile type to forward to roadside at a rate of 19.2 m^3/SMH and a cost of \$6.90/m^3 or \$15.87/ODT. This was due to a number of factors, including the excessive breakage when building the piles, and later, when pulling them apart created many short pieces which then became difficult for the loader to collect and move. Productivity was also slowed when the operator tried preserving piece length (i.e., being very careful with each piece). Pieces shorter than 2.5 m were abandoned on site as they were too short for the chipper to process, and this created higher fire fuel levels and impediments to plantability compared to the residues left after hoe-chucking the oriented piles.

Table 4. Hoe-chucking productivity by pile type

	Productivity	Cost	
Pile	**m^3/SMH**	**\$/ODT**	**\$/m^3**
Oriented	129.8	1.15	2.65
Burn	19.2	6.90	15.87

ODT: oven dried tonnes

SMH: scheduled machine hours

Residue transport

After the loader forwarded the residues to roadside, pieces were loaded onto a variety of trailer and bin configurations.

Loading

Pieces were loaded into two different bin sizes, 34.4 m^3 and 45.9 m^3, as well as a roll-off bunk and tri-axle trailer configuration. For the bins and roll-off bunks, pieces needed to be cut down to size to avoid creating air space in the bins and to avoid contact with the pieces loaded onto the tri-axle trailer. Residue pieces could be loaded onto the tri-axle trailer without modifying their length.

The loading times and costs were similar for both bins at \$4.95/m^3 or \$11.39/ODT for the small bin and \$4.19/m^3 or \$9.65/ODT for the big bin (Table 5). The cost of loading the roll-off bunk alone was the highest at \$8.03/m^3 or \$18.45/ODT. However, when paired with the companion tri-axle trailer, the lower loading cost of the trailer offset the higher cost of loading the bunk and made the total cost for the trailer/roll-off bunk combination comparable to the cost of loading the bins.

Table 5. Loading cost by bin/trailer type

Bin/trailer type	Average loading time (h)	Average loading cost ($/m^3)	Average loading cost ($/ODT)
Small bin (34.4 m^3)	0.29	4.95	11.39
Big bin (45.9 m^3)	0.36	4.19	9.65
Roll off and trailer	0.93	5.16	11.87
Roll off only	0.64	8.03	18.45

ODT: oven dried tonnes

The cost to load residues from the two pile types was also analyzed (Table 6). Loading residues from the oriented piles was more productive and less costly than loading residues from the burn piles. This was likely due to the larger piece sizes preserved in the oriented piles which facilitated easier handling and reduced cycles to load the trailer or bin.

Table 6. Productivity and cost of loading residuals by pile type

Pile type	Loading productivity (m^3/SMH)	Loading cost ($/m^3)	Loading cost ($/ODT)
Oriented	13.8	4.29	9.87
Burn	8.3	8.38	19.27

ODT: oven dried tonnes

SMH: scheduled machine hours

Transport

The 34.4 m^3 bin loads averaged the smallest load size of 9.4 m^3 or 4.1 ODT, followed by the roll-off bunk at 12.8 m^3 or 5.5 ODT (Table 7). The 45.9 m^3 bin loads averaged 13.6 m^3 or 5.9 ODT. The trailer and roll-off bunk combination had the largest load size and averaged 28.8 m^3 or 12.5 ODT.

Table 7. Average load size by truck and trailer type

Truck and bin/trailer type	Average gross weight (green tonnes)	Average tare weight (green tonnes)	Average net load weight (green tonnes)	Average net load weight (ODT)	Average net load volume (m^3)
Tandem truck + 34.4 m^3 bin	23.65	15.71	7.94	4.08	9.38
Tridem truck + 45.9 m^3 bin	29.99	19.22	10.77	5.91	13.59
Tridem truck + roll-off bunk + tri-axle trailer	49.65	25.21	24.44	12.54	28.83
Tridem truck + roll-off bunk	28.92	19.34	9.58	5.55	12.76

ODT: oven dried tonnes

The transport cost for the small and big bin configurations was \$17.78/m^3 or \$39.74/ODT and \$13.30/m^3 or \$31.82/ODT, respectively (Table 8). The roll-off bunk had the highest transport cost at \$18.61/m^3 or \$46.78/ODT. The roll-off bunk and trailer combination had the lowest transport cost at \$9.80 m^3 or \$23.08/ODT.

Table 8. Transport cost by bin/trailer type

	Average load		Average transport cost	
Bin/trailer type	(m^3)	(ODT)	(\$/m^3)	(\$/ODT)
Small bin (34.4 m^3)	9.38	4.08	17.78	39.74
Big bin (45.9 m^3)	13.59	5.91	13.30	31.82
Roll off and trailer	28.83	12.54	9.80	23.08
Roll off only	12.76	5.55	18.61	46.78

ODT: oven dried tonnes

Other options for transport, such as hayracks, are available within the industry and would increase load size; however, they were not available for this trial. Hayracks used in a 2017 FPInnovations residue chipping study had an average load of 30.4 m^3, but required only 0.4 hours to load (Spencer & Blackburn, 2017).

Overall cost assessment

All of the costs associated with each pile and transportation type were aggregated and summarized in Table 9. The lowest cost method of harvesting residues, at $16.11/m^3 or $37.60/ODT, involved establishing oriented piles in the processing stage and then transporting the residues with the roll-off bunk and tri-axle trailer. The smaller transportation types, combined with burn piling, represented the highest cost options.

Table 9. Aggregate cost to pile and move residual tops to a chipper location 7 km from the cutblock

ODT: oven dried tonnes

		Piling cost		Hoe-chuck cost		Loading cost		Transport cost		Total cost	
Pile type	Bin/trailer type	$/m^3	$/ODT	$/m^3	$/ODT	$/m^3	$/ODT	$/m^3	$/ODT	$/m^3	$/ODT
Oriented pile	Small bin (34.4 m^3)	-	-	1.15	2.65	4.95	11.39	17.78	39.74	23.88	53.78
	Big bin (45.9 m^3)	-	-	1.15	2.65	4.19	9.65	13.30	31.82	18.64	44.12
	Roll off and trailer	-	-	1.15	2.65	5.16	11.87	9.80	23.08	16.11	37.60
	Roll off only	-	-	1.15	2.65	8.03	18.45	13.78	31.67	22.96	52.77
Burn pile	Small bin (34.4 m^3)	1.27	2.92	6.90	15.87	4.95	11.39	17.78	39.74	30.90	69.92
	Big bin (45.9 m^3)	1.27	2.92	6.90	15.87	4.19	9.65	13.30	31.82	25.66	60.26
	Roll off and trailer	1.27	2.92	6.90	15.87	5.16	11.87	9.80	23.08	23.13	53.74
	Roll off only	1.27	2.92	6.90	15.87	8.03	18.45	13.78	31.67	30.25	68.91

The costs shown in Table 9 can likely be reduced in a production setting and by increasing load sizes with larger trailer configurations. Larger load sizes can reduce the cost of transport, but reducing preparation time for each load can also play a role in reducing cost. A sensitivity analysis was performed utilizing data from a 2017 FPInnovations residue chipping trial in which hayracks were used to convey residual tops to the chipper (Spencer & Blackburn, 2017). In this study, the hayracks averaged a load size of 30.4 m^3, and had an average loading time of 0.4 h. The loading time for the hayracks was approximately 0.5 h less per load than the time needed to load the roll-off bunk. This is because the pieces could be loaded onto the hayrack as is, whereas with the roll-off bunk and trailer combination, the tops had to be cut to size for the roll-off bunk. The reduced loading and preparation time (approximately 0.5 h) for a hayrack would translate into a cost saving of approximately $2.30/m^3 or $5.50/ODT when compared to the roll-off bunk and trailer combination.

Post-secondary harvest evaluation

After the secondary harvest, the sites where the residue piles were located were evaluated visually to estimate fuel fire hazard levels and plantability.

At the oriented pile sites, very little residue was left after hoe-chucking and loading (estimated at <5% of original volume). At the burn pile sites, an average of 25% of the original volume was left behind. Much of this volume was broken and tangled, making it extremely costly and difficult for the loader operator to move to roadside one piece at a time (Figure 15).

Figure 15. Residual volume left after harvest of a burn pile.

The plantability after the removal of the oriented piles was good, with no anticipated problem finding plantable spots. However, the burn pile sites had significant volume left behind that would have inhibited planting due to a reduction in plantable spots.

After discussion with Island Timberlands employees, it was determined that no further work was necessary to clean up the sites where the oriented piles were located. However, the burn pile sites required piling and most likely burning of the remaining residues to reduce fire hazard and allow planting in the spring. It should be noted that costs for re-piling and burning after the secondary harvest were not included in the costs outlined in the Table 8 burn pile costs and would be additional.

Chip quality assessment

Chip samples were assessed for quality attributes that would be relevant for both mechanical and kraft pulping processes. For both processes, contaminants in the form of inorganic materials, sand, metal, and plastic are highly detrimental; none of these contaminants were observed in any of the samples that were evaluated in this trial. Bark is also deleterious to these processes and many pulp mills issue penalties against chip deliveries that contain bark content above a given allowance (0.5% in summer and up to 1.5% in winter are typical). On average, bark contents determined for the oriented samples were above the typical limit (Figure 16). These averaged 5.8% for Oriented A and 5.7% for Oriented B. However, these values highlight the importance of equipment maintenance; once this was performed for the chipper, low bark content was achieved. Only two of the Burn samples contained bark content over 1%, which was well within the specifications for winter chips with an average of 0.7%.

Moisture, basic, and bulk (chip packing) density were also determined for each sample. These attributes impact the amount of dry mass that will enter a kraft digester and will affect both the liquor-to-wood ratio and pulp production.

The moisture values determined for the oriented samples are consistent with what would be expected for fresh wood chips (Figure 17). In comparison, the Burn piled samples were somewhat lower in moisture, but still within the range of typical values for fresh chips.

The basic density determined for these samples was somewhat variable (Figure 18), but likely reflected the differences in species ratios between samples (Figure 19). The Douglas-fir content ranged from 91% for Oriented A to 75% for Oriented B, which would have an impact on basic density values.

Although oven-dry bulk density is also highly variable (Figure 20), it is lowest for Oriented B, suggesting differences in bulk density could arise from chip swelling from moisture variability, chip size distribution, or chip geometry, as these impact how well chips pack together. Higher bulk density is more desirable as it provides more wood mass in a given volume compared to chips with lower bulk density.

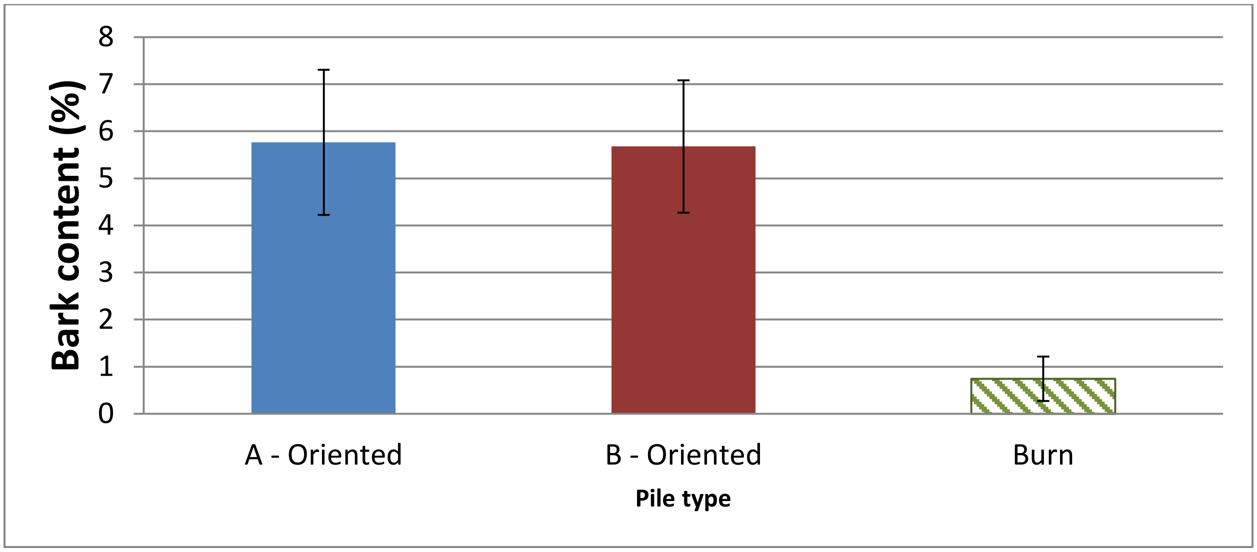

Figure 16. Average bark content of each sample type, as a percentage of total mass.

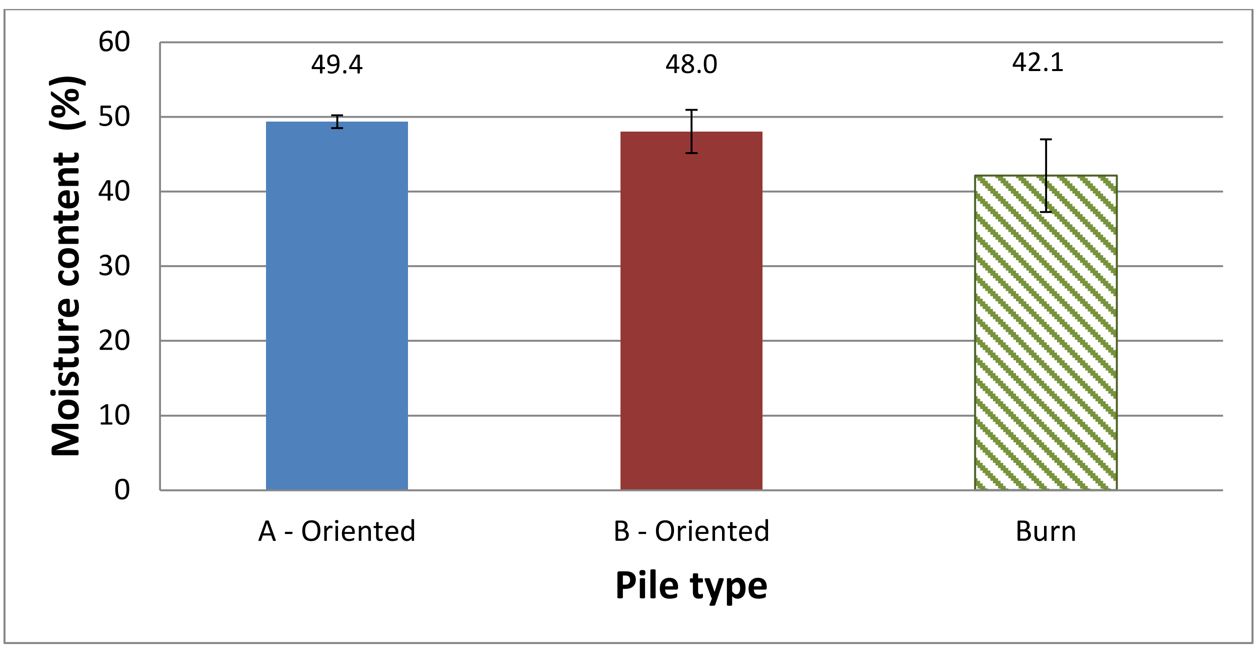

Figure 17. Average moisture content of each sample type, as a percentage of total mass.

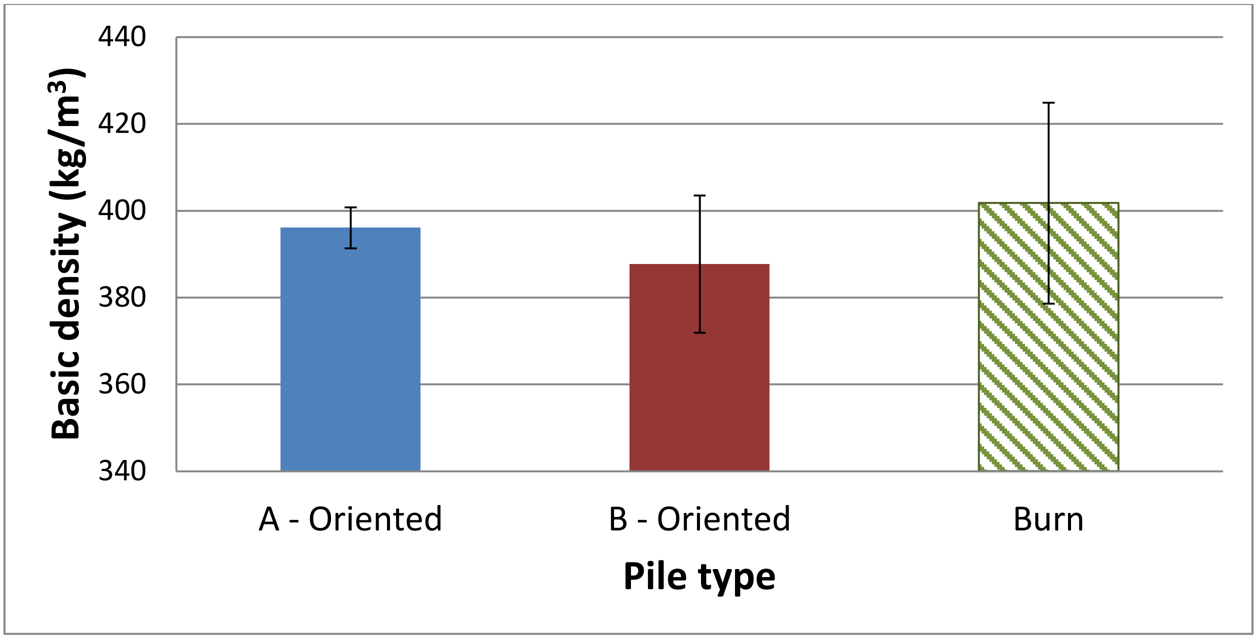

Figure 18. Basic density for each sample type (kg oven-dry mass/green m^3).

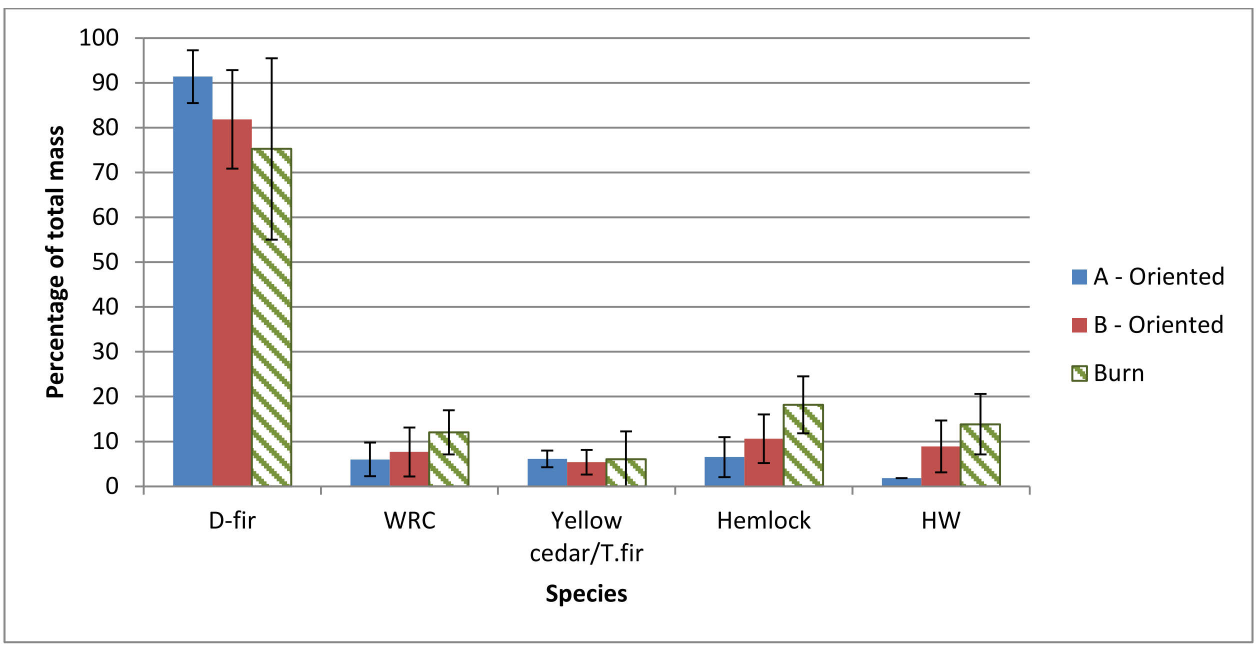

Figure 19. Average species ratios for each sample type, as a percentage of total mass.

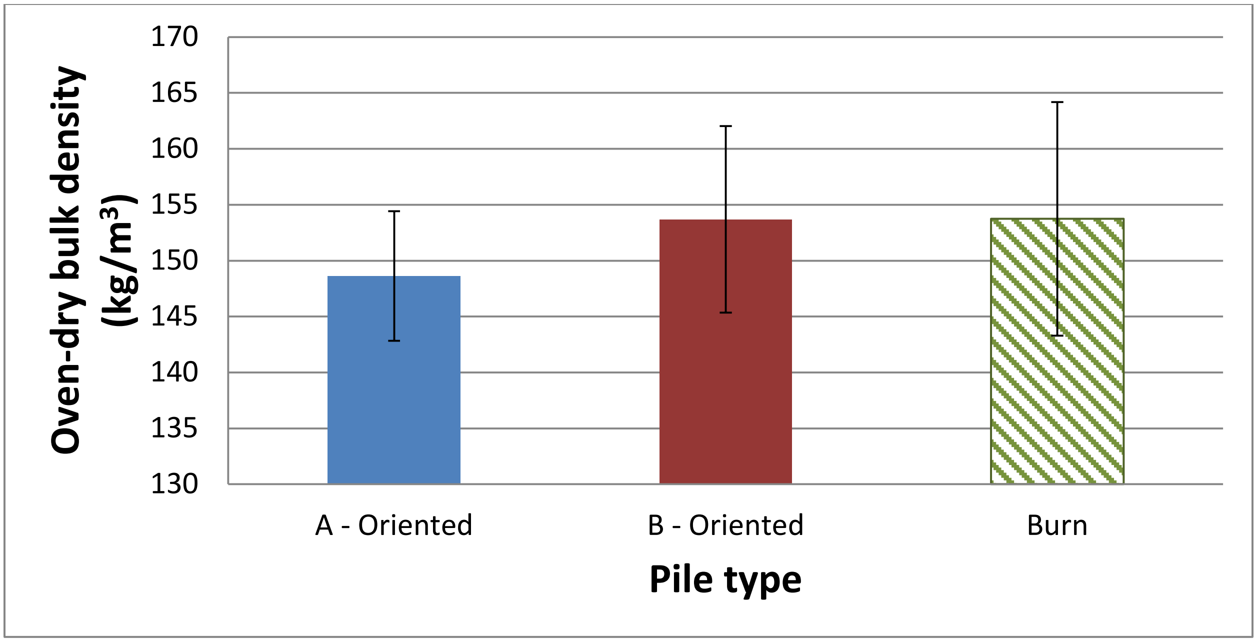

Figure 20. Bulk (chip packing) density determined for each sample type (oven-dry kg/green m^3).

Chip thickness distribution is also an important chip quality attribute, as it affects how well pulping liquor can penetrate the chip's thickness (Figure 21). The best chips for kraft pulping have an effective chip thickness between 2 and 8 mm. Pins and fines (<2 mm) are undesirable as they impact yield, digester operation, liquor flow, and fibre strength attributes. Kraft mills should not feed more than 10% pins, and fines should be kept out of the digester although inclusion of a small portion of fines is unavoidable. Scalping screens remove the gross overs (greater than 45 mm round hold screen), so anything greater than this is lost fibre. Oversized chips, typically greater than 8 mm thickness, must be reprocessed (nominal thickness reduced) to be appropriate for cooking. Typically, both over- and undersized wood chips carry a penalty if present in amounts greater than 5% for each; alternatively, a bonus may be given if their amounts are less than a specified limit.

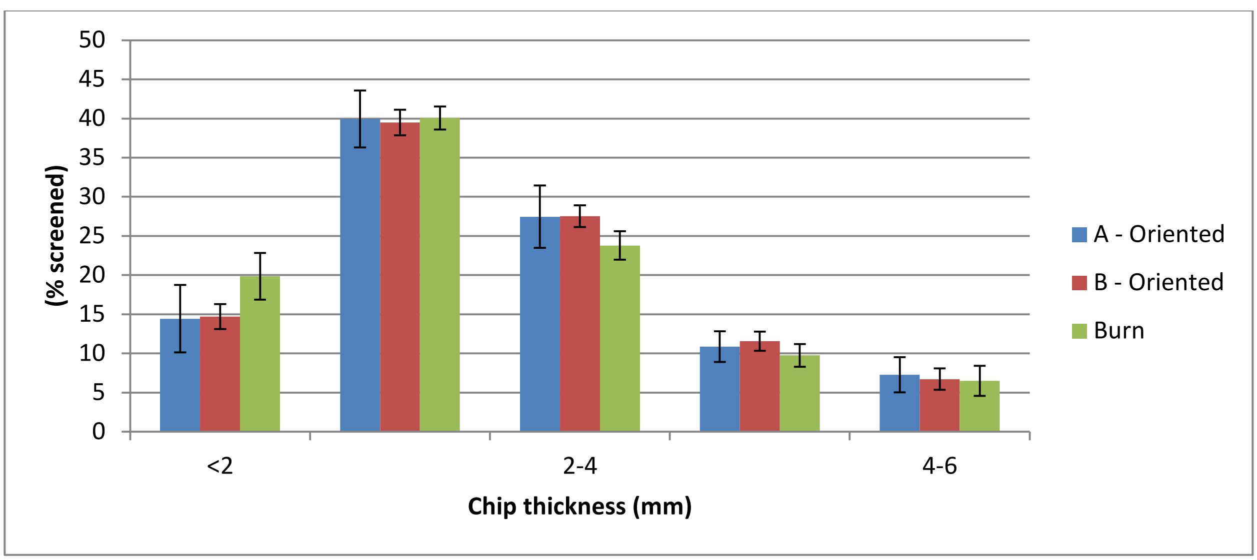

Figure 21. Chip thickness distributions for each sample type.

5. RECOMMENDATIONS

Residue handling behaviour

Where secondary harvesting is economically and logistically feasible, licensees or landowners should consider having the primary harvester (processor) drop the tops neatly into piles rather than scattering them behind the merchantable decks. There is no reduction in processor productivity associated with the change in handling method while many advantages can be realized by leaving the tops ready for secondary harvesting.

Maintaining long piece sizes

Whenever possible, operators should attempt to maintain longer tops to realize the following benefits:

- By maintaining longer tops, fewer residues are left on the site. When tops are broken, smaller pieces are abandoned and contribute to fire fuel and potentially block plantable spots.
- When tops are cut to a specific length to fit a bin or short trailer, short leftover pieces are either left at roadside or taken to the chipper where they become part of the chipper debris because they are too short to chip.
- The time taken to cut the tops to a specific length incurs a cost with longer loading times.

Maximize load size

The difference in cost between using small bins or roll-off bunks and larger trailer configurations is quite large and demonstrates the value in maximizing load sizes. As distance between a cutblock and the chipping location increases, load size needs to increase in proportion.

6. CONCLUSIONS

Productivity and cost

FPInnovations monitored the productivity and cost differences between two methods of handling logging residuals and transporting them to a chipping location. In the processing phase, there was no difference in productivity between handling residues in a disorderly manner (leaving residues wherever they may fall, or flinging residues haphazardly away from the processor) and methodically dropping residues in a neat pile.

In all phases after processing, handling residues that originated as oriented piles was more productive and less expensive than handling residues from burn piles. Piling residues for burning incurred a cost of $1.27/m^3 or $2.92/ODT. There was no piling cost for oriented piles. Forwarding the tops to roadside was $5.75/m^3 or $13.22/ODT less than hoe-chucking tops from burn piles. Also, residual volume left at the pile site after forwarding was far less for oriented piles (5%) than with the burn piles (25%). Loading the residuals into the bin or trailer was $4.04/m^3 or $9.40/ODT less expensive when loading from oriented piles than burn piles.

Productivity and cost analyses were also performed for four different bin and trailer configurations. The largest loads and lowest cost were found with the roll-off bunk and trailer configuration. Average net load size for this bunk/trailer configuration was 28.8 m^3 or 12.5 ODT. The cost of transport using the bunk/trailer configuration was $9.80/$m^3$ or 23.08/ODT.

The lowest cost option of handling and transporting residues to the chipper required the processor to produce oriented piles and the residuals to be loaded onto the largest truck and trailer configuration, which was the roll-off bunk and trailer combination.

This cost of $16.11/$m^3$ or $37.60/ODT can likely be improved by upgrading the trailer configuration to a hayrack system where the tops do not need to be cut to length prior to or during loading. It is estimated that as much $2.30/$m^3$ or $5.50/ODT of further savings could be found by switching to hayracks.

There were three major recommendations as a result of this trial: handle residuals with care, maintain piece size length to increase productivity and reduce cost in the secondary harvest stage, and maximize load size when transporting residuals to the chipper.

Chip quality

Overall, the chip quality was good but there could be improvements in bark content and chip thickness. Bark content must be monitored and the chipper maintenance performed accordingly. Pulp mills target less than 0.5% bark as it is a contaminant in both mechanical and kraft pulp processes. Pins and fines (less than 2 mm thickness) are also less desirable for pulping. Pulp fibre length is negatively impacted by overly fine material as is liquor use and fibre mass flow through the digester. Secondary screening to remove the fines material, which will pass a 3 mm round-hole screen, would increase the amount of material preferred by chip customers (2–8 mm thick chips).

7. REFERENCES

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