Residues after eucalypt harvesting in New Zealand

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1. ABSTRACT

Although there are many reports on eucalypt biomass, there is a scarcity of data in New Zealand on residues remaining after harvesting operations. A study was conducted on two 19 year old *Eucalyptus fastigata* stands and a 22 year old *E. regnans* stand in Kinleith Forest to determine the volume, composition and piece size of cutover residues from eucalypt harvesting with ground based systems. The study found that the average post-harvesting residues from the three eucalypt stands was 35.2 m^3/ha. Most of this material consisted of stem residues while large branches and small branches were the next main components. Foliage and bark were minor components in comparison. Considerable variation occurred between plots, with one plot having as much as 191 m^3/ha residues.

The moisture content of the residue material was higher in the stem pieces, but the wood density was higher in the branch material.

The eucalypt residue was approximately 6.4% of the standing volume, this is higher than ground based harvesting of pine, but lower than hauler logging of pine.

This study has shown that the most realistic material for collection from a eucalypt harvesting site is the stem wood sections, which contributes approximately 40% of the residue volume and any branch material still attached to them. However, this is unlikely to be economic unless the residue material is given a sufficiently high value to warrant collection.

2. INTRODUCTION

Considerable data exists in New Zealand for total tree biomass for eucalypt stands for various ages (Madgwick *et al*., 1981, 1991a, 1991b), (Frederick *et al*., 1984; Frederick *et al*., 1985a, 1985b, 1985c, 1986), (Oliver, 1991) (McKenzie and Hay, 1996) and (Nicholas *et al*. (2000).

There is a large amount of biomass information available for radiata pine of different ages and for radiata pine post-harvest cutover residues (Hall, 1996a, 1997, 1998a, 1998b, 1998c, 1999).

There is a lack of data on eucalypt post-harvest (clear-fell) cutover residues. Total stem volume of stands can be inventoried or modelled (E. Hay, pers comm), however, the amount that is likely to be left behind after harvesting has not been reported.

This amount is likely to differ to the amounts or proportions left in radiata harvesting as the tree types are quite different, with large differences in crown shape and structure. Felling breakage is a significant contributor to the post harvest residue volume of radiata pine stands.

The crown shape and structure of different species, as well as the harvesting system may have an effect on felling breakage and so influence the post harvest residue volumes.

To address this lack of data, a study of current eucalypt harvesting operations was conducted in 2000. The study collected data on the volume of stem wood and other coarse woody residues left on the cutover from eucalypt harvesting operations in Kinleith Forest in the central North Island, New Zealand.

New Zealand has approximately 40,000 ha in eucalypt plantations, a small area compared to the 1.6 million ha of radiata pine (NZ Forest Owners 2003). Kinleith Forest has a small percentage (3.7% or 4000 ha) of its total forest area of approximately 108,000 hectares established in eucalypt species in order to provide short fibre for the Kinleith pulp mill. Currently the company is establishing around 650 hectares per annum in eucalypts to be grown on short rotation (12-15 years). The pulp mill also has a 40 MW dual fuel (gas and biomass) co-generation plant on site. This plant provides heat and power to the pulp mill. The biomass fuel demand at the co-generation plant is rising as gas prices rise and the cost effectiveness of recovering biomass from the forest is improving. This means that on top of the current supply of pulp and sawmill residues the co-generation plant is looking to augment its fuel supply with biomass from the forest. A trial system has been set up to recover radiata and eucalypt wood waste from logging landings created during harvesting. A key to the success of this system is cost which is largely driven by transport distance and fuel moisture. It may be that cutover fuels that are close to the mill site and with low moisture content will be more financially attractive to recover than landing waste that is green and further away. One of the variables that will affect the viability of recovery of fuel left on the cutover, is the volume of recoverable residue. Therefore, information on cutover residue volumes and composition are necessary for determining quantities of available fuel.

The eucalypt stands studied have been grown on a pulp production regime and are currently being harvested for chip production. Because of previous forest policy, these stands are older than is currently grown for pulp in the region, but as the only eucalypt harvesting operation in the region at the time, they were selected for the study, despite being atypical for pulp and/or for bioenergy.

This initial data can be used as a baseline data set to predict total in-forest residue volumes of eucalypt stands of similar productivity. Further work is required to extend the data base.

3. METHODS

Three fresh eucalypt cut-overs were identified and both line intersect sampling (LIS) and area plots were used to determine stem wood and other residue volumes (Hall, 1996b). These stands had been harvested with ground based systems.

3.1 LIS

An intensive sampling strategy was used, five 50 m plots per hectare — with the 50 m plots being installed in two 25 m sections at right angles to each other. The LIS assessed the stem and branch (diameter at intersection, large > 50mm, small < 50mm) material only.

3.2 Area plots

Total biomass per hectare was estimated by using area plots. Five 4 m^2 plots were established for each hectare of cutover using stratified random locations. For each of these plots all material above the litter layer was segregated into:

- stem wood,
- large (> 50 mm) and small (< 50 mm) branches,
- leaves,
- loose bark.

The material was then weighed and sub-sampled. The sub-samples (short sections by residue component) were weighed both wet and dry to determine moisture content. The sub-sample sections were also measured for volume (simple cylinder) to determine the wood density. Bark content of the sub-samples were also determined (% of dry weight).

The moisture content and densities were then applied to the total plot weights to determine the dry weight and volume of material per plot and per hectare.

4. RESULTS

4.1. Pre-harvest inventory data

Pre-harvest inventory data was obtained for the three study sites (Table 1).

Table 1. Sample stand descriptions

Location (units)	Species	Age (years)	Total standing volume (m^3/ha)	Stocking (stems/ha)
Blocks 1 & 2	*E. fastigata*	19	425	560
Block 3	*E. regnans*	22	668	460

4.2. Residue sampling data

Table 2. Line intersect sampling results – residue volume, m^3/ha

	Block 1	Block 2	Block 3	Average
Stem	7.6	7.8	12.2	9.2
Large Branch (> 50 mm)	5.6	9.1	10.1	8.3
Small Branch (< 50 mm)	8.9	4.2	7.1	6.7
Total	22.1	21.1	29.4	24.2
No. Plots	49	57	50	
Block area (ha)	3.0	3.5	3.2	

The line intersect sampling estimated the total average assessed residue volume as being 24.2 m^3/ha (Table 2), with a block range of 21 to 29 m^3/ha.

Table 3. Area plot results – residue volume, m^3/ha

	Block 1	Block 2	Block 3	Average
Stem	14.9	8.0	26.9	16.6
Large branch	9.0	12.8	10.7	10.8
Small branch	8.7	12.6	13.0	11.4
Foliage	1.8	3.2	3.1	2.7
Loose bark	0.4	1.1	1.1	0.9
Total	34.8	37.7	54.8	42.4
No. Plots	20	30	35	

The area plots estimated the total volume of residues per hectares as 42.4 m^3 (Table 3), with a block range of 35 to 55 m^3/ha.

Table 4. Percentage of pieces (%P) compared with percentage of volume (%V)

	Block 1		Block 2		Block 3		Average	
	% P	% V	% P	% V	% P	% V	% P	% V
Stem	8	44	4	23	9	51	7	39
Large branch	12	28	16	38	19	21	16	29
Small branch	80	28	80	39	72	28	77	32

The distribution of volume by component is important if residue harvesting is being considered. The focus of any residue harvesting will always be on the larger piece sizes. In this case the stem wood (on average) contributed 7% of the pieces and 39 % of the volume (Table 4 and Figure 1). The average stem wood residual piece size was 0.019 m^3.

The stem wood and large branches together contribute 23% of the pieces and 68% of the volume.

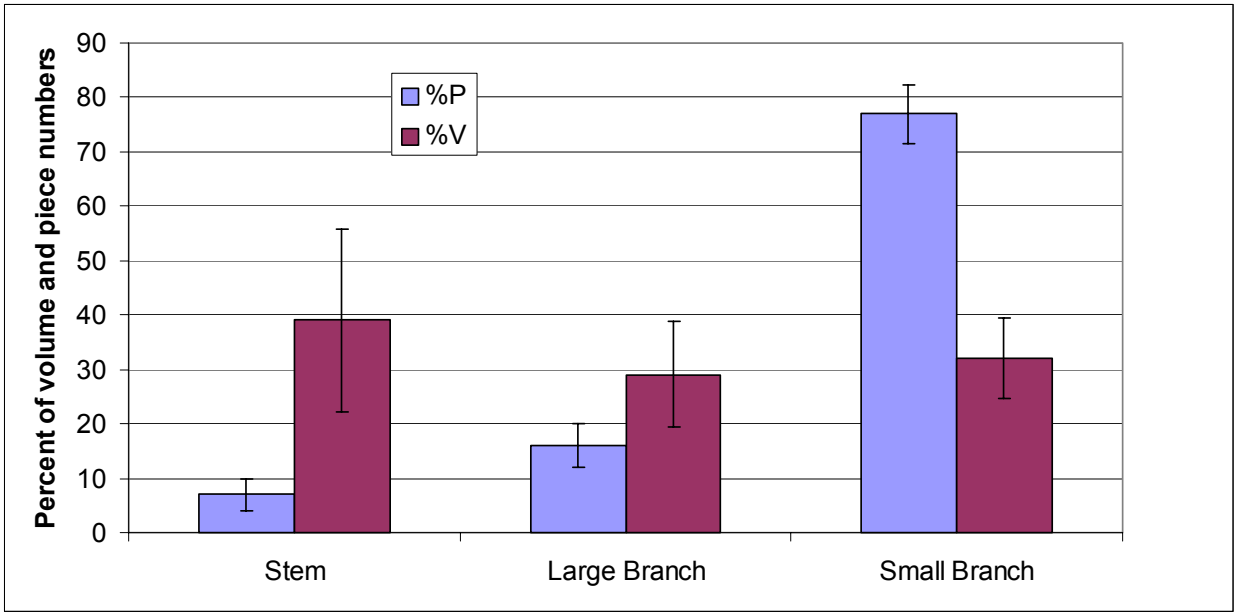

Figure 1. Proportions of piece numbers and residue volume

4.3. Residue samples from area plots

Samples were collected from Blocks 1 and 2 approximately three months after harvest and Block 3 approximately 1 month after harvest.

Table 5. Percent moisture content, wet basis

	Block 1	Block 2	Block 3	Average*
Stem	52	52	52	52 a
Large branch	42	51	44	46 b
Small branch	33	31	34	33 cd
Foliage	23	15	17	18 c
Loose bark	47	65	44	52 abc

* = values with the same letter do not differ significantly (p = 0.05).

The stem wood had higher moisture contents than the smaller diameter branch material (Table 5).

Table 6. Samples – wood density (kg/m^3 – oven dry)

	Block 1	Block 2	Block 3	Average*
Stem	470	440	477	462 a
Large branch	594	490	560	548 ab
Small branch	627	639	581	615 b
Loose bark	168	157	260	195 c

* = values with the same letter do not differ significantly (p = 0.05).

The branches had higher densities that the stem wood (Table 6).

Table 7. Bark content (% of dry weight)

Stem	2.8
Large branch	7.5

Note – bark % is for stem wood as found, that is some bark was removed by the harvesting operation due to felling, delimbing and extraction.

5. DISCUSSION

Table 8. Comparison of this study with pine residues

	Eucalypt average (m^3/ha)	Pine average (m^3/ha)
Merch stem	—	0.4
Unmerch stem	12.9	19.5
Large branch	9.6	14.1
Medium branch	—	8.3
Small branch	9.1	4.8
Foliage	2.7	0.1
Loose bark	0.9	3.9
Total	35.2	51.1

Table 8 indicates there are less residue remaining in the eucalypt operations than there are for pine, however there are also differences in the age of the material. Pine tends to be closer to 28 years old compared to the oldest eucalypt stand assessed which was 22 years old. The other main differences are that the eucalypt stands assessed have more small branch material and foliage remaining than pine stands.

Table 9. Residues as a % of standing volume (546.5m^3)

Component	%
Stem	2.36
Large branch	1.76
Small branch	1.67
Foliage	0.49
Loose bark	0.16
Total	**6.44**

On a percentage of total standing volume basis, these figures suggest that 6.4% of the stand remains on site, while for a pine stand on hauler country it is approximately 8.7%, and with pine ground based systems it is about 4.8%. Most of the difference is due to more branches and less stem wood left on steep terrain.

More work is required to investigate stands closer to normal felling age for a pulp or bioenergy crop to determine the universality of these results across crop types.

The volume per hectare is relatively low, and the residues were spread widely, with few large concentrations. Only the stem and large branch material is realistically recoverable, this was 2.1% of total standing volume (TSV). This would make cutover recovery and extraction relatively expensive. However, recovery of piles of processing waste from landing surrounds is likely to occur in the near future.

The moisture content of the stem wood material was still high, indicating that a longer period than 3 months would be required between harvest and residue recovery for the larger diameter material to dry out. A study of landing residues in Kinleith forest showed that radiata pine

stem wood residues in piles dropped from 55 % moisture content to 35% moisture content in six months. If the residues in this study had been left for a similar period, they may have dropped to a similar level.

6. CONCLUSIONS

The average post-harvesting residue volumes from the three eucalypt stands studied was 35.2 m^3/ha or 6.44% of TSV. The largest contributor to this material was stem residue (12.9 m^3/ha, 2.36% of TSV or 36.6% to total residues), while large branches and small branches were the next main component. Considerable variation occurred between plots, with one plot having as much as 191 m^3/ha of residues.

The moisture content of the residue material was higher in the stem pieces, but the wood density was higher in the branch material.

7. ACKNOWLEDGMENTS

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