BIOENERGY FUEL FROM STEM-TO-LOG PROCESSING WASTE USING CONVENTIONAL FOREST HARVESTING SYSTEMS*

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ABSTRACT

The harvesting and use of in-forest residues as bioenergy is not common in New Zealand. However, most of the large wood-processing plants (pulpmills, papermills, and sawmills) have co-generation plants for converting woody residues from wood processing (bark, shavings, and sawdust) into process steam and electricity.

In a number of New Zealand's major areas of forestry, changes in harvesting practices have recently taken place, from conventional landing-based stem-to-log processing to the use of two-stage extraction with full stems being taken to central processing yards or super skids for conversion into logs. These changes have brought about a concentration of stem-to-log processing waste at the central processing sites. This waste is of such a volume as to create a disposal problem (cost).

Use of this material as bioenergy fuels at nearby processing plants, or as panel fibre, is economically and environmentally desirable.

Keywords: harvesting; waste; bioenergy.

INTRODUCTION

In logging operations in New Zealand, unmerchantable material arising from log making and delimbing on the landing is often of sufficient volume to cause potential environmental problems (Coker *et al.* 1990). This material consists of branches, head logs, slovens, and off-cut stem wood that is unmerchantable. During the log-making operations this material is discarded, often then pushed off the edge of the landing on to the cutover. The piles can build up to a height of several metres, around much of the landing edge. They often contain some soil as well as the wood waste. When the logging operation is completed the residue piles remain.

In hauler (yarder) operations such piles often form on hill tops and are referred to as "birds' nests". There are a number of instances where these large piles of branches and stem

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wood have collapsed downhill, damaging young recently re-established trees, and some have either fallen or been washed into water ways. Where they can be seen by the public, these "birds' nests" or collapses tend to draw adverse public comment.

There are now systems available to reduce the volume of stem wood being placed in these birds' nests by removing some of the stem wood as short (<3.0 m, >1.0 m) chip logs (Hall 1995). Another alternative being tried currently is using an excavator to load the waste material into trucks for dumping on sites with less environmental risk. Transport of the material is expensive and the large pile of residue remains, though at a different site. Another approach is to comminute the material either before or after transport and use it for boiler fuel, fill-slope stabilisation, or mulch.

If the logging residues are segregated, then it is possible that the larger sections of stem waste could be processed and utilised as pulp or panel chip. The remainder can be processed as hog fuel or simply abandoned. In super skid or central processing yard (CPY) operations there is minimal branch material amongst the residues.

In the central North Island of New Zealand, harvesting operations are changing from landing-based stem-to-log processing to CPY or super skid-based stem-to-log processing. In one situation, these changes have concentrated the stem wood residues arising from the processing of 2 400 000 m^3 of logs at three CPYs.

Data from previous studies were collated to describe the potential resource and the systems being trialled to manage this material.

METHODS

Data on current and future harvests and wood flows passing through the CPY operations were obtained from the forest managers. Figures on stem waste as a proportion of harvested volume were available form previous studies (Hall 1998, 1999). Operational data from systems being trialled to dispose of the stem wood were gathered, and the systems were costed.

Some of the environmental benefits of utilising the stem residues were summarised.

RESULTS

In the forest area concerned (approximately 175 000 ha of contiguous plantation forest in the central North Island of New Zealand) the annual harvest is approximately 4.5 million m^3. Of this, currently 2.4 million m^3 per annum are being processed at three separate CPYs. This figure is projected to rise over the next year as the total harvest volume rises and the CPYs are fully commissioned.

The principal crop being harvested is *Pinus radiata* D. Don. Typically, these trees are harvested by clearfelling at age 24 to 29, when they have a piece size of between 1.5 and 2.5 m^3. The stands generally have around 300 stems/ha and a standing volume of 600 m^3/ha. Most of the stands have received intensive silviculture with multiple prunings and at least one thinning. The pruning generates high value logs in the lower stem, and maximising value recovery from the stands requires that the maximum volume of pruned logs possible be cut from the stems.

The system used to harvest these stands varies with terrain but much is harvested from flat-to-rolling terrain using ground-based systems. These consist of a large mechanised feller-delimber-buncher, grapple skidders, and a heavy-duty log-loader to place the stems on the trucks (stems can be up in excess of 30 m long, but typically are 24 to 26 m long). The harvested cost on truck is approximately $8.50/tonne. Some of the crop is harvested from steep terrain with cable systems. These use manual felling, large yarders, delimbing at landing, and then loading in stem lengths on to trucks. Costs for these systems can be as high as $25/tonne.

The stem length material is transported on purpose-built off-highway trucks on private roads to the CPYs.

The CPYs use a combination of computer optimisation to determine optimal value to be cut from the individual stems, and motor-manual methods to cut the stems into logs. Stems are described by a logmaker into a handheld computer with automated length and diameter measurement. Each stem is then "optimised" by an algorithm in the computer, based on different log grades required and their respective prices. The log maker marks the cuts to be made and these cuts are then made by chainsaw operators.

Based on previous data from a variety of harvesting operations using this type of log making, it has been determined that the proportion of stem wood that is discarded as waste is around 4 to 5% by volume. One percent is in very short sections of less than 1.0 m. These figures vary with terrain, crop type, and harvesting system used.

Based on these figures it could be expected that the three CPYs would produce between 13 800 and 55 200 m^3 of stem residue per annum (Table 1). This material is variable in length, diameter, and piece volume (Table 2).

TABLE 1–Stem residue volumes by site (000 m^3/annum)

	CPY 1	CPY 2	CPY 3	Total
Volume processed	300.0	900.0	1200.0	2400.0
Long waste >1.0 m	10.8	32.4	43.2	86.4
Short waste <1.0 m	3.0	9.0	12.0	24.0
Total waste	13.8	41.4	55.2	110.4

TABLE 2–Mean residue piece dimensions

Mean diameter (cm)	37	Range 16 to 70
Mean length (m)	0.63	Range 0.16 to 3.7
Mean volume (m^3)	0.070	Range 0.02 to 0.4

Piece Length Distribution

The stem residue has a large percentage (50 to 60%) of very short (<0.5 m) pieces (Fig. 1). However, the bulk of the volume is in the longer sections (>1.0 m).

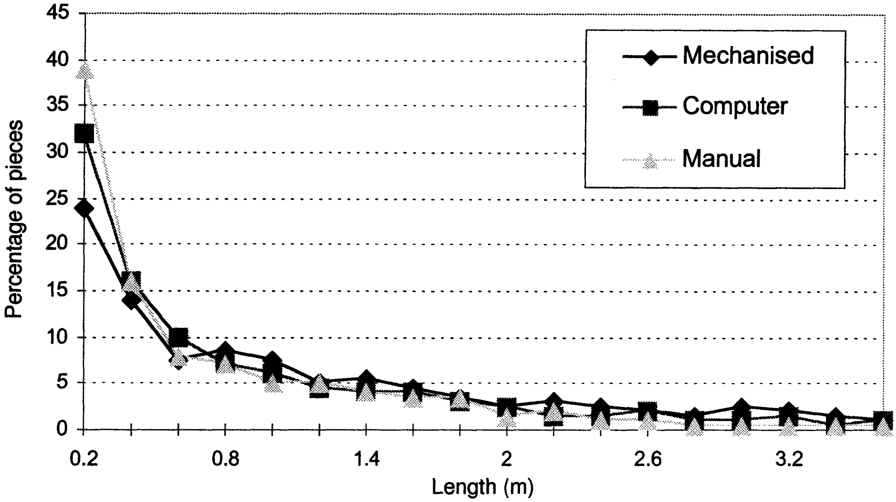

FIG. 1–Frequency distribution (%) of waste piece lengths for three log-making systems.

Bark Content

The material being produced at the CPYs has been processed and handled several times, and much of it has been mechanically delimbed. A substantial amount of the bark has been removed by the time the material is placed in the waste pile at the CPY.

Commonly the bark volume of *P. radiata* tree stems is of the order of 8% of the total volume (under-bark basis). A sample of the stem sections (n=50) was assessed and on average they had only 8% of the original bark left on the stem. This equates to an estimated bark content of 0.6%.

Dirt Content

As this material is regarded as waste it has not been handled with any regard for its quality and so the dirt content can be quite high, especially during periods of wet weather. The dirt content of some of the piles of stem waste was estimated at 20%. However, this can be substantially reduced during subsequent handling and loading prior to hogging. A sample of the hogged fuel (undebarked) had a dirt content of approximately 1%.

The options trialled to deal with this waste were:

(a) Transporting waste to an abandoned quarry and dumping
(b) Incinerating waste at individual CPYs
(c) Processing waste into boiler fuel for a local pulpmill
(d) Segregating waste and converting it to boiler fuel and other higher value products.

System costs were derived using standard costing templates (Riddle 1994). The systems were given detailed costs for individual machines and other inputs (labour, supplies, overheads, etc). The daily system costs were divided by production rates of the system.

Transport costs were derived the same way. Production rates were derived either by observation of the systems or by obtaining long-term production data. Where the system produced a saleable product, then revenue per tonne was subtracted from the cost to give a net cost or revenue.

The cost of System (a) (dump in abandoned quarry), was $7.58/tonne for a total annual cost of $836,832 (Table 3). This is entirely transport cost as there were asumed to be no dumping charges attached. If dumping charges were incurred, they would be approximately $10/tonne.

TABLE 3–Net costs and revenues for the different systems

Costs (NZ$)	System (a)	System (b)	System (c)	System (d)
Per tonne (net)	–$7.58	–$11.88	–$4.16	+$14.14
Per annum	–$836,832	–$1,311,552	–$459,264	+$1,718,010

The cost of System (b) (incinerate on site with Air Curtain Destructor (ACD)), was $11.88/tonne for a total annual cost of $1,311,552. This system assumed three small pit burners, one at each CPY. The ACD uses forced draft combustion to reduce the residue to ash.

The cost of System (c) (convert to hog fuel for pulp mill) was $4.16/tonne for a total annual cost of $459,264. The costs of the hogging and transport were not completely covered by the revenue generated from hog fuel sales because of low hog fuel prices ($10/tonne). The average haul distance for the hog fuel was approximately 40 km.

The costs for System (d) (segregate and convert into hog, panel fibre, and pulp chip) were $21.70/tonne. However, although these costs were the highest per tonne, they were offset by higher revenues for the products created by segregating the residues. This system generated a total annual profit of $1,718,010 giving a net revenue of $14.14/tonne.

DISCUSSION

The environmental impact of the residue management varies with the system used. There were assumed to be no cutover nutrition issues other than those associated with the harvesting operation as this material is being removed by the harvesting system regardless of the log-processing system (Hall 1998).

The dumping of the residues (System (a)) has the greatest impact as there are costs and emissions from this, with no mitigation. Long term it would have increased costs as the free dumping of the residues would eventually end. There are risks associated with the long-term dumping of residues such as this. If the piles have sufficient small particle debris (loose bark) they can self heat, catch fire, and thus incur increased management costs.

The burning of the residues to waste (System (b)) avoids the long-term dumping and storage issues of space and leachate but creates immediate greenhouse gas emissions. These emissions from the wood could be regarded as neutral, if accelerated, as the wood would decay over time and release its stored carbon. Moving the waste to the burning site and the operation of the Air Curtain Destructor create extra emissions. There are risks associated with the pit burning in the middle of a large forest estate which may limit the burning operation to a short season.

The conversion of the residues to boiler fuel (System (c)) has substantially lower net costs than the first two options. There are net energy gains from harvesting this material and the emissions from its combustion can be considered neutral. There are financial risks associated with putting such a system in place as its viability is dependent on the demand for hog fuel. In this specific case the demand has yet to develop to a point where the price makes the operation profitable in its own right. It is viable only because it costs less than Systems (a) and (b). If the price of hog fuel was to rise by $4.00 to $5.00/tonne, then System (c) would break even.

The last system (System (d)) is not a pure bioenergy system. The bulk of the residues (90%) are converted into higher value products such as pulp chip and panel fibre. The bioenergy fuel is largely that which comes from the debarking and screening of this material. What it does do is improve the value recovery from the forest resource whilst providing a solution to the waste problem at an overall net profit. There are financial risks with this operation as it depends on obtaining markets for an increased volume of industrial fibre.

All of the residue harvesting systems have benefits when applied to steep slope harvesting operations as they remove from the landing surround large, unsightly, and potentially unstable piles of debris.

CONCLUSIONS

The system that is most cost-effective is that which takes some of the stem-to-log processing residue as bioenergy fuel but that also sends the bulk of the residue to higher-value end-uses such as pulp chip and panel fibre.

However, regardless of which of the harvesting residue utilisation systems is implemented, they are economically and environmentaly superior to dumping or waste incineration.

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