FUTURE FORESTS RESEARCH

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Using Hauler Engine Power to Drive a Wood Chipper

Summary

This study evaluates the technical and economic feasibility of installing a chipper run from the hauler power source to comminute logging residue material (off-cuts, limbs and tops of trees) to either wood fuel (if there is a market) or to disposal on the skid site. Due to lack of market economics as wood fuel, the feasibility is measured against the current cost of disposal, not the cost of producing saleable chip/hog fuel. The aim is to reduce the problems associated with logging residues in steep country harvesting, and to find a cost-effective way of dealing with these issues.

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Introduction

Harvesting in New Zealand is moving to steeper country, and the forestry sector has identified steep country harvesting as marginally profitable in many areas of New Zealand. The Forest Owners Association's Science and Innovation Plan has prioritised the need to reduce steep-land harvesting costs. In addition to cost, forest owners and management companies must also manage the ever increasing risks associated with steep land harvesting. Changing weather patterns have seen more frequent high intensity storm events, and these events have resulted in mass soil movement, including movement of associated logging residues. The licence to operate on steep country is becoming more difficult to maintain and there is a risk that steep country forestry (arguably the best commercial land use) becomes unattractive to investors due to high costs and associated risks.

The need to manage erosion and debris flow risks was clearly articulated at the recent Future Forests Research (FFR) Steeplands Workshop in Gisborne in March 2012, and has been consistently highlighted in interviews to determine environmental research priorities with a range of forestry stakeholders (Richards, 2012). Regional regulatory pressure is increasingly being applied to ensure that operational practices do not result in negative impacts to the environment.

The FFR harvesting research programme aims to improve efficiency, increase productivity and reduce costs of steep land harvesting. Hauler engines are typically idle for a large percentage of the time, and one idea to improve efficiency was to investigate the potential of utilising the spare hauler engine capacity to run a chipper to alleviate the residue disposal problem on hauler processing sites.

The objective of this study was to assess the feasibility of installing a chipper run from the hauler power source to allow residue material (off-cuts, limbs and tops) to be safely, quickly and effectively converted to wood fuel or disposed of – either to a recovery container for removal, or to be distributed over the site, avoiding build-up and subsequent environmental issues. The potential to retrofit machine capability to existing yarder equipment, and the related engineering challenges, were key parts of the investigation. The economic feasibility of such a development measured against the current cost of residue disposal was investigated.

Study Method

Literature on cable yarding as well as biomass harvesting and comminuting technology was reviewed. International and local developments in the logging industry, specifically related to forest residue harvesting were investigated and summarised. Discussions were held with

forestry equipment manufacturers and design engineers on the feasibility of installing an additional functional group, more specifically powering another device such as a chipper, to a hauler.

Results

Literature Review: Hauler Utilisation in New Zealand

In order to assess the feasibility and productivity benefits of using spare hauler engine capacity for other functions, it is important to understand firstly the extent to which they are utilised. Time studies, shift level data and regression model predicted values were found to range from 53% to 81%. More recent case studies have found similar values (Evanson and Amishev, 2009; Evanson and Amishev, 2010). These values include the production cycle elements such as gravity-return out-haul, hook-on and unhook which could be considered as available time in terms of hauler engine capacity utilisation. These figures indicate that hauler engine capacity is not fully utilised for up to 70% of the time. This amount of available time provides a good rationale for undertaking feasibility evaluation studies into utilising spare hauler engine capacity. Machine utilisation values for yarders were also found to be positively correlated with longer average haul distances, minimal downhill logging, use of a mobile tail hold and larger harvest setting areas (Evanson and Kimberley, 1992).

Logging residues – an industry opportunity or a problem?

Logging residues can actually be both an opportunity for the forest industry and a problem potentially impacting on its licence to operate in some areas of New Zealand.

The current volume of forest residues potentially available (excluding steep terrain cutover) is around 2.3 million tonnes per annum, with 1.1 million tonnes at landings (Figure 1). About 25% (250,000 tonnes) of easily-accessed residues is used each year as hog fuel and binwood for pulp production, leaving at least 750,000 tonnes per annum still available for alternative uses (Hall, 2012). Availability of logging residues at landings is set to increase with the expected increase in annual harvest volumes.

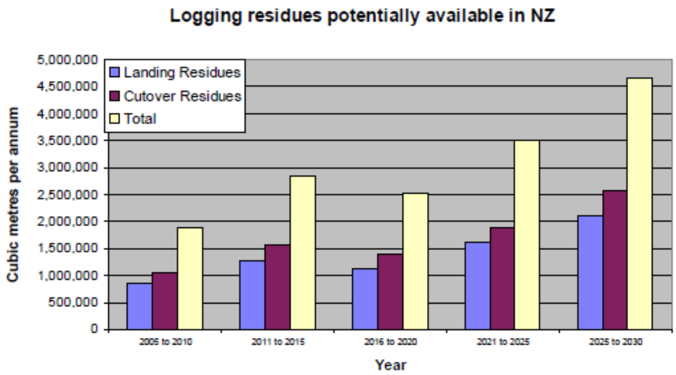

Figure 1: Logging residues potentially available in New Zealand (Hall and Evanson, 2007)

According to the Forest Owners' Association, a large-scale development such as a mega wood-fuel plant is a possibility in order to take advantage of the bioenergy opportunities (Rhodes, 2012). Furthermore, removal of residues off-site generates a lower greenhouse footprint than retention of residues on site or burning on site, with no significant immediate nutrient losses (Ximenes *et al.*, 2012).

In New Zealand, logging residues at landings comprise 4% (manual log making) to 6% (mechanised log making) stem waste and about 0.5% branch waste from the total extracted stem volume. Logging residues on the cutover comprise 5% stem waste and 10% branch waste (Hall and Evanson, 2007). Retrieving cutover residues is both costly and environmentally unsustainable (forest nutrition, soil compaction, etc.) and is not considered further in this study.

Regarding the volume of logging residues at landings, the average hauler crew produces 200 tonnes per day (Visser, 2011), and assuming an average value for landing residues of about 5% of total extracted stem wood, approximately 10 tonnes of landing residues is generated each day at each hauler operation. Each harvest area takes an average of about 35 work days to

harvest (Visser, 2011) and will produce about 350 tonnes of residues. Piles of loose residues have lots of air space in them which means they have low density. To store 360 tonnes of logging residues at the landing requires a volume of approximately 1450 m^3 (Hall, 2009). Additionally, if that material is piled a minimum of 4.0 metres high it would take up an area of 360 m^2 (or 15-18% of landing area) that is unplantable and effectively lost to timber production for the next rotation unless some disposal costs are incurred. At an average 300-350 stems/ha, this equates to 10-12 trees at final harvest worth up to NZ$2000 (FOA, 2011) foregone from this landing area.

This large volume of logging residues creates a problem in terms of space and risk of collapse and migration to waterways. In extreme weather events these volumes may mobilise, forming dangerous and damaging debris flows, potentially causing extensive damage to infrastructure (roads, watercourses, bridges), neighbouring property and the surrounding environment. Recent events that caused significant damage have raised public concern (Wardle, 2011, Rose, 2012) in both the North Island (Bay of Plenty in 2010 and 2011, Coromandel in 1995, 1999 and 2006, and Gisborne District in 1988 and 2010), and in the South Island (Nelson in May 2010 and December 2011, and Marlborough in December 2010). This public concern may become critical in forest owners and managers maintaining their licence to operate in steep, erosion prone forests.

Currently Available Technology

Technology for comminuting landing residues was reviewed to determine suitability for mounting on or integrating with a hauler power source. The types of available technology are chippers, hoggers, tub grinders and shredders.

Chippers

Disc chippers are commonly used in the pulp industry; they produce a high quality product that is specifically designed as a pulp feedstock. They can be used to produce wood fuels, but they require the material they are working on to be clean, and in stem sections of at least 1.0 meter in length. They come in all sizes, from those used at pulp mills to those that can be towed behind a pickup truck (Fig. 2).

Figure 2: Small trailer-mounted disc chipper, limited to material less than 30 cm diameter.

Depending on their size, chipper prices range from about NZ$160,000 to close to NZ$800,000. Most disc chippers do not cope well with short length material (< 1.0 m) as the short sections can bounce and turn, resulting in chipping along the grain as opposed to across it, creating chip quality and size issues.

Drum chippers are more suitable for residual material than disc chippers as they will take a variety of sizes and shapes without as much disruption to the processing and material quality.

Figure 3: Small trailer-mounted drum chipper, limited to material less than 41 cm diameter.

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The Europe Chipper C950 (Fig. 3) is equipped with a 140 hp John Deere engine. It is available with a PTO option, has a self-feeding crane/grapple and its delivered cost is around NZ$200,000. It can handle material up to 40 cm in diameter.

Drum chippers will typically not produce pulp quality chip, but will produce a fuel chip. Knives can be either fixed or swing type. Most of these machines can also be fitted with a self-feeding crane/grapple, or they can be fed by an independent machine, where the loader driver controls the chipper via a remote control.

Hoggers

Hoggers are much more able to cope with dirt contamination than chippers, as the knives on the drums of hoggers are more like hammers (and can be either fixed or swing type), and are designed to tear pieces off the in-feed material rather than cut them. However, contamination with dirt and rocks should still be minimised, as this will end up in the fuel.

Figure 4: Crambo 6000 turning stem off-cuts, bark and packaging waste into boiler fuel.

Due to the high speed rotation of the knives, contamination of the in-feed material with metal objects such as shackles, pins, track plates etc. (which occurs more frequently than it should) can cause catastrophic damage to the hog hammers. They come in two principal configurations; track mounted and self propelled (Ripper and Crambo 6000) and semi-trailer mounted and towed by a truck (WoodWeta and Wastepro) (Hall and Evanson, 2007). The SCS RP2140TD Ripper is a Caterpillar-powered 400hp vertical shaft hogger, weighing 27.5 tonnes. The cost of the latest version is approximately NZ$640,000. The Crambo 6000 (Fig. 4) is a Caterpillar-powered 600 hp hogger weighing 26.0 tonnes. The cost of the tracked version is approximately NZ$800,000. The WoodWeta 495F (Fig. 5) is a Caterpillar-powered 500hp hogger weighing 36.0 tonnes. The cost of the latest version is approximately NZ$700,000.

Figure 5. WoodWeta vertical disc hogger with trommel pre-screen.

Tub Grinders

Tub grinders have a drum with fixed or swing hammers mounted horizontally in the bottom of the tub (in line with engine drive shaft). The tub rotates, dragging material past the hogging drum/screen. Tub grinders work best when the drum is at least half full, as the weight of the material on the top presses the material at the bottom against the hogger drum. Further, if the drum becomes empty the hammers can catch loose chunks of wood and eject them over the side of the tub. In some cases a moveable cover may be required to stop excessive amounts of material being thrown from the tub. There is a range of sizes for tub grinders, and sizing will depend on the material that makes up the bulk of the in-feed material. Smaller machines have lower capital cost, but also a lower production rate, and will be limited in the maximum piece size of the material they can accept. The Morbark 1300 can be fitted with different-size engines. The machine owned by Pederson holdings is a Caterpillar-powered 860hp tub grinder with a 13 ft (3.96m) tub and weighs approximately 40 tonnes (Hall and Evanson, 2007). The cost of the latest version is approximately NZ$850,000.

Shredders

Another type of comminution machine is the low-speed high-torque shredder. In these machines the knives contact the wood at much lower speeds (30 rpm as opposed to 300 to 600 rpm). Due to the configuration of these machines the material produced tends to be longer and more splintered, but this also depends on the type of material being fed in, and the screen size. These machines are also remote controlled by the loader operator.

Biomass Harvesting Operations

Internationally, forest residue harvesting occurs in a variety of ways based on the specifics of the local environment, including existing infrastructure and expertise, end user requirements and residue characteristics, volume and distribution. Key areas in the supply chain with significant potential to affect costs and efficiencies are storage and transport. While the characteristics of each source of residue being considered for recovery and processing will vary for individual locations, Hall and Evanson (2007) established a range of typical costs based on New Zealand case studies.
The formula the authors suggested is:

$$DC = (TL \times DL) + CC + (DM \times TC) * DMLF$$

Where:
DC = delivered cost of forest residues ready for use as fuel ($/tonne)
TL = $ cost per km of loading and transporting residue to the central processing site
D1, D2 & D3 are the distances (km) between individual landings and the central site
DL = Average distance loaded (km) (=D1 + D2 + D3 / No. landings
CC = cost per tonne of chipping at the central site or at utilisation plant ($)
DM = Distance from central site to the utilisation plant
TC = cost per tonne of on-road transport (either chipped residue or un-chipped residue ($)
DMLF = dry matter loss factor (suggested 0.97).

Comparing these costs with alternative fuels based on the calculated energy output, biomass residue likely costs would range from NZ$2.50 to NZ$5.00 per Gigajoule and be more favourable than coal (NZ$5 to 7 per GJ) or gas (NZ$10 to 15 per GJ). This is based on costs and prices as at February 2007.

Stand-alone biomass harvesting operations can be prohibitively costly, mainly because of the high capital cost of the larger residue processing machines ($600,000-$850,000), low volumes available on hauler landings (10 tonnes per day) and space constraints. New Zealand case studies reported processing rates ranging from 25-40 tonnes per hour when large hoggers/tub grinders were used, and corresponding costs ranging from NZ$18/tonne to NZ$24/tonne of processed biomass residue (Hall and Evanson, 2007). Similar values were reported in radiata pine plantations in Australia (Ximenes *et al.,* 2012), where the average cost of harvesting residues was AUD25/tonne, ranging from AUD15/tonne when extracting roadside stacked residue crown stem wood and bole wood (named FibrePlus), to almost AUD60/tonne when using a bundler to recover almost 70% of the residue biomass on the site. In these Australian studies, less than 40% of the study sites carried sufficient biomass to be obvious candidates for a stand-alone biomass harvesting operation. It was also concluded that site impacts and production costs can be reduced where biomass is extracted with other products through an integrated operation, also avoiding the minimum pulpwood yield thresholds (80+ tonnes per hectare) that apply to stand-alone operations (Ximenes *et al.,* 2012). The drivers

behind recommended integration of residue recovery with log harvest for minimised costs and for integration are minimal handling, material losses, contamination, and machinery moving, resulting in maximised machinery utilisation (Hall 2009).

Manufacturer Discussions

In terms of powering a chipper from the engine of existing haulers in New Zealand, discussions with forestry equipment manufacturers and design engineers highlighted some engineering issues. Some manufacturers and design engineers expressed an opinion that it was not feasible to run a chipper from the yarder engine power.

Powering a chipper electrically would require fitting a generator to the yarder engine. It was stated that fitting a 300kW generator to the drive line which already has a transmission and hydraulic pumps fitted to the PTO is not feasible.

Powering a chipper hydraulically could work on some haulers (most track mounted haulers), as oil driving the track motors could be diverted through a diverter valve to a hydraulic motor driving the chipper. This method would require additional oil cooling as a lot of heat would be generated with the additional hydraulic use. Using the hauler PTO was thought to be the most practical way to proceed.

The other issue that was highlighted was getting a chipper which would process the size of slovens/branches typical on most skid sites. If chipping >600-mm slovens, a large chipper is needed, with high horsepower (up to 600 hp). If only smaller sized material (<40 cm diameter) was to be processed, then a 200-240 hp chipper would be suitable.

Engineers stated that the cost of running a chipper is significant, and if it is only being used for less than one hour per day to process ten tonnes of residues, or one day every ten, the utilisation of the capital invested is very low, and would be difficult to justify. It was also emphasized that the crew would have to be capable of maintaining the chipper in an everyday operation.

No engineering firm was prepared to estimate a price to build a chipper to function from the hauler PTO, and therefore a search of chippers available internationally was carried out on which to base the economic feasibility.

Two options were identified and compared to current cost of disposal: a hauler PTO driven chipper to be integrated into the harvesting operation and an independent mobile chipping forwarder to “service” several harvesting operations simultaneously.

Economic Feasibility

This project is about economic feasibility of comminuting logging residues to reduce the problems associated with them. The aim is to reduce the problems associated with logging residues in steep country harvesting and to find a cost-effective way of dealing with these issues Therefore in this study, the economic feasibility is measured against the current cost of disposal, not the cost or likelihood of producing saleable chip/hog fuel.

Removal of available volumes of biomass does not seem to be cost-effective under current biomass pricing and renewable energy policies and current extraction systems. In New Zealand, Hall (2009) stated that there were barriers to the utilisation of forest harvest residue resources such as cost, quality, and security of supply. A 57% increase in the value of bioenergy is required to enable it to compete directly with pulp and paper and particle board manufacturers. Current markets are not expected to change in the short term (1-3 years), but in the medium term (4-10 years) projected growth in the demand for bioenergy and biofuels is likely to be sufficient to make it cost-effective (Ximenes *et al.,* 2012).

The first option identified to be compared to the current cost of disposal was a hauler PTO-driven chipper to be integrated into the harvesting operation. The Heizohack HM 10-500K drum wood chipper from German-based Heizomat GmbH (www.heizomat.de) was quoted at 65,000 Euro plus another 10,000-18,000 Euro for the chassis (depending on required specifications). A remote control, a crane and all the required accessories for it to be a remotely-controlled PTO-driven self-feeding drum chipper adds another 35,000-40,000 Euro. At the current exchange rates it can be delivered at around NZ$ 200,000. It has a maximum permissible drive power of 170 KW (230 HP) through a PTO shaft and V belt transmission. It can handle up to 500-mm trunk diameter, while the width of the feed is 877 mm. Using a standard costing approach, a cost estimate for this unit would be $650/day. Spread across the average production of 200 tonnes/day (Visser, 2011), the cost of disposing of residues at the landing would be $3.25 per tonne of merchantable wood produced.

The second of the two options identified was an independent mobile chipping forwarder to "service" several harvesting operations simultaneously. The Scandinavian-developed Bruks 805.2 STC mobile chipper is the fifth generation of Bruks mobile chippers, with a drum diameter of 800 mm. It features a fuel-efficient 331 kW (450 hp) Scania diesel engine, a self-feeding crane and high-dumping chip bin. It can process parts of trees and round wood up to 50 cm diameter and the machine can be installed on forwarders, trucks or other types of vehicles. An Australian-based former Taupo logger, Jamie Low, has leased one from Scandinavian Forestry Pty Ltd and is establishing a business clearing wind-thrown trees, fire-salvage timber and regenerating pines (Low, 2012). The Bruks 805.2 STC mobile chipper was also studied harvesting forest biomass in pine plantations in Australia (Ghaffariyan *et al.,* 2011) and was found to be a viable option for harvesting biomass. The authors reported that chipping residues at the roadside had the highest productivity (43.9 green tonnes/PMH) and the lowest cost (AUD 16.90/tonne), as concentrating non-merchantable logs reduced the need for chipper movement, as well as increasing multi-log processing opportunities. For the other treatments, productivity ranged from 8.3 to 17.6 green tonnes/PMH, and costs ranged from AUD27.30 to AUD36.90 per tonne.

In one operation four trucks a day were filled and at 100 tonnes on a daily basis the operation would be profitable given the AUS$ 1.1 million purchase price (Low, 2012). Using a standard costing approach, a daily cost estimate for this unit would be about NZ$2,000. It would have to "service" at least three average crews (totalling 720 tonnes/day) which would result in an average cost of about $2.80 per tonne of merchantable wood produced.

Current practices of residue disposal involve the use of excavators and trucks (bin-trucks or standard logging trucks) to shift the residue to a "safe" location. It is usually done a couple of times a week for each skid site or after harvesting the setting. Assuming the use of an excavator, and standard loading time, average distance to disposal site, calculated truck time and number of trips per day, it was found that these practices cost between NZ$700 to NZ$1000 per day, or between $3.00 and $4.00 per tonne of merchantable wood produced.

Conclusions

Internationally, forest residue harvesting occurs in a variety of ways based on the specifics of the local environment, residue characteristics, volume and distribution, existing infrastructure and expertise, and end user markets and requirements. There are several different options for processing residue biomass available such as chippers, hoggers, tub grinders and shredders.

In New Zealand, with current logging methods the volume of residues can be seen as a problem through off-site debris flow damage and loss of plantable area, and as an opportunity for additional income through wood energy options.

There are a number of operations disposing of hauler landing residues to mitigate environmental risks, both by burning and by removal. Removal of biomass for wood energy does not appear to be economically viable under current biomass pricing, renewable energy policies and costs of current extraction systems.

The economic feasibility of this project was measured against the current cost of disposal, not the likelihood of producing saleable chip/hog fuel. The use of either a hauler-powered mid-size chipper or a mobile chipper/forwarder was found to be economically similar in cost to the current practices of residue relocation and disposal (although higher than the cost of burning). As opposed to using a chipper, relocation/disposal of the residue does not produce any merchantable product regardless of the market price, and in most cases these relocated residues still take up space and potentially can be a safety hazard.

Future harvesting research in this area should focus on further integration of chipping the residues within the harvesting operation. Implementing a chipper powered by the hauler engine should be evaluated in the field, and possible spill-over benefits assessed. Such changes would necessitate thorough investigation of harvest systems design and logistics.

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