FORMEC 2010
Forest Engineering: Meeting the Needs of the Society and the Environment
July 11–14, 2010, Padova–Italy

FOUR LANDING BIOMASS RECOVERY CASE STUDIES IN NEW ZEALAND CLEAR-CUT PINE PLANTATIONS.

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Keyword: Biomass Recovery; Landings; Timber Harvest; Bio-energy

Abstract: *New Zealand forest operations are primarily based on large scale pine plantation clear-cuts. Previous studies have shown that relatively large volumes of woody biomass residues accumulate at the landings. This includes not only the branches and tops, but a very aggressive value recovery program focusing on quality results in a large volume of relatively short large diameter off-cuts. Through a program supported by the NZ Energy Efficiency and Conservation Authority (EECA), four field studies were carried out to assess productivity characteristics and logistical options to optimise the recovery of landing biomass. The first field trial looked at using a tub grinder to comminute very large, but contaminated volumes of biomass from a super-skid, whereby a comparison was made between fresh and old residues. The second looked at recovering short logs from the biomass piles and loaded directly by excavator into a bin truck, or stacked for a self-loading truck. The third focussed on longer logs trucked to a centralised landing area: the resulting stack covered for drying and subsequently chipped. For the latter study, an additional trial was set up to assess moisture content change over time of timber stacked, with treatments of covered and larger logs split. At time of writing the fourth trial had yet to commence. The results to date indicate that the difficulty of recovering the biomass from the landings significantly impact the ability to comminute cost-effectively. Sieving tests of the comminuted biomass indicated high levels of contamination, with large percentages of fines. While system costs were comparably moderate, production levels were low given the size and potential of the equipment used.*

Introduction

In most countries biomass recovery from existing timber harvesting operations is recognised as an important component of any bio-energy program. Woody biomass is available from three common sources; (a) Forest residues: Branches, tops of trees and other stem wood from harvested trees and unmerchantable trees: (b) Wood processing residues: Bark, sawdust, shavings and off-cuts from processed wood such as panel board, construction timber and furniture, and (c) Woody crop plantations: These comprise short rotation forest crops grown specifically for energy purposes.

A number of studies have been completed in NZ to provide an overview of the market and barriers at the larger scale (Hall and Jack 2008; Hall and Jack 2009). Landing residues are likely to be one of the lowest cost options for woody biomass that can be delivered in large enough quantities and quality (Hall and Evanson, 2007; Stampfer and Kanzian 2006; Hakkila 2004).

Figure 1: Typical yarder landing showing the biomass discarded 'over the side'. Such biomass piles are becoming larger as the market for pulpwood decreases

This paper deals with the first source of woody biomass only; wood fuel arising primarily from forest harvesting. Wood fuel is a term we are using to describe any woody-biomass that is being considered for energy production. All useable 'residues' are therefore potentially wood fuel. It is estimated that there are over 1 million m^3 of potential wood fuel produced on forest landings annually. As the NZ forest estate matures the volume available will increase over the next 10-15 years[1]. In many regions there is also a diminishing market for lower quality wood for pulp manufacture, and this factor could also significantly increase the volume of woody biomass available.

A number of national and regional renewable energy initiatives, especially targeted at the demand for wood fuel, may also provide additional opportunity for wood fuel production. This includes support programs from EECA that provides capital for purchase of wood fuel conversion technology. Currently, only approximately 25% (250,000 tonnes) of the easily-accessed residues was utilised nationally in 2009, leaving at least 750,000 m^3 per annum available for use as wood fuel products.

Biomass recovery adds to the complexity of forestry operations, but also offers opportunities to increase efficiency, raise value recovery and reduce harvesting and management costs (Björheden 2000). Typically residue constitutes a problem for both processing as well as the subsequent planting. Like any forest product, wood fuel has supply, processing, transportation, storage and demand considerations (Hall 2008). However, many machine and system concepts, as well as product type and quality issues are common to all woody biomass supply options (Visser et al. 2009).

At present there are relatively few biomass recovery operations in New Zealand, despite the very large amount of residue generated by large-scale harvesting operations in plantation forests. Ninety-five percent of NZ plantation forests (Pinus radiata and Douglas Fir) are grown on a rotation that targets recovery of veneer, clear wood and or sawlogs (NZFOA 2009). Potential residue recovery as a by-product is therefore very much secondary to the main harvest, which generates the largest revenue.

One of the main hurdles to the development of a NZ forest energy sector is the limited demand for wood fuel: without a market capable of absorbing significant amounts of wood fuel at a reasonable price, it is very unlikely that operators will develop modern and effective biomass production chains. Currently the bulk of the wood fuel market for landing residues is commercial scale heat, or for combined heat and power (CHP). This form of wood fuel, typically just hog fuel, is at the low cost end of the spectrum. The drivers behind the development of a forest energy sector can be many, both public and private in character (Björheden 2006). The possible growth of bioenergy in NZ is not exclusively dependent on national policies against climate change.

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[1] See http://www.maf.govt.nz/forestry/ for a range of statistics about the NZ plantation forestry resource.

The development of a large-scale renewable wood fuel program will likely require step changes government policy (or regulation), market demand and conversion technology. However, a key component will always be the cost-effective delivery of the raw material. Having recognised the opportunity of forest landing residue, the focus is now the machinery and systems that can convert this residue to a wood fuel. This paper focuses on the effective and efficient recovery of landing residues, its comminution and subsequent transportation to market. It uses a case study approach to overcome the complexity of the large number of factors concerning site, system and market.

Case Studies

A series of case studies were completed on existing successful wood fuel contractors as part of this project. The full report on the four systems can be viewed at the BKC[2] website. A brief summary of three operations are given here, and we gratefully acknowledge the cooperation of the contractors.

Case Study 1: Hogging at a super-skid in Canterbury.

Contractor: Burnside Contracting Ltd, Christchurch

This is a post-harvest hogging operation where biomass was being recovered from an old super-skid. It is a one-man operation, who mainly operates an excavator with a root rake; but two alterative grapples are available depending on the raw material being processed. The residue is hogged by a Diamond Z tub-grinder into a hog fuel to the ground (Figure 2), and the hogger is operated remotely from the excavator. A front-end loader with bucket is used to pile the hogged material, as well as load out the trucks. The loader was operated by the truck driver. Delivery was by chip truck and trailer with a payload of 27-29 tonnes. The distance to market was less than 60 km from all locations.

Figure 2: The excavator retrieving and piling the larger residue. The pile would then be hogged through the tub grinder.

The success of this operation was based on the very large volumes of biomass available at the old super-skids. Up to 2000 tonnes was at individual landings, but much of it was old (>12 months) and some buried up to 3 meters deep.

As part of the study a comparison was made comparing the particle size distribution between hogging green and old material. The old (partially buried) material had moisture content very similar to the fresh material at 55%. The main finding was that the fresh material reduced the percentage fines in the hog fuel. A comparison was also made with the machine hogging whole trees (clearing a shelterbelt), and this greatly improved the productivity and the utilisation of the hogging machine.

The productivity of the system ranged from about 50 to 100 tonnes per day for the more favourable conditions. System cost was estimated to range between $2750 and $3400, depending on the utilisation rate of the hogging

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[2] Bioenergy Knowledge Centre: www.bkc.co.nz

machine. The average cost of recovery, hogging and transportation was calculated to be $45/tonne. This equates to $6.50/GJ.

Case study 2: Recovering wind-throw and landing residues in Bay of Plenty for firewood.

Contractor: Shane Hooker Ltd, Rotorua

This operation focuses on the recovery of larger length log residues. The market for this wood was either for pulping at a mill, or for a firewood processing plant. The distance to market ranged from 25-100km. The system consists of a single excavator with grapple, and matched with either a bin truck (Figure 3) or a logging truck configured for short logs. The spread of the residue material meant the majority of the time was spent shovelling either to the landing or to the roadside, only 10-15% of the time is actually loading out the trucks.

Figure 3: Recovering biomass from the landing and cutover and loading it into a bin truck.

A self-loading truck was also used depending on availability and destination (Fig 4). The average payload for the self-loading truck was 24 tonnes, only slightly higher than that achieved in the bin trucks of 23.5 tonnes.

Figure 4: Self loading truck.

The success of the operation was based on the owner identifying, and only working on, landings where enough quality residue was present to make the move of the equipment cost effective. The owner suggested this was at least 200 tonnes per landing.

The productivity of the system ranged from 50 to 75 tonnes per day. System cost was estimated to range between $1850 and $2175, depending on the utilisation of trucks. The average cost of recovery and transportation was calculated to be $28-32/tonne. The wind-thrown residues had dried somewhat, with an average MC of 45%. This equates to $3.55/GJ, but note that this price excludes the cost of comminution to either pulp chips or firewood.

Case study 3: Integrated residue recovery for firewood in Otago.

Contractor: Gillion Logging Ltd, Waikouaiti

This one-person operation was integrated with the harvesting activities in the area (same contractor). It was semi-mobile and located on suitable old landings that were located near to the logging operations. It was based on a small truck frequently recovering the residues on the operational landings. However, a preference had developed for moving larger log piles from the active landings with a self loading logging truck. The logs were stacked on the firewood landing, processed into fuel wood through the firewood machine, and then moved by conveyer directly into the small truck (Figure 5).

Figure 5: In-forest firewood operation in Otago.

The firewood pieces were then tipped onto the ground for drying. After approximately 4-6 weeks, a second excavator would be used to turn the firewood over and create a larger pile (Figure 6). This benefited the drying, and also minimised the impact of rainfall. The short truck was then used to deliver orders for firewood to residential and small commercial customers.

Figure 6: Excavator with a tined bucket, used to both pile for drying, as well as load out firewood.

The basis for the success of this operation was the integration with the logging operations, good cooperation with the forest owner, and being able to deliver a high quality fuel wood into a well established firewood market.

The average productivity of the firewood machine was just over 12 t/PMH. The optimum log diameter for the firewood machine was 50 cm. At the optimum the firewood machine was able to produce 20 t/hr, with a steep decline for both smaller and larger logs (due to double handling). Loosely stacked firewood has a density factor of 0.5. The average round-trip for loading and delivery was about 2 hours. The cost of running this operation $1240/day, average production was about 30m3 (15 tonnes) and the moisture content of the delivered firewood was 18%. This equates to $5.54/GJ delivered.

Case Study 4

Drying Study
The project design consists of three replicates each of the four described drying techniques;

1. small logs (dia < 35cm),
2. small logs covered (dia < 35cm),
3. large logs covered (dia > 35cm), and

4. large logs split and covered.

whereby these logs were stacked onto pallets and left to dry with the stack being weighed periodically in order to calculate moisture loss over time. All the logs were ‘fresh’; they had been harvested within just a few days prior to the study.

The delivered logs were separated into ‘small’ and ‘large’, whereby the cut-off between the categories was approximately 35 cm diameter. Half of the large logs were split prior to bucking to length; this was done with an excavator with a mounted ripping tine (Figure 7). The log was placed up against another log resting between the tracks of the excavator and the tine pulled towards the excavator splitting the log. This splitting technique proved to be both difficult and time consuming with the logs often splitting unevenly with a large proportion breaking when the tine came to a large whorl or other large defect.

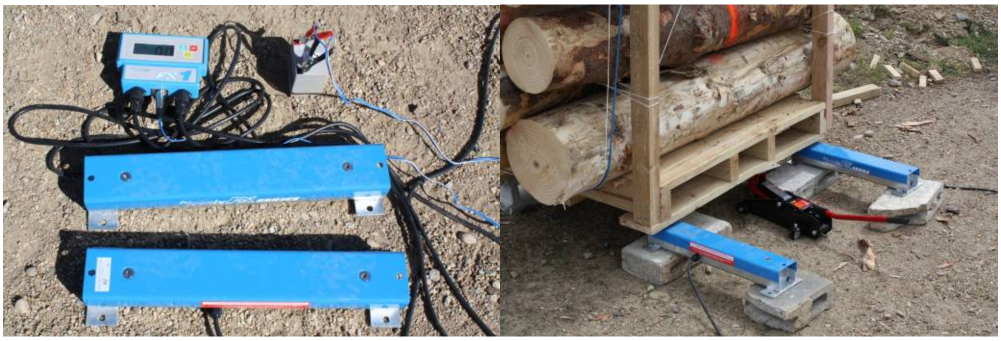
Figure 7: The excavator, with attached ripping tine, used for the unloading, handling and splitting of the logs.

The logs were cut to a length of 1.8m. At this stage 11 biscuits were cut randomly from the logs for determining the initial moisture content.

The pallets were ordered from a local manufacturer, with minor modifications to improve strength due to the large expected weight. Wooden uprights were bolted to the pallet to safely retain the logs (Figure 8). The pallets were then situated on top of cinder blocks to allow for ease of lifting and weighing as well as to provide a stable platform for the scales to rest on. The elevation of the pallets also stops the effect of ground moisture affecting the weight of the pallet and therefore the overall weight. The logs were carefully stacked by the loader to a height of approximately 1.6m with one trial type per pallet

Figure 8: One of the 12 pallets with fitted uprights situated on cinder blocks; and pallets being loaded with logs prior to covering.

Scales were placed under the pallets to periodically measure the change in weight from which the change in moisture content could be calculated. Iconix stock scales were used, which consisted of F1X load cells and an indicator (Figure 9). The load cells are designed to take the combined weight of both bars, with each bar consisting of two load cells. The process of weighing consisted of lifting the pallet on one side with a trolley jack (Figure 9). The weighing data was then entered in to a spreadsheet were it was used to calculate moisture loss from the known initial moisture content calculated at the start of the trial.



Figures 4a and b: The scales, indicator and battery; and the scales placed under the pallet for weighing.

A series of 11 biscuits were cut from the delivered logs. MC ranged from 48 - 61% with an overall average of 53%. There was no correlation between MC and diameter, so all log stacks were considered to have a starting MC of 53%.

The stacks were weighed weekly for the first month, and then approximately at 2 weekly intervals for the remainder of the trial. The results shown in Figure 6 indicate a rapid and relatively even drying for the first 13 weeks–followed by a levelling off.

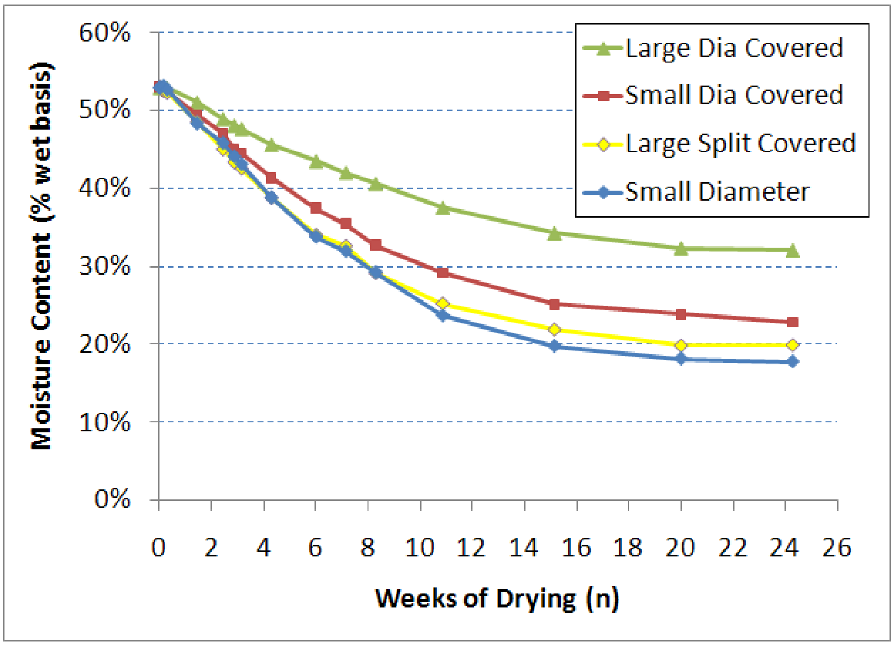


Figure 6: The moisture content for each treatment at the specified date

The large split logs dried the fastest, drying to 21% in just 17 weeks. In contrast, the large unsplit logs only dried to 30%. The small uncovered logs dried faster than those covered (23% versus 26% respectively). This suggests that while the cover would have prevented rain from wetting the logs, it may have inhibited airflow and or shaded the logs to reduce overall drying. It should be noted that it was particularly dry and hot for the duration of the study.

The main difference between the main stack trial and the pallet drying study was the average log length, as well as exposure to wind and sun. This indicates that smaller stacks of shorter logs will dry much faster. Destructive sampling of the study logs had not yet been completed at the time of writing this report to check to see if the MC estimated by weighing was accurate.

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