Biomass recovery and drying trials in New Zealand clear-cut pine plantations

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New Zealand commercial pine plantation forests are grown on a regime to maximise the recovery of higher value veneer or sawlogs. In some locations a lack of fibre market or long transportation distance can result in negative returns for the lower value logs. With log specifications that focus on quality, not quantity, radiata pine plantations generate relatively large numbers of reject logs that can include oversize logs, logs with large knots, excessive sweep or other defects. A small, but increasing, market for higher quality biomass product is developing. This includes pellets for wood burners as well as low moisture content chips for medium sized commercial boilers. Radiata pine at time of harvest typically has a moisture content (MC) of 55-60%, whereby the preferred MC for higher quality chips is less than 30%.

City Forests commenced a production focussed trial for woody biomass by stacking 1500 tons of pine logs in rows. The study location is just south of Dunedin in a location with relatively low humidity in the summer. An additional study was set up to assess moisture content change over time of stacked logs, with treatments of covered and larger logs split. The wood was stacked on pallets and weighed at approximately 1-2 week intervals. This latter study was supported by the NZ Energy Efficiency and Conservation Authority (EECA). The study showed that the larger split logs dried to 21% in 17 weeks. Small diameter logs dried more quickly than large diameter logs (23 and 32% respectively). Covering the stacks did not show to be beneficial for summer drying.

Introduction

City Forests Ltd is a major New Zealand forestry company based in the South Island that manages approximately 17,000 hectares of plantation forest. It has identified that there is the potential to further develop the regional biomass market as a carbon neutral alternative to coal. It is also a region with an overall decreasing market for other fibre-wood products. To investigate their ability to produce a larger volume of higher quality biomass chip, City Forests has stacked approximately 1500 tonnes of round-wood in the Milners Quarry for the purpose of drying and subsequent chipping. The stacks are approximately 4-6 meters wide and 4-5 meters high (Figure 1).

Figure 1: 1500 tonnes of stacked logs at Milners Quarry.

The stack consists of over sized, under-sized and other logs that do not meet sawlog grade due to defects such as sweep and knot size. Log lengths range from 2 to 6 meters. It was recognised that very little applied knowledge was available in the region as to the best option for drying the logs. Consideration was given to both covering the whole pile, and also splitting the biggest over sized logs.

There are a number of options for drying wood fibre for wood fuel: green chipping and then drying with either a blower or through the natural drying process, drying as round-wood onsite or off, and many other variations with regards to storage and drying techniques of either chips, slash or round-wood. The storage and drying of chips has shown to be problematic. Fungal and microbial activity can result in large volumes of dry matter being lost as well as very high temperatures within the piles that pose self ignition risk. Storage on an active landing is difficult due to contamination risk from dirt that significantly reduces the value of the biomass for fuel (Hall, 2009) and limited accumulation of volume for subsequent chipping (Visser et al, 2009).

Hall (2009) concluded that the best method with regard to cost of final product is one that contains as little handling steps as possible while still obtaining a fuel of adequate quality (dollars per GJ). The mass storage of round-wood lends itself well to this as handling costs are often minimised and chipping efficiency optimised.

National and international studies regarding the drying of conifer round-wood and slash has shown varied results. Climate, in terms of temperature, humidity and wind, is the most important external factor for the drying rate and final moisture content. Stacking and ensuring adequate airflow also greatly increase drying rates. A number of studies in wetter regions have found that covering has been greatly beneficial to the rate of drying of round-wood (Jirjis 1995; Kofman and Kent, 2009) due to the high risk of re-wetting caused by rain or snow. A study done recently in Wellington (New Zealand Clean Energy Centre, 2009) found that drying through the dry summer did not warrant the cost of covering, but covering the residue in the wet winter was beneficial. Needles decrease the value of the bio-fuel (Nurmi 1999) and they should be removed prior to chipping or preferably left on the site for their high nutrient content.

The purpose of this project is to determine the best and most cost effective method for air drying round-wood within the Otago region, South Island. In addition to monitoring the moisture content of the large stack trial, an experiment was set to better understand drying rates for various design options.

Methods

Moisture content
Percent moisture content (%MC) used throughout this project is wet basis. Oven dried weight was established by placing the sample in an oven at 105 degrees Celsius for 48 hours.

%MC = (total sample weight – over dried sample weight) / total sample weight.

Large Stack Trail
The 1500 tonne large stack was built up over a 2 month period over September and October 2009. The first of the chipping commenced in May 2010. That is, the total drying time was approximately 6-7 months. The moisture content of this large stack was measured by taking biscuit samples twice during the drying period, as well as measuring the moisture content of the bio-fuel chips after chipping.

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.

The logs used for this study consisted of under-sized, over-sized and reject logs between 2.5 and 4.5 metres in length. 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 2a). 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 (Figure 2b). 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.

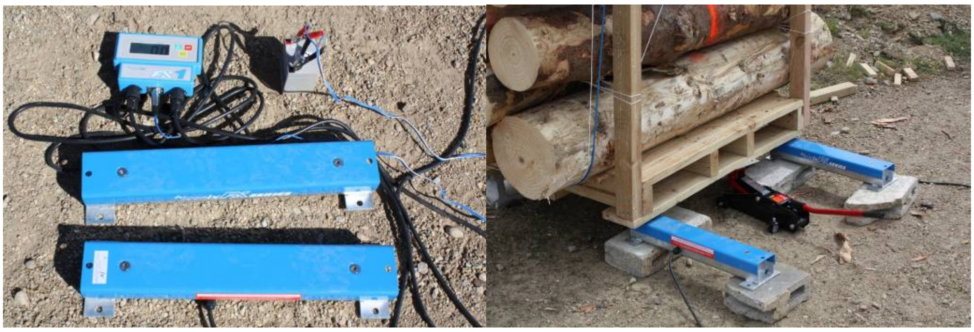
Figures 2a and 2b: The excavator, with attached ripping tine, used for the unloading, handling and splitting of the logs.

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 3a). 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

Figures 3a and b: 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 4a). 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 4b). 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.

Finally, a small, medium and large diameter log was left on the landing to dry. These were laid out onto bearers to avoid ground contact. The logs were destructively sampled to check on the drying effect along the log length by cutting a series of biscuits were cut from 3 logs at 30cm intervals.

Results

Large Stack Trial

Biscuits were cut at intervals from the large stack. Testing in January (approx 4 months drying time) indicated that the MC in the ends of the logs varied quite significantly. The MC of the 8 biscuits cut ranged from 19% to 38%, with an average of 29%.

In April (approx 6 months drying time) 17 samples were taken from the main stack of wood, including biscuits from the ends as well as from the middle of the logs. Moisture content again varied considerably with a strong correlation with diameter (Figure 5), as well as middle wood versus end wood being a factor.

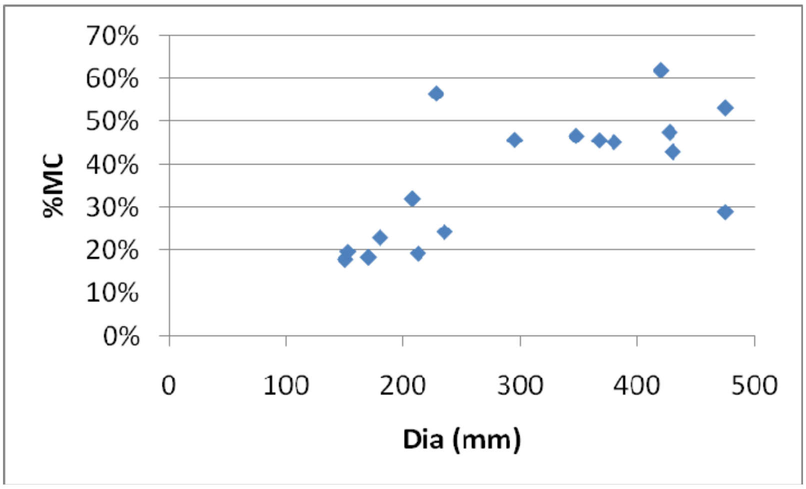


Figure 5: Moisture content results from samples taken from the main biomass stack

Overall, the average MC of the large stack was 37%. This is still quite high considering the goal was to drop the MC below 30% to achieve the higher quality wood fuel chip. However, even at 37%, the energy value per tonne would have increased from 7 Gigajoules per tonne to 11 GJ/t.

Drying Study
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.

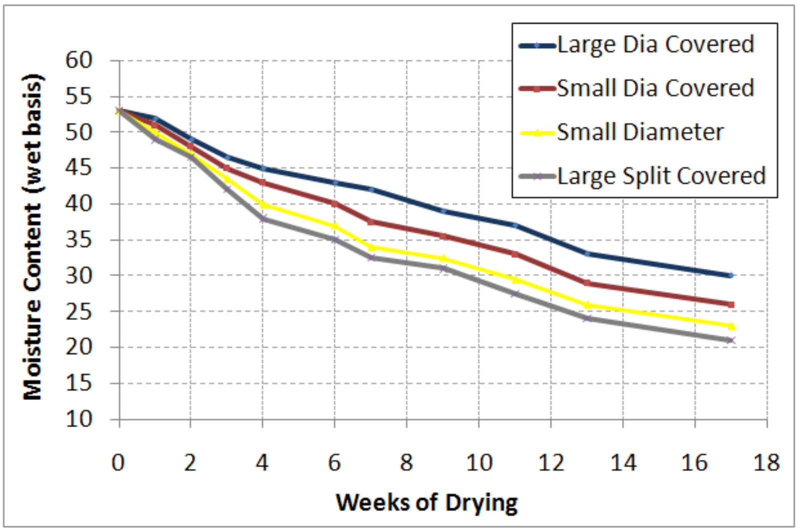


Figure 6: The moisture content for each treatment at the specified date

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.

Figure 7 shows the results of the logs that were dissected (at 30cm intervals) to discern the rate of drying along the logs. There is a clear drying effect at the ends of the logs. This is consistent with the knowledge that logs primarily dry along the grain of the wood fibres, and reinforces the benefit of drying shorter logs.

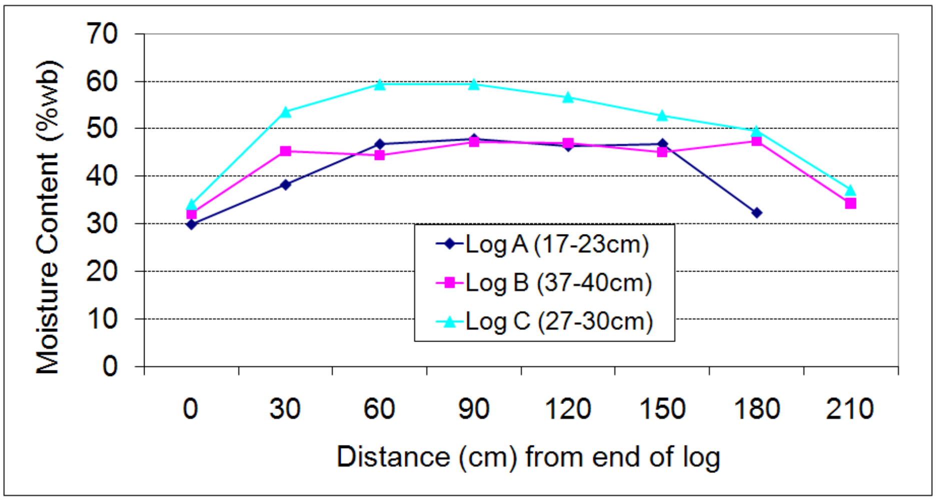


Figure 7: The moisture content along three sample logs

Conclusion

Biomass drying trials were undertaken by City Forests and University of Canterbury in summer in southern New Zealand. The overall goal was to produce higher quality chip for wood fuel. A large stack containing approximately 1500 tonnes, stacked 4 meters high, dried from approximately 55% to 37% in 6 months. While this improved energy density from 7 to 11 GJ/t, it did not achieve the intended target of 30% moisture content. A detailed study consisting of shorter logs showed that large diameter split wood dried faster than small diameter. The trial also indicated that covering the stack during summer did not improve drying rates, whereby there was minimal rainfall during the study. All of the short log stacks dropped below 30% moisture content in 17 weeks of drying.

Acknowledgements

We would like to thank the NZ Energy Efficiency and Conservation Authority for supporting this study; in particular Amber Uren (Advisor - Business) and Shaun Bowler (Program Manager Wood Energy).

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