Natural drying and optimising a forest residue supply chain to reduce the total operating costs: A case study in Western Australia

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Introduction

Forest harvesting residue is a renewable sustainable source of biomass currently in use in Europe and North America for power and heat generation. In Australia, collection of forest harvesting residues for bioenergy use is still in its infancy. Previous studies conducted by the CRC for Forestry have shown that there was a significant amount of harvesting residue in different clear-felled pine and eucalypt plantations. These residues can be a considerable source of renewable bioenergy if harvested sustainably considering the environmental impacts, site sustainability due to nutrient removal and operating costs of the supply chain to ensure a profitable business for the investors and plantation owners.

This project aimed to introduce an approach to optimise eucalyptus plantation forest residue supply chains in Western Australia through a simplified, generic example in the optimised biomass supply chain planning tool BIOPLAN. BIOPLAN is a linear programming model used to determine total operating costs of the supply chain and the best storage period for natural drying of residues at the forest road prior to chipping and transportation to meet quality criteria for moisture content of bioenergy. Reducing operating cost of biomass supply chain is a key driver to make an economical viable operation, one of the major factors impacting costs is the moisture content of residues. This project is an investigation of biomass moisture content management through natural drying in Australian conditions.

Study area and method

Natural drying

Without available knowledge on how woody residues dry in Australian conditions, initial estimates needed to be established through a local case study. The study site for the natural drying was located in Western Australia (WA) in a *Eucalyptus globulus* plantation near Rocky Gully. The residue pile was 103 m long, 4.8 m wide and 2.9 m high. The moisture content of the pile was sampled monthly from August 2011 (month of felling) to August 2012. The samples were collected from three cross sections (with the same spacing between each) at the top, centre and bottom of the pile. The biomass samples (1-2 kg) contained normal biomass components (bark, leaves, wood, small branches). The biomass samples were stored in plastic bags before determining the moisture content by weighing each sample before and after drying at 105°C in an oven. From the data collected, a natural drying curve over time was produced. The total rainfall per month (mm) and average maximum temperature and minimum temperature were collected from the nearest weather station.

Based on the long term climate data (rain fall, maximum temperature and minimum temperature) in the study area, natural drying curves with different starting date of storage were estimated for the purpose of exploring the optimised model and help demonstrate the potential value of accurate drying knowledge to support future expanded research.

Biomass supply chain

Since bioenergy is still an emerging industry in WA, there are not established supply chains to act as the basis for this project. As such, a fictitious scenario based on a typical 45 000 ha of eucalypt plantation estate in WA was used. The area was assumed to supply harvesting residues to a bioenergy plant with an average round trip haul distance of 160km from the plantations. The supply chain consisted of *Eucalyptus globulus'* harvesting residues as the source of biomass. The residues were scattered over the harvest area following the use of the CTL harvesting method to remove the primary pulpwood product. The amount of retained harvest residues in the case study area was assumed to be about 58 GMt/ha based on past field trials in WA (Ghaffariyan and Sessions, 2012). In this project, it was conservatively assumed that the maximum residue recovery will be 50% of the harvest residues (25 to 30 GMt/ha) as this is enough to meet the assumed energy demand and ensures that slash is left on site to avoid denuding the soils of nutrients. It is anticipated that the recovered residues will be collected and extracted to roadside by conventional wheeled forwarders and chipped by a mobile chipper directly into a truck.

Forest biomass optimising tool: BIOPLAN

The biomass supply chain was optimised with BIOPLAN, software developed by AFORA in collaboration with the Finnish Forest Research Institute (METLA) and the University of Eastern Finland (Acuna et al. 2012). BIOPLAN is based on a linear programming method in Excel to optimise three biomass supply chains (whole tree from early thinning, stemwood from early thinning and logging residues from clearfelling). The objective function of the strategic, non-spatial optimisation model minimizes the total costs associated with harvesting, storage, chipping and transport according to moisture content curves, which are included as explicit parameters in the optimisation model. The model considers a 2-year planning horizon. Decisions on the amount of biomass material to harvest are made on a monthly basis (24 periods) over that time horizon. The model parameters are listed in Table 1. Dry material loss rate of 2.0% per month was assumed for the harvesting residues (Laitila, 2006).

Operating costs of the supply chain under study (Table 2) included the forwarding cost, chipping cost, storage cost and transportation cost (Ghaffariyan and Sessions, 2012). Chipping cost was predicted using AFORA's recently developed chipping productivity and cost simulator based on an assumed average piece size of 0.03 m^3 and using the Bruks mobile chipper mounted on a forwarder chipping directly into the truck at the road side. The annual interest rate of 10% (with a range of 5% to 15%) was used in the analysis which has an impact on the storage cost and total operating cost associated with the procurement of the logging residues.

Table 1. *Parameters and conversion factors used in the BIOPLAN*

Parameters/conversion factors	Value
Energy content of *E. globulus* at 0% MC (MJ/kg)	17.38
Basic density (kg/solid m^3)	535
Bulk density (kg/loose m^3)	224.7
Solid content (chips from residues)	0.42
Ratio loose-m^3 to solid-m^3	2.38
Truck payload (tonnes)	23.0/50.0
Truck volume (loose m^3)	70/160
Round trip distance (km)	160
Material loss rate (%/month)	2.0

Table 2. *Operating costs of the harvesting residues supply chain in Western Australia*

Costs	Value
Forwarding ($/$m^3$)	6.9
Chipping MC%<=20 ($/$m^3$) 21<MC%<35 ($/m^3) MC%>=35 ($/$m^3$)	 20.1 18.3 16.3
Transportation in round trip distance ($/km)	3.2

Results

Natural drying curves

The residue pile in the study dried rapidly during the first month (felling in August, year 1) as the moisture loss was relatively high (about 20%) (dashed line in Figure 1). For the rest of the drying period, moisture content decreased from 23% to 10% (a 13% moisture loss over five months). Figure 1 illustrates the estimated curves for every felling month. Depending on felling time, the drying rate is different. For each drying curve, the moisture reduction increased during warm months with lower rainfall (Ghaffariyan, 2013). It is important to note that significantly more drying trials are required to underpin these models and explore the assumptions used.

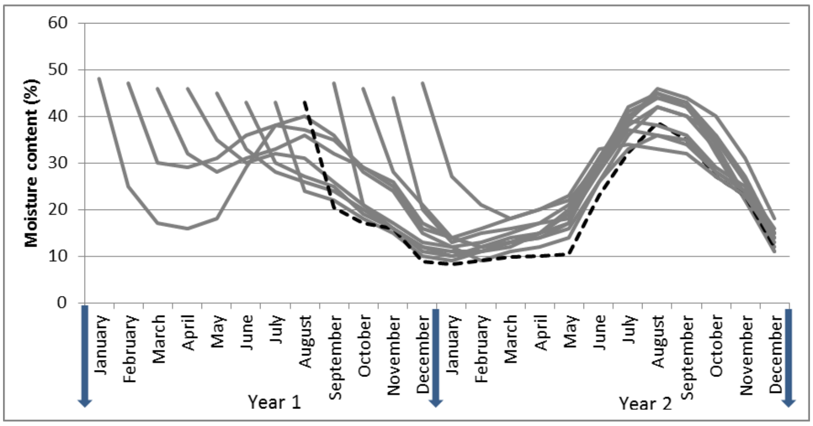

Figure 1. *Natural drying curves for harvesting residues at different felling times*

The drying rates of the harvesting residues are higher compared to European and North American studies. The drying study results were put into the BIOPLAN to optimise the supply chain in the case study area.

Optimised biomass supply chain

For an assumed monthly energy demand of 18 000 GJ, annual interest rate of 10%, round transport distance of 160 km, truck payload of 23 t (semi-trailers) and a moisture content range of 20%-35%, the minimum biomass supply chain cost was about $1 079 515 excluding stumpage value to produce the total energy of 216 000 GJ. Chipping ($17.04/m^3) and transportation ($16.29/m^3) accounted for most of the operating costs (Table 3). The higher chipping cost is due to the small piece size, high machine hourly operating cost and relatively low productivity. The extraction cost is low as it included only forwarding residues and excluded the cost for felling and processing because the residues have been produced as a by-product of the initial pulpwood harvesting operation. The lowest cost occurred for storage expenses, was due to no machines being involved. When using larger truck payload (50 t- road train chip vans) the transportation cost decreased considerably from $16.29/m^3 to $7.64/m^3 (Table 3). From table 3 it should be also noted that chipping and transport are critical factors in determining feasibility of biomass and therefore critical areas of R&D for the industry.

Table 3. *Operating costs for the harvesting residue supply chain*

	Extraction	Storage	Chipping	Transport	Total
$/m^3 harvested (semi-trailer)	6.90	0.68	17.04	16.29	40.91
$/m^3 harvested (road train chip van)	6.90	0.69	17.03	7.64	32.26
$/GJ (semi-trailer)	0.84	0.08	2.08	1.99	4.99
$/GJ (road train chip van)	0.84	0.08	2.08	0.93	3.93

The optimised model yielded a tactical plan with an even harvesting volume of just over 1079 ODt a month or 70 truckloads per month (2.3 semi-trailers per day) to meet the constant demand of 18 000 GJ. In the case of using road train chip vans (payload of 50 t) 33 trucks per month (1.1 trucks per day) are required to meet the same energy demand.

Take-home messages

- Natural drying of harvesting residues is significantly faster in WA than rates reported in Europe & North America which could be an advantage for bioenergy in Australia.
- BIOPLAN can be effective at exploring bioenergy from Australian plantation residues, though better specific knowledge is required on the amount of residue available, natural drying curves and machine performance within the potential supply chain if the model is to be used to support real commercial decisions.
- This study showed that under optimal planning, biomass supply chains in WA have the potential to be cost-effective with a modelled total cost of $40.91/m^3 (for

transportation with semi-trailers) and $32.26/m^3 (for road train chip vans) but there is still room to improve in chipping and transport costs.

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More information

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References

Acuna M, Anttila P, Sikanen L, Prinz R, Asikainen A. 2012. Predicting and controlling moisture content to optimise forest biomass logistics. Croatian Journal of Forest Engineering 33 (2): 225-238.

Ghaffariyan MR. 2013. The natural drying process of logs and harvesting residues - preliminary results. February 2013, Industry Bulletin 2, 3 p.

Ghaffariyan MR, Sessions J. 2012. Comparing the efficiency of four harvesting methods in a blue gum plantation in south-west Western Australia. CRC for Forestry. Bulletin 29. 4 p.

Laitila J. 2006. Cost and sensitive analysis tools for forest energy procurement chains. Forest Studies/ Metsandulikud Uurimused 45: 5-10.