Analysing the effect of five operational factors on the operating costs of a biomass supply chain: A case study in Western Australia

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Introduction

Forest harvesting residues produced by clear felling operations can be a significant source of biomass to produce renewable energy. The key issue is collecting the residues with the optimal harvesting operation plan to minimise the operating costs and environmental impacts. Based on the previous research findings in Europe and North America, the important factors includes moisture content (MC), gross calorific value, ash content, the capability of the plant, efficiency and economy of the combustion. Moisture content is the most important factor which can affect the calorific value, transportation and storage costs of the residues. One of the current methods to diminish the moisture content of the residues is natural drying while storing materials at the road side or in the forest. The study aimed to verify the impact of five parameters (energy demand, interest rate, transport distance, truck payload and moisture content of the residues) upon the costs of a sample forest residue supply chain in Western Australia in Eucalypt plantations.

Study area and research method

An area of 45000 ha of Eucalypt plantations in Western Australia was assumed to supply harvesting residues to a bioenergy plant. The harvesting residues are collected by a forwarder from clear-felled Eucalyptus globulus, harvested with cut-to-length method. About 50% of the scattered slash over the site was assumed to be recovered (Ghaffariyan, 2012). Moisture content values used in the analysis were based on a natural drying study of Eucalyptus globulus residue (Ghaffariyan, 2013). The BIOPLAN software (Acuna et al. 2012, AFORA's collaboration with METLA and University of Eastern Finland) was used to model the supply chain based on the parameters listed in Table 1.

Table 1. Parameters and conversion factors used in the analysis

Parameters/conversion factors	Value
Energy content of E. globulus at 0% MC (MJ/kg)	17.38
Basic density (kg/solid m3)	535
Bulk density (kg/loose m3)	224.7
Solid content (chips from residues)	0.42
Ratio loose-m3 to solid-m3	2.38
Truck payload (tonnes)	40
Truck volume (loose m3)	130
Transport distance (km)	80
Material loss rate (%/month)	2.0

Operational costs (Table 2) included forwarding cost, chipping cost, storage cost and transportation cost.

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

Costs	Value
Forwarding ($/m3)	6.9
Chipping MC<=20% ($/m3) 21%<MC<35% ($/m3) MC>=35% ($/m3)	 20.1 18.3 16.3
Transportation in round trip distance ($/km)	3.2

Impact of operational factors on supply chain cost

Operational factors tested in the analysis were energy demand, interest rate, moisture content, transport distance and truck payload. In each run of BIOPLAN, one parameter at a time was tweaked within its operational limits while holding the other parameters constant (Table 3). Then the costs for different values of each parameter were graphed on a bar chart. The results of the analysis are presented in terms of the total supply costs and the cost for each operational activity (forwarding, storage, chipping and transportation).

Table 3. Constant values and range of the parameters in this study

Parameter	Constant value	Range
Energy demand (GJ/month)	18000	3600-43200
Interest rate per year (%)	7	0-15
Moisture content (%)	20-30	10<MC<20 20<MC<30 30<MC<40 40<MC<50
Transport distance (km)	80	20-120
Payload (t)	40 (B-double)	23 (Semi-trailer) and 50 (Road train chip van)

Results

Effect of energy demand on supply chain costs

By increasing the energy demand from 3600 GJ to 43200 GJ, total cost of the supply chain increased from $179,087 to $2,149,043. Increasing the energy demand increased the total supply chain cost in a linear fashion. This was due to the increased harvesting residue volume in the plantation management area which resulted in a higher total cost ($33.9/m3) of harvesting, chipping, storage and transport. The highest operating cost was related to chipping ($17.0/m3) and transportation ($9.5/m3) while storage allocated lowest costs of $0.5/m3. The harvesting cost included the operating cost for forwarding residues to the road side which was about $6.9/m3 in this analysis.

Effect of interest rate on supply chain costs

The total cost (and cost per cubic meter) of the supply chain was sensitive to the interest rate. Within the range of 0 to 15% for the annual interest rate the total cost increased from $882,432 to $911,423. When the interest rate increased from 0% to 15%, the supply chain cost increased accordingly from $33.39/m3 to $34.49/m3 (Figure 1).

For higher interest rate, the storage cost increased due to increased period of storage and higher opportunity costs. Harvesting (forwarding), chipping and transportation remained the same for different interest rates as they do not impact these elements (Figure 1).

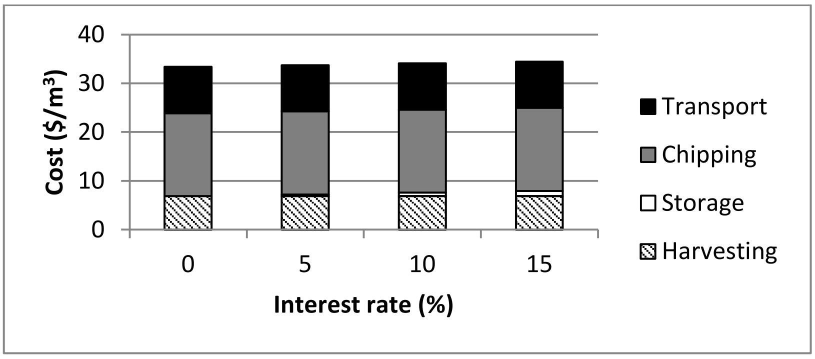

Figure 1. Operating costs for different interest rates

Effect of moisture content on supply chain costs

When the model was run for residues with a moisture content ranging between 10%-20%, the optimisation model was not able to find any feasible solution. The highest operating cost ($33.87/m3) occurred for the moisture content rate of 20%-30% although according to Figure 2 the difference between operating cost for different moisture content was very low. According to the sensitivity analysis, for higher moisture content the chipping cost decreased slightly. Higher moisture content increased the transportation costs slightly due to increasing weight of the load when travelling loaded.

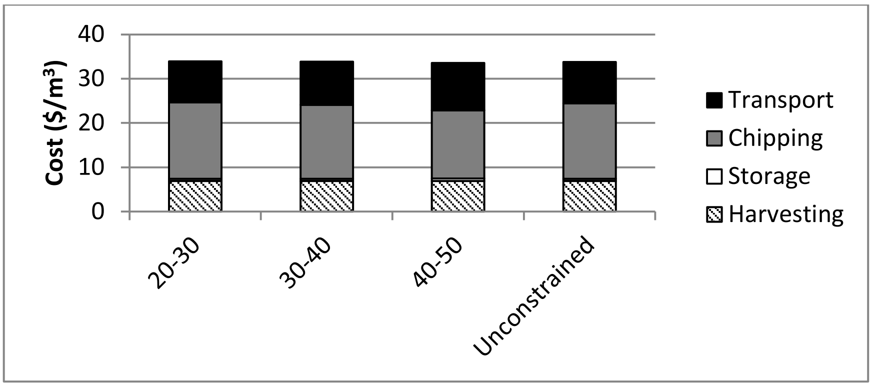

Figure 2. Impact moisture content on total cost of biomass supply chain

Effect of transport distance on the supply chain costs

Increasing transport distance resulted in higher supply chain cost in this study (Figures 3). This is due to increased transportation cost for longer distances. In this case study, the transport cost increased 2.36 $/m3 for increasing 20 km in transport distances (0.12 $/m3/km). The trucks will spend longer time for travelling loaded and unloaded when transport distance increases.

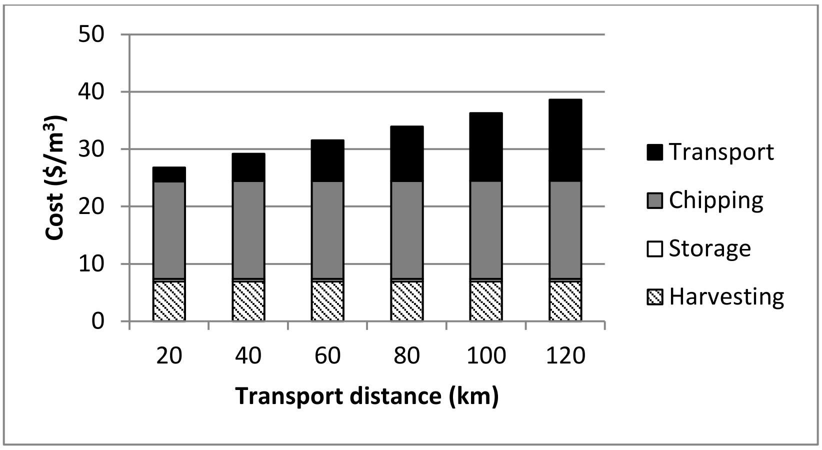

Figure 3. Operating costs for different transport distances

Effect of truck payload on the supply chain costs

Three truck payloads were studied including 23 GMt (semi-trailer), 40 GMt (B-double) and 50 GMt (road train chip van) while the other parameters were held constant. As expected, the total cost dropped for larger payloads (Figure 4) as they result in lower transportation cost due to increased transport efficiency. In this case study, by increasing truck payload from 23 GMt to 50 GMt, total operating cost decreased from $41.52/m3 to $32.07/m3.

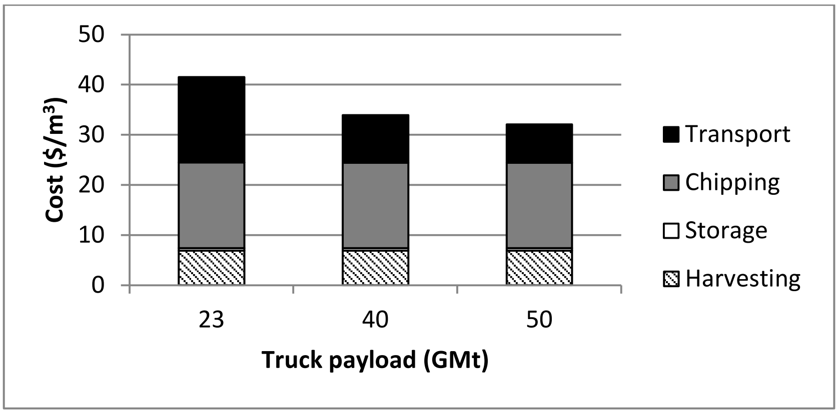

Figure 4. Operating costs for different truck payload

Take home messages

- Increasing energy demand increased the supply chain costs considering maximum slash recovery of 50% of total available harvesting residues.
- Higher interest rates increased operating costs due to its impact on storage cost.
- Moisture content ranging from 20% to 30% caused highest operating cost of the supply chain. Moisture content may impact the volume of harvested and stored materials which can be studied in future.
- The relationship between transport distance and supply chain cost can be used for optimal location of the plantation establishment and energy plant for minimising the supply chain costs.

More information

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