EFFICIENCY OF BIOMASS HARVESTING IN POOR QUALITY STANDS OF EUCALYPTUS IN WESTERN AUSTRALIA

Mohammad Reza Ghaffariyan[a], Mark Brown[b] and John Wiedemann[c]

[a] Corresponding author, Research fellow, CRC Forestry, University of Tasmania, Australia
Email: ghafari901@yahoo.com)

[b] Harvesting and Operations Program Leader & Manager Industry Engagement, CRC Forestry, University of Melbourne, Australia
Email: mwbrown@unimelb.edu.au)

[c] Forestry technician, CRC Forestry, WAPRES, Manjimup, Australia
Email: john.wiedemann@wapres.com.au)

ABSTRACT

Using forest biomass to generate energy has been started in recent years in Australia. There is a pelletizing plant in Western Australia which utilizes some of the forest biomass as source of energy. In this project, a poor quality stand of Eucalyptus with small tree size was harvested with a tracked Tigercat feller buncher. Then the whole trees where extracted by grapple skidder. A chipper was used to chip whole trees into containers of the trucks. Time study method was applied to collect the data to evaluate the production rates for the machines of biomass system. Working delays were recorded in three categories; personal, mechanical and operational delays. Using the multiple regression approach a productivity predicting model was developed. Skidding distance and load weight were significant parameters affecting the productivity of grapple skidder. The results of analysing productive and non-productive time of the equipments indicated that the percentage of the working delays are relatively high which requires more appropriate logistic management. Finally the biomass yield per area and per ha was evaluated which can be used for biomass supply chain management.

Keywords: Biomass, productivity, feller-buncher, skidder, chipper

INTRODUCTION

In conventional logging, the stem of trees is usually utilized, and may only contain about two-thirds of the tree volume with the remaining one-third left in the field or at roadside. Thus the residues from conventional logging can be used in biomass harvesting (Karjalainen et al. 2004). Dedicated energy crops are another source of woody biomass for energy. Short-rotation (3-15 years) techniques from growing poplar (Populus), willows (Salix) and Eucalyptus or even non-woody perennial grasses have been developed over the past 2-3 decades. Harvesting usually occurs in the winter and the harvested stems are often converted to chips on the site and then transported to the conversion plant (IEA Bioenergy, 2002).

Studies in many countries show that crown mass removal may endanger the sustainability of production capacity, depending on the site characteristics and amount and composition of removed biomass. However, field experiments usually incorporate uniform distribution of material after logging in control plots and complete removal of crown components from whole-tree logging plots (Kuiper, 2006).

Negative ecological impacts can be reduced by appropriate timing of operations, minimizing the nutrient removals from the forest sites and recycling of ash from the combustion installation. These methods will not completely compensate the nutrient loss, but will certainly reduce it. The removal of forest residues from poor sites should be avoided in all cases, because this would further reduce the nutrients availability in these already nutrient poor sites (Burgers, 2002; Hakkila, 2002).

In Scandinavian countries a significant proportion of their harvest is from ground-based systems, which are highly mechanized. These have in many areas had their work methods adjusted to leave the logging residue in piles (as opposed to spread out) to enhance the efficiency of the residue harvesting operation. Chipping can be operated in following places; at mills, at storage yards, at forest roadside or in the stand (Kuehmaier et al. 2007). In Denmark in stand chipping is often used in thinning and small tree diameter harvests (Talbot and Suadicani, 2005). The felling and bunching of trees is carried out by a feller-buncher in the extraction corridors. After being dried for about 20 weeks, the material is chipped in the stand and transported to the road side with an integrated container, or with machines carrying separate containers. Then the materials are transported to the plant with truck containers. Silversides and Sundberg (1989) suggested that the greatest advantage may be realized in chipping of multiple stems simultaneously. In this case the chipper is less susceptible to the negative cost-effects of the »piece-volume-law« (which states that increasing piece size typically results in increased production).The most common option in the production of woody biomass is chipping at the forest roadside and transportation of chips. About 70% of the annual woody biomass production in Finland is produced in this way (Ranta and Rinne, 2006; Junginger et al. 2005).

Using forest biomass to produce energy is just starting to be explored in Australia. There are some woody biomass utilization programs including power stations that co-fire wood waste with coal, at Delta Electricity in Wallerawang, Vales Point and Mount Piper (NSW), Macquarie Generation at Liddell and Bayswater (NSW), Envirostar's Stapylton (QLD) and Western Power's Muja power stations (MBAC, 2003). Plantation energy pelletizing plant in Albany, Western Australia is being commisioned to use forest biomass.

With emerging opportunities in Australia to use forest fibre in energy uses like wood pellets and heat to energy plants, some land owners are considering this market option for plantations with limited returns from current pulp chip markets. Part of this decision is driven by an expected savings in the harvest cost for the lower quality chip product, this study evaluates harvest productivity and costs in a very low productivity mixed hardwood plantation to be used as biomass in a pelletizing plant.

STUDY AREA AND HARVEST SYSTEM

The study area was a low productivity mixed Eucalypts mainly *E. GXC hybrid* located at Quindinup WA (table 1). The stand was not economically viable to harvest for export pulp chip so was harvested with full-tree chipping as a supply to a pellet plant.

The harvesting system (Figure 1) included a tracked feller-buncher (Tigercat 845C), grapple skidder (Tigercat 730C) and mobile chipper without delimber/debarker (Husky Precision 2366) to maximise biomass production.

Table 1: Study area description

Area (ha)	5.2
Stand density (n/ha)	637
Average DBH (cm)	14
Average tree size (tn)	0.100
Terrain	Flat

Stand	**Skid trails**	**Landing/forest road**
		
Tigercat 845C feller-buncher	***Tigercat 730C skidder***	***Husky Precision 2366 chipper***

Figure 1: Biomass harvesting system

STUDY METHOD

Standard CRC Forestry time and motion study methods were used and total production was measured through truck weights of the total biomass delivered to the client. Productivity is calculated on an as-received tonne both on PMH_0 (excluding all delays) and PMH_{15} (including delays up to 15 minutes). Work delays were classified into three categories; personal, mechanical and operational delays. The reason for any down time was noted during time study. Working cycle for skidder contained of travel empty, loading, moving during loading, travel loaded, unloading and clearing debris.

RESULTS

Table 2 shows a low productivity for feller-buncher and chipper, which is a result of the small tree size in the study area.

Table 2: Summary of production rates of biomass operation

Machine	Production (tn/PMH_0)	Production (tn/PMH_{15})
Feller-buncher	50.1	47.9
Skidder	44.6	37.1
Chipper	50.8	44.8

The productivity models for the skidding (Figure 2 and 3) show, as expected, decreasing productivity as the snig distance increases and increasing productivity with increasing payload.

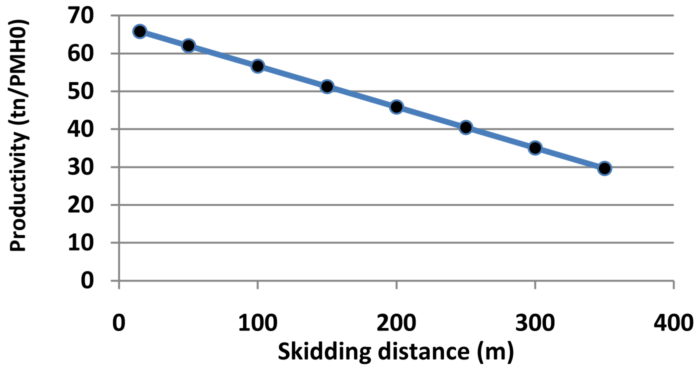

Figure 2: Skidding productivity vs Skidding distance (for average load of 3.02 tn)

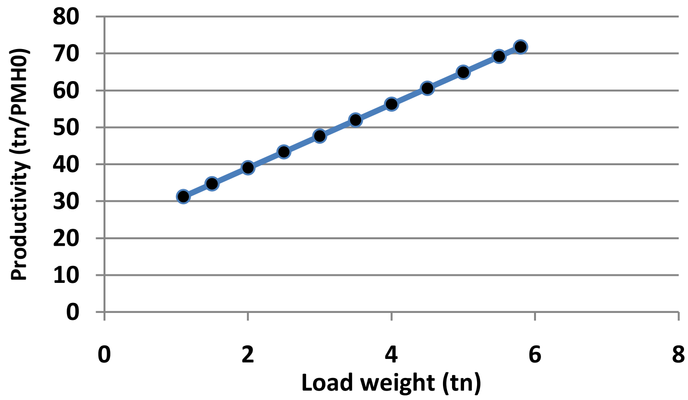

Figure 3: Skidding productivity vs Load weight (for average distance of 182 m)

The harvest delivered 63.9 tonnes per hectare based on the recorded load weight of 7.5 trucks (Table 3). It must be noted that the biomass weight was recorded between 7 & 8 days after harvesting.

Table 3: Biomass production summary from study area

Total harvested biomass (tn)	332.13
Area (ha)	5.2
Biomass yield (tn/ha)	63.9

Figure 4 and 5 shows the feller-buncher was productive 79% of the total harvester time. Of the 18% lost to long delays (>15 min.), service time comprised (19%), supervisory meeting (17%) and 64% for meal break. Short delays (<15 min.) included idling time, task planning and taking breathers.

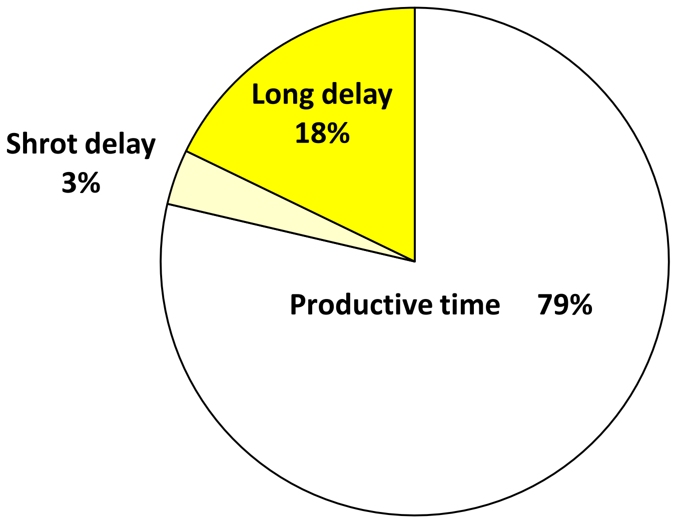

Figure 4: Working times for feller-buncher

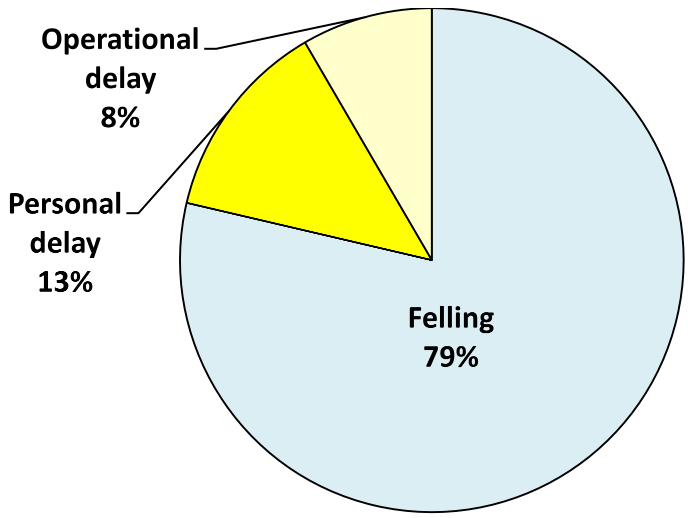

Figure 5: Percentage of work time elements and delays for feller-buncher

Figure 5 shows skidder was working productively 59% of the study time (6% of time was debris cleaning). Figure 6 provides the proportion of time spent in each work element too.

Almost all of the short delays involved waiting for the chipper. Had the skidder staged these loads and left to extract another load, chipper productivity may well have dropped through increased time waiting for wood.

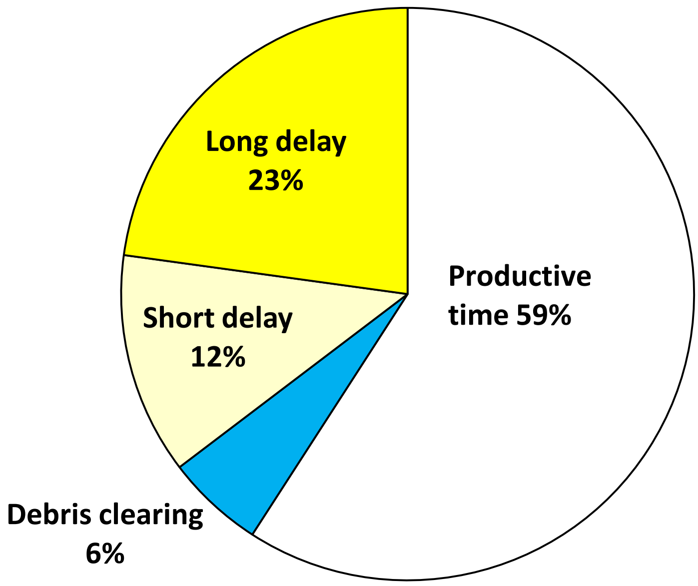

Figure 6: Working times for skidder

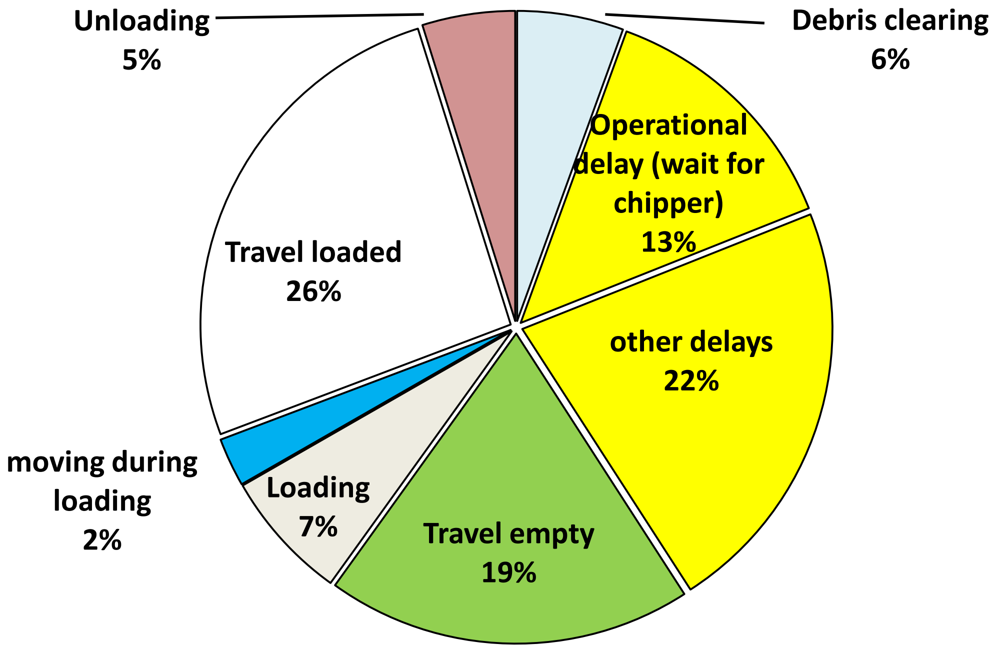

Figure 7: Percentage of work elements and delays for grapple skidder

Productive chipping time, Figures 6 and 7, included only 55% of total study time for the chipper with the other half of its time split between, relocating chipper (10%), waiting for trucks (10%) & wood (4%), knife changes (11%), mechanical (1%) and personal delays (9%).

Table 4 summarizes the delays of the biomass harvesting operations in the study, which shows there is room for productivity gains by focussing on minimizing these significant delays in all phases of the operation.

Table 4: Delays of biomass operation

Machine	Delay (% of worksite time)
Feller-buncher	21
Skidder	25
Chipper	35
Average	27

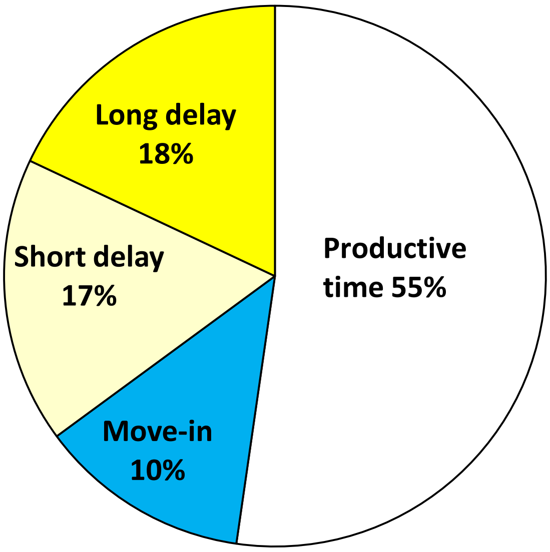

Figure 6: Working time for chipper

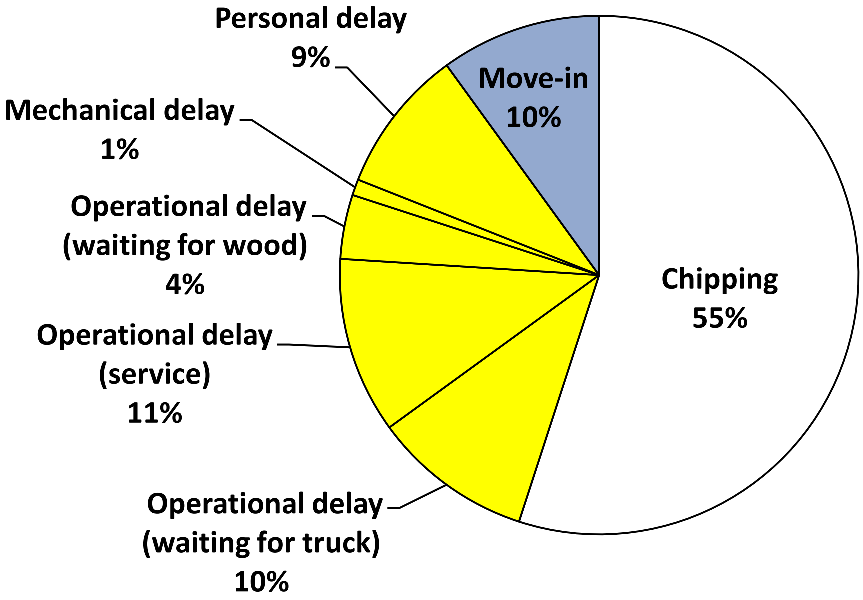

Figure 7: Percentage of work elements and delays for chipper

CONCLUSIONS

Reasonable productions rates can be achieved in very low productive stands when producing energy wood quality chips. Short delays within production time account for around 10% of the study times for each machine studied. Worksite time categorized as long delays for this operation averages over 20%. This significantly affects the utilization rate of the equipment. In-field chipping operations are particularly sensitive to logistics schedules with 10% of the chipper time lost to waiting for trucks.

LITERATURE CITED

Burgers, J.A., 2002. Soil and long-term site productivity values. In: Richardson, J., R. Björheden, P. Hakkila, A.T. Lowe, C.T. Smith, 2002 Bioenergy from Sustainable Forestry – Guiding Principles and Practice. Kluwer, The Netherlands.

Hakkila, P., 2002. Operations with reduced environmental impact. In: Richardson, J., R. Björheden, P.Hakkila, A.T. Lowe, C.T. Smith, 2002 Bioenergy from Sustainable Forestry – Guiding Principles and Practice. Kluwer, The Netherlands

IEA Bioenergy. 2002. Sustainable production of woody biomass for energy. A position paper. 12 p.

Junginger, M., Faaij, A., Bjorheden, R. and W.C. Turkenburg. 2005. Technological learning and cost reductions in wood fuel supply chains in Sweden. Biomass-and-Bioenergy 29(6): 399–418.

Karjalainen, T., Asikainen, A., Ilasky, J., Zamboni, R., Hotari, K-E. and D. Roeser. 2004. Estimation of energy wood potential in Europe. Working papers of Finnish Forest Research Institute 6/2004.

Kühmaier, M., Kanzian, C., Holzleitner, F. and K. Stampfer. 2007. Wertschöpfungskette Waldhackgut. Optimierung von Ernte, Transport und Logistik**.** Instituts für Forsttechnik, Department für Wald- und Bodenwissenschaften an der Universität für Bodenkultur Wien. 283 p.

Kuiper, L. 2006. The harvest of forest residues in Europe. Biomassa-upstream Stuurgreop. 7 p.

MBAC Consulting Group. 2003. Web site, at http://www.mbac.com.au

Ranta, T. and S. Rinne. 2006. The profitability of transporting uncomminuted raw materials in Finland. Biomass and Bioenergy 30(3): 231–237.

Silversides, C. R. and U. Sundberg.1989.Operational efficiency in forestry practice. Vol. 2: 1–169.

Talbot, B. and K. Suadicani.2005. Analysis of two simulated in-field chipping and extraction systems in spruce thinnings. Biosystems Engineering 91(3): 283–292.