SHORT REVIEW ON OVERVIEW OF FOREST BIOMASS HARVESTING CASE STUDIES IN AUSTRALIA

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Abstract

The article presents a summary of five research projects on different biomass harvesting systems in Australian plantations. The first trial assessed the productivity and cost of slash-bundling the harvesting residues in clear felled area using Pinox slash-bundler in Eucalypt plantation in Tasmania. Second project investigated the efficiency of a European mobile chipper to collect pine harvesting residues Green Triangle (Victoria) while in the third project a conventional forwarder was studied to recover pine residues logs (called Fibre plus material) as an integrated biomass operation in Western Australia. The product quality and fuel consumption of the biomass harvesting systems were also assessed within the trials. Whole tree biomass harvesting (including feller-buncher, grapple skidder and chipper) was another trial carried out in low-productivity Eucalypt stands in Western Australia to produce biomass chips for bioenergy purposes. Where bioenergy markets are strong, thinning materials (e.g. large branches) may also be utilised as a source for bioenergy. The operating costs and environmental impacts (including remaining residues assessment to sustain soil quality in biomass recovery operations) of different technologies were compared/discussed in this article.

Key words: Harvesting, Productivity, Cost, Slash-bundling, Mobile chipper, Integrated biomass recovery

INTRODUCTION

The generation of energy from biomass has a key role in current international strategies to mitigate climate change and enhance energy security. The target of European Union (EU) was to produce 20% of their energy from renewable sources, including bioenergy, by 2020 (Routa et al., 2013). Australia’s target for 2030 is 20% while USA has recently announced same target for 2030. EU-28’s target for 2030 is 27%. One of the main sources is using forest biomass to help the countries meeting their long term renewable energy targets. Biomass can contribute in stabilizing carbon dioxide concentrations in the atmosphere in two ways, through: (1) biomass production for fossil fuel substitution and (2) carbon dioxide storage in vegetation and soil (Ericson, Nilsson, 2006). According to the IEA’s definition forest biomass supply can be defined as 1) the current production of roundwood for conventional wood products (e.g. sawlog, pulp and paper, panel), 2) the potential stem wood that could be additionally harvested within the sustainable harvest limit, 3) primary forestry residues, e.g., logging residues, early thinnings and 4) secondary forestry residues, residues from the industrial processing
of wood (IEA Bioenergy, 2015). Forest biomass is primarily consumed locally due to its low energy density and high transportation costs.

Australia is at an early stage of exploring the use of forest biomass to produce energy. Woody biomass utilisation programs include power stations that co-fire wood waste with coal in New South Wales. An energy-pelletising plant in Albany (Western Australia) was commissioned to use forest biomass (Ghaffariyan et al., 2011a). There are three main sources for woody biomass in Australia including harvesting residues, dedicated plantations and mill residues. The estimated forest harvesting residues based on the Australian Biomass for Bioenergy Assessment (ABBA) project outcomes (uploaded into AREMI, 2016) is about 2.1 million dry tonnes per year (Norman, pers. comm., 2017).

FOREST BIOMASS HARVESTING CASE STUDIES IN AUSTRALIA

HARVESTING RESIDUES COLLECTION

Harvesting technology and working method can significantly impact the level of recovered and retained biomass (Ghaffariyan, 2013). One of the technologies tested to recover harvesting residue from Eucalypt clear cuts was Pinox slash bundler (Fig. 1, 2). This slash bundler recovered 65% of the harvesting residues. It was applied under two treatments. Firstly, it collected residues from cut over area (average productivity of 4.9 green metric tonnes per productive machine hours (GMt/PMH0)) which costed 45.5-49 $/GMt to deliver the bundles at road side. Secondly the residues were raked by an excavator then collected by slash-bundler which resulted in higher bundling productivity (10.5 GMt/PMH0) of 24.5-28 $/GMt at road side (Ghaffariyan at al., 2011 (b)). The chipping cost needs to be added to the bundling and forwarding costs which will increase the total cost. Given the price of delivered biomass chips at the mill gate around 21-28 $/GMt in Australia the slash-bundling system does not seems to be economically viable option. The other issue is when applying an excavator to rake the residues for the slash-bundler considerable contaminants can be introduced into the bundles which reduce the moisture content and might cause damages to the residue processing equipment.

Another technology for harvesting residue collection is Bruks chipper mounted on a forwarder (Fig. 3, 4) which was tested in Victoria to recover harvesting residues from a pine clear felled plantation (Ghaffariyan et al., 2012). The study was carried out within five study treatments. The treatments were: (a) collecting stem wood with minimum branches distributed over the site; (b) collecting only stem wood distributed over the site; (c) stem wood concentrated by excavator; (d) collection of all residues distributed over the site and (e) chipping residue logs at road side. The productivity-cost of operation, biomass yield, slash remaining after biomass recovery, and fuel consumption for each treatment were documented. In cut-over area, the higher productivity rate occurred for collecting stem woods concentrated by an excavator. Collecting all residues resulted in highest yield and largest biomass recovery. The largest quantity of remaining slash occurred with the stem wood with minimum branches treatment. Bruks mobile chipper in this study was more productive to chip residue log piles (stacked at road side) into
trucks (Table 1) rather than collecting residues scattered in cut over area when operating as terrain chipper (Ghaffariyan et al., 2012). The biomass recovery rate ranged from 15% to 50% in different study treatments.

Integrated biomass harvesting was found as an efficient way to harvest residue logs during the sawlog and pulpwood recovery by conventional forwarders in pine plantations (Ghaffariyan et al., 2015). Residue logs (called Fibre plus) that did not meet the minimum length and diameter of a sawlog or pulpwood could be collected and extracted by forwarders during the operations with reasonable operating cost (Fig. 5, 6). The work efficiency of the integrated energy wood harvesting system was evaluated and compared with conventional log harvesting in a 32-year-old *Pinus radiata* plantation located in south-west Western Australia. The harvesting system consisted of a harvester and a forwarder. The study included two treatments: a conventional log-harvesting operation where merchantable sawlogs and pulp logs were produced at the stump by the harvester and extracted by the forwarder; and an integrated energy wood operation where the harvester produced sawlogs, pulp logs and energy wood at the stump that were extracted by the forwarder. In the integrated energy wood harvesting plot, 37 GMt/
ha\(^{-1}\) of energy wood was extracted in addition to the sawlog and pulp log volumes. Extracting the additional energy wood reduced the productivity of the forwarder and increased the cost of extraction compared with the control plot. Harvesting system cost was not significantly impacted. Diameter at breast height (DBH) was a significant factor influencing the working time of the harvester, whereas load volume, extraction distance and extraction type (sawlog, pulp logs, and pulp log/energy wood) significantly impacted forwarding time. Increasing DBH resulted in longer working cycles for the harvester. Heavier loads and longer forwarding distances increased forwarding cycle time, while extracting sawlogs was least expensive and energy wood extraction was the most expensive. The marginal cost of the integrated biomass system was slightly higher conventional operations. Additional material recovered in the integrated energy wood plot resulted in less remaining residues on the plot (103.2 GMt/ha\(^{-1}\)) than the control plot (144.2 GMt/ha\(^{-1}\)) (Ghaffariyan et al., 2015). A previous trial on integrated biomass recovery in Pine plantations in New South Wales (NSW) yielded 23 GMt/ha (5% of the total yield) of woody biomass (fibreplus) (Walsh, Strandgard, 2014). The recovery rate of integrated biomass operation is about 20% to 25%. Recently Strandgard, Mitchell (2019) studied a fuel adapted harvesting technique in pine plantations in Western Australia (WA) where harvester-processor felled the trees and piled logs and residues separately. Residues are left in piles during fuel-adapted harvesting rather than being scattered as in conventional harvesting. This technique slightly increased biomass yield per ha.

**WHOLE TREE OPERATIONS**

Whole tree chipping has been applied to harvest a low quality and failed Eucalypt plantations in Western Australia (Fig. 7, 8). The trees were cut by a tracked feller-buncher, then extracted by a grapple skidder to road side.

A Husky Precision chipper was applied to chip whole tree into truck at road side and the wood chips were transported to Albany pelletizing plant. The biomass recovery was very high (90%-95%) due to whole tree extraction which may result in high nutrient
removal. Biomass yield was 63.9 GMt/ha based on the recorded load weight of eight trucks. Harvesting costs in this case study were high because of the low productivity of the machines caused by small tree size and low yield per hectare in the study area. Options to minimise total delivered cost of biomass (transport and harvesting) include: a) targeting plantations closer to the energy plant to reduce transport costs reducing work delays in the harvesting system and b) using harvesting systems that might be more efficient with smaller tree sizes (i.e. a harvester-chipper combined with an agricultural tractor for chip extraction).

**THINNING OPERATIONS**

Thinning within forest management is generally carried out for one of three purposes: improved future stand growth and quality to produce higher value products for later final harvest, remove fuels to reduce fire risk and to meet ecological goals such as increasing biodiversity. Thinning materials are usually small size woods such as pulp logs, large branches and tops with limited industry uses. Pulp logs are used for pulp and paper making purposes or, where bioenergy markets are strong, they can be used for bioenergy. Large branches and tops generally do not meet industrial wood standards thus are only recovered for bioenergy applications. Thinning operations in Australian pine and Eucalypt plantations which are almost exclusively conducted by harvester-processors and forwarders. Harvester-processors fell the trees, processes them into logs and sort the logs in small piles (Fig. 9). After tree felling and processing, forwarders are used to collect/load logs into bins and extract them to road side. At roadside logs are stacked into piles (Fig. 10). A research project was conducted in 2018 to develop productivity and cost predicating models for thinning operations (Ghaffariyan et al., 2018) which indicated that harvester machine productivity was primarily a function of tree volume. Forwarder productivity depended on the extraction distance. Slope of the skid trails could also impact the forwarder productivity. An average productivity and cost and of both machines are presented in Table 1 where a summary of productivity and cost of most efficient biomass harvesting systems tested in Australia are also presented.
**CONCLUSIONS**

Main source of forest biomass in Australia is harvesting residues scattered in the cut-over areas (from cut-to-length operations) or concentrated in landing (yield from whole tree processing at road side). Low price of biomass has led to application of integrated biomass and conventional wood recovery to reduce the cost (Ghaffariyan et al., 2017, Ghaffariyan et al., 2015, Spinelli, Magagnotti, 2011) while in European

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**Table 1. Summary of most efficient biomass harvesting technologies in Australia**

<table>
<thead>
<tr>
<th>Harvesting system</th>
<th>Machine</th>
<th>Model</th>
<th>Productivity (GMt/PMH₀)</th>
<th>Cost ($/GMt)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Harvesting residues from clear cut</td>
<td>Forwarder</td>
<td>Ecolog 594C forwarder</td>
<td>30-45</td>
<td>8.0</td>
</tr>
<tr>
<td>(log size= 0.2 m³ and forwarding distance= 196 m)</td>
<td>Mobile chipper</td>
<td>Bruks 805.2 STC mounted on an</td>
<td>43.8</td>
<td>6.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Integrated biomass operations</td>
<td>Harvester</td>
<td>Cat 541 with a Rosin</td>
<td>88.3</td>
<td>3.2</td>
</tr>
<tr>
<td>(tree size= 1.5 m³ and skidding distance= 107 m)</td>
<td>Forwarder</td>
<td>RD977 processing head</td>
<td>71.2</td>
<td>2.7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Valmet 890.3</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Total: 14.5</td>
<td></td>
</tr>
<tr>
<td>Whole tree biomass</td>
<td>Feller-buncher</td>
<td>Tigercat 845C</td>
<td>50.1</td>
<td>3.0</td>
</tr>
<tr>
<td>(tree size= 0.1 m³ and skidding distance= 182 m)</td>
<td>Grapple skidder</td>
<td>Tigercat 730C</td>
<td>44.6</td>
<td>2.7</td>
</tr>
<tr>
<td></td>
<td>Chipper</td>
<td>Husky Precision 2366</td>
<td>50.7</td>
<td>7.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Total: 13.3</td>
<td></td>
</tr>
<tr>
<td>Cut-to-length operations (thinning)</td>
<td>Harvester</td>
<td>Timbco 475</td>
<td>32.1</td>
<td>7.4</td>
</tr>
<tr>
<td>(tree size= 0.5 m³ and forwarding distance= 400 m)</td>
<td>Forwarder</td>
<td>Timbco TF840-B</td>
<td>41.4</td>
<td>6.7</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Total: 14.1</td>
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</tbody>
</table>

**Note:** GMt/PMH₀ is green metric tonnes per productive machine hours.
countries separate biomass recovery (e.g. application of mobile chippers) still sounds as an economically viable option. Although the mobile chippers have been designed to collect the scattered residues on cut over area however to gain higher efficiency of the chipper the best practice is to apply them for chipping at road side. Based on study results, using slash-bundlers to collect harvesting residues is one of the most expensive options that may increase operating costs. This is mainly due to high hourly machine cost and relatively low productivity. Transporting bundles (and consecutive chipping at the mill) is relatively expensive, in comparison with chipping whole trees or logs in the forest or at the intermediate chipping terminals. Thinning materials can be an alternative source for bioenergy depending on the market conditions.

Cost-productivity is very important factor in biomass supply chain management which gives key information to the industry users. However future research will be required to include environmental and social impacts of the biomass harvesting systems.

REFERENCES


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