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Productivity and cost of harvesting a stemwood biomass product from integrated cut-to-length harvest operations in Australian *Pinus radiata* plantations

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ABSTRACT

Significant quantities of woody biomass from the tops of trees and larger woody 'waste' pieces that fall outside existing sawlog and pulpwood specifications are left on site post final harvest in Australian radiata *Pinus radiata* (D. Don) (radiata pine) plantations. Woody biomass is a potential product for pulp making or energy generation. Commercial use of woody biomass from radiata pine plantations would add extra value to the Australian plantation estate through improved resource utilisation, and potentially reduced post-harvesting silvicultural costs. This study investigated the productivity and cost impact of the harvest and extraction to roadside of woody biomass in an integrated harvest operation in a typical Australian two machine (harvester/processor and forwarder), cut-to-length, clearfall operation in a mature, thinned radiata pine plantation.

The harvest operation yielded 23 GMt/ha (5% of the total yield) of woody biomass (known as 'fibreplus'), 443 GMt/ha of sawlogs and 28 GMt/ha of pulpwood. The mean quantity of biomass left on site was 128 GMt/ha, mainly consisting of branches and needles, sufficient to minimise nutrient loss and protect the soil from erosion. Woodchips derived from the fibreplus product were suitable for kraft pulp making, (when blended in small amounts with clean de-barked roundwood woodchips), and for energy generation.

The method trialed with the fibreplus product being produced did not impact harvesting and processing productivity and costs, but extraction was 14% less productive. Through analysis of the productivities of each phase and development of a cost model the harvest and extraction of the fibreplus product was estimated to increase total unit costs by ∼4.9%.

1. Introduction

Woody biomass is a potential product for the Australian wood products market for pulp making or energy generation. Wynsma et al. [1] define woody biomass as 'the by-product of management, restoration, and hazardous fuel reduction treatments, including trees and woody plants (i.e. branches, tops, needles, leaves and other woody parts, grown in a forest, woodland or rangeland environment)'. This definition

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includes the aboveground biomass (AGB) of the tree not utilised in commercial harvesting operations. Two Australian studies in *Pinus radiata* (D. Don.) (radiata pine) plantations in New South Wales (NSW) estimated that approximately 20.5% [2] and 16.8% [3] of total AGB by weight was potentially available woody biomass that was not extracted as commercial sawlog or pulpwood, nor was part of the stump. Turner [4] estimated that the woody biomass component of the AGB of the trees was up to 9% of the total recoverable volume from radiata pine plantations in Victoria. Commercial use of at least a proportion of this woody biomass would add extra value to the plantation estate through improved utilisation of the resource, and potentially reducing post-harvesting silvicultural management costs. However, development of a new woody biomass market adds another log product grade and assortment to harvest operations. This will impact on the productivity and cost of harvesting and, more particularly, of extraction [5–7] and needs to be evaluated in the context of the overall management and planning of the log supply chain.

There are four methods used for the harvesting of woody biomass:

- the use of specialised machines;
- post-harvest operations following conventional harvesting;
- pre-harvest operations prior to conventional harvesting, and;
- integrated one-pass conventional operations harvesting roundwood and biomass products simultaneously [8,9].

A number of studies have shown that the last method was most economical when woody biomass was produced simultaneously with other higher value forest products in integrated, one-pass harvest systems, particularly when considering the post-harvest silvicultural management costs incurred from leaving the biomass behind and other forest management benefits that could accrue from their utilisation [10–13]. However, the research also indicated costs were highly variable depending on the harvesting system used, site conditions, the amount of woody biomass produced, the type and value of higher value products produced, primary extraction distance, transport distance and storage [12,14–17].

Recent research in the production of woody biomass has focused on assessing the economic feasibility of harvesting in a range of stand conditions, using a variety of machines and/or machine combinations, to achieve various silvicultural objectives including, removal and/or thinning of small-diameter trees to restore a forest's natural 'balanced' state and reduce fire hazard [18,19]; to improve and protect forest health [20]; to utilise otherwise non-commercial stands with poor growth and form [21]; or to add value through greater utilisation of the resource [22–24]. These studies were not all integrated commercial harvesting operations. Those that were have generally focused on small tree harvesting and woody biomass utilisation using traditional harvesting equipment [8,13,18,19,25,26] and/or purpose built equipment [27–31].

The advent of potential new markets for woody biomass has highlighted a lack of detail on the methods, potential productivity and cost impacts of harvest systems designed to remove woody biomass [25,32], particularly in an Australian context. Work has been done in New Zealand radiata pine plantations similar to those in Australia to investigate and identify the most cost-effective collection and delivery systems for woody biomass for energy generation [22–24,33–36]. However, in contrast to typical Australian CTL harvesting operations, woody residues in New Zealand are concentrated around roadside landings or central processing yards following whole-tree ground-based or skyline/cable extraction, rather than spread out over the harvest site. In addition, where it occurs, woody biomass is generally collected as part of a separate operation and not as part of an integrated CTL harvest operation.

Australian plantation managers have expressed interest in the potential for harvesting stemwood biomass in radiata pine plantations using existing conventional harvest machines as part of an integrated harvest operation. This stemwood biomass would be roughly delimbed by the harvester during processing and extracted to roadside by a conventional forwarder, along with other log products, for later comminution to woodchips for pulp making or for energy generation. Similar production methods for harvesting woody biomass are the most common options used elsewhere in the world [17] and have been proven to be effective. For example, the predominant method used in Finland and Sweden has been to forward residues to roadside from final fellings for comminution [14,37,38].

The economics as well as the integrated management of the logistics activities to deliver the right quantity of in-specification materials in a timely manner, without detrimental environmental impacts, will be vital to the success of the new woody biomass product [39,40]. To this end this study sought to investigate the:

- Productivity and cost impact of harvesting and extracting to roadside an additional stemwood biomass product integrated within an existing harvest operation producing sawlogs and pulpwood.
- Quantity and quality of stemwood biomass removed.
- Quantity of retained biomass on site following stemwood biomass removal.

2. Methods

2.1. Study design

The site was located in a Forestry Corporation of New South Wales (FCNSW) *Pinus radiata* plantation approximately 50 km north-east of Tumut, New South Wales (NSW), Australia. The site was in a homogenous stand with the same silvicultural treatment history and site conditions – trees of good form and quality, and flat terrain with no obstacles or rock present. The stand was twice thinned and 34 years old at the time of clearfall.

The study area consisted of two 2 ha sites (the 'Control Site' and the 'Fibreplus Site') and two 100 tree plots (~0.5 ha) (the 'Control Plot' and the 'Fibreplus Plot'). The 2 ha sites and the 100 tree plots were harvested to existing sawlog and pulpwood

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