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Proportion of above-ground biomass in commercial logs and residues following the harvest of five commercial forest species in Australia

Fabiano A. Ximenes [a,*], W. David Gardner [a], Amrit Kathuria [b]

[a] Forest Resources Research, NSW Department of Primary Industries, Cooperative Research Centre for Greenhouse Accounting, PO BOX 100, Beecroft, NSW 2119, Australia
[b] Forest Resources Research, NSW Department of Primary Industries, PO BOX 100, Beecroft, NSW 2119, Australia

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ABSTRACT

A significant factor influencing the contribution of wood products to carbon (C) storage is the proportion of above-ground tree biomass (AGB) recovered in commercial logs at harvest. This study examined the proportion of AGB in logs and residues at the harvest of radiata pine, cypress pine, blackbutt, spotted gum and messmate. Messmate and spotted gum had the highest variation in stem diameter and height. The average AGB ranged from 2000 to 3000 kg for the hardwoods and 220–1000 kg for the softwoods. Blackbutt had the overall lowest proportion of AGB recovered in commercial logs (45.5%) and radiata pine the highest (65%). The proportion of AGB in the bark of the hardwoods was significantly lower than in the softwoods. The proportion of the AGB in forest residues following harvest ranged from 30 to 55% depending on the species.

The proportion of AGB recovered in high quality commercial logs ranged from 15% for spotted gum to 63% for radiata pine. The differences were due to the natural characteristics of the selected species and variations in regional market availability. The highest retention rates of AGB in high quality hardwood commercial logs were obtained for trees with DBH between 500 and 600 mm (messmate and blackbutt) and greater than 600 mm for spotted gum.

The mean moisture content of the wood of the different species ranged from 35 to 50%. Messmate and radiata pine logs had the highest moisture content (48 and 50%, respectively).

The C concentration of blackbutt, radiata pine and cypress pine was slightly higher than 50%. The softwoods had significantly higher C concentration than the hardwoods. The C concentration between positions (cross-section, sapwood and heartwood) also varied for the different species.

The highest proportion of the above-ground C was in the debarked log for all species with the exception of blackbutt.

The cellulose concentration of the wood ranged from 56 to 64% for hardwoods and 40–52% for the two softwoods. The lignin concentration of the wood ranged from 16 to 19% for the hardwoods and 25–35% for the two softwoods. The hardwood species could not be distinguished from one another based on the cellulose, hemicellulose and lignin concentration, but within the softwood species, cypress pine and radiata pine formed separate clusters.

1. Introduction

The planting of trees on unforested land is an effective measure to reduce the accumulation of carbon dioxide in the atmosphere. In commercial forests, the forest products obtained significantly extend the term of storage of carbon (C) sequestered in trees beyond the time of harvest (Karjalainen et al., 1994; Skog and Nicholson, 1998; Nabuurs and Sikkema, 2001; UNFCCC, 2003). Studies have shown that the net sequestration effect can be greater for a sustainably harvested forest producing timber products than for a forest that is not harvested (e.g. Marland et al., 1997; Perez-Garcia et al., 2005).

A significant factor influencing the contribution of wood products to C storage is the proportion of the above-ground tree biomass (AGB) that is removed in harvested logs.

The estimation of biomass in trees and tree components is often based on volume measurements derived from diameter at breast height (DBH) and tree height, combined with wood density. However, direct measurement by weighing is more accurate (Snowdon et al., 2002) and is an essential component in the development of accurate biomass regression models (Brown, 2002). The use of volume and density to derive biomass may lead

* Corresponding author. Tel.: +61 2 9872 0143; fax: +61 2 9871 6941.
E-mail address: fabianox@sf.nsw.gov.au (F.A. Ximenes).

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to significant overestimates, particularly in larger trees containing hollows or decayed wood. It has been reported that the proportion of eucalypt trees containing hollows with medium and large entrances is positively correlated with DBH (Gibbons et al., 2000).

The proportion of AGB recovered in commercial logs varies according to various factors such as market availability (e.g. whether there is local demand for pulp logs), species, harvesting system, silvicultural systems (e.g. clear fell versus selective logging) and stand quality.

The AGB retained in the harvest residues (crown, bark and stump) in the forest may be released at varying rates for the different components, impacting on the greenhouse gas emissions due to forestry activities. Accurate determination of the AGB in the different types of residues at harvest is important for long-term planning of their utilisation (e.g. for bioenergy).

This study examined the proportion of AGB in logs and residues at the harvest of radiata pine (*Pinus radiata*), cypress pine (*Callitris glauca*), blackbutt (*Eucalyptus pilularis*), spotted gum (*Corymbia maculata*) and messmate (*Eucalyptus obliqua*). The three hardwood and two softwood species included account for approximately 65% of the total volume of sawlogs harvested in Australia (Ximenes and Gardner, 2005). Saw and veneer logs represent one of the main uses of roundwood harvested in Australia, with approximately 12.8 million m^3 of saw and veneer logs removed in 2005/2006 (ABARE, 2006).

The main aims of the research were:

- To determine the proportion of AGB recovered in commercial logs for each harvested tree.
- To determine the proportion of AGB that remained as a residue in the forest as bark, crown and stump at harvest.

The secondary aims of the study were:

- To determine the relationship between diameter at breast height (DBH) and the biomass in commercial logs.
- To determine the carbon, cellulose, hemicellulose and lignin concentration of the different species.

2. Materials and methods

A total of 309 radiata pine, cypress pine, blackbutt, spotted gum and messmate trees were harvested across five locations (Fig. 1). The location of each harvesting study and the type of forest harvested are included in Table 1.

The plantation radiata pine trees were harvested at 35 years, the typical rotation age for radiata pine in that region. Cypress pine is naturally very slow-growing and the site selected contained mostly trees that were 110 years old at the time of harvest. The spotted gum and blackbutt trees were from regrowth forests with trees of varied ages. The messmate study area was a regeneration tall messmate wet forest, with a full range of successional stages, where the oldest trees were approximately 100 years old.

Fig. 1. Location of the five harvest study sites in Australia.

2.1. Harvest system

The harvesting and weighing technique used for the different species are outlined in Table 2. Each site was selectively harvested primarily for sawlogs. Selective harvest ensures that a proportion of the trees are preserved in order to maintain the forest structure and wildlife habitat, and to maximise future commercial potential of retained trees. For each species, stems of a range of diameters were selected for the study.

2.2. Field studies

The trees of commercial size were randomly selected to represent the range of sizes and quality of trees typically harvested in the study regions. The DBH, length and height of trees and diameter of the stumps were measured. The commercial logs were cut, weighed, debarked (with the exception of radiata pine and cypress pine logs, which are typically debarked at the sawmill), graded and re-weighed. Samples were cut from the log products, crown and bark for laboratory analysis.

Most trees yielded at least two commercial logs. Three weighing systems were used in the studies (Table 2)—a log truck fitted with scales (Fig. 2a), suspended load cells (Fig. 2b) and a purpose-built trailer fitted with weigh bars (Fig. 2c). The log truck scales were capable of weighing up to 43 tonnes in 10 kg increments. Two portable load cells were used, with maximum capacities of 2.5 and 5.0 tonnes, respectively, and variable increments according to the range chosen. The biomass-weighing trailer was equipped with two weigh bars with a combined capacity of 5 tonnes, at increments of 0.2 kg.

The logging truck fitted with scales was used to weigh all blackbutt logs – before and after debarking – and the blackbutt crowns. The suspended load cells were used to weigh all the blackbutt commercial logs after grading and radiata pine trees and

Table 1
Characteristics of each of the harvest study sites in Australia

Species	Number of trees harvested	Forest type	Site	Location	Annual rainfall (mm)
Radiata pine	54	Plantation	Greenhills State Forest	Tumut, New South Wales	900
Cypress pine	51	Regrowth	Baradine State Forest	Baradine, New South Wales	600
Blackbutt	35	Regrowth	Candole State Forest	Grafton, New South Wales	1050
Spotted gum	125	Regrowth	Mogo, Clyde and Flat Rock State Forests	Batemans Bay, New South Wales	1000
Messmate	44	Regrowth	Warra Long-term ecological research area	Port Huon, Tasmania	900