Comparison between a two machine and a three machine harvesting system in a mature Pinus radiata (radiata pine) plantation

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Introduction

In Australia, the majority of radiata pine (Pinus radiata) harvesting operations are currently conducted using a harvester/forwarder harvesting system. This harvesting system can harvest radiata pine plantations quickly and efficiently and deliver wood to roadside at a low cost per m3. However, harvesters have a limited ability to control a tree's progress to the ground during falling. To slow the rate at which trees fall and hence reduce the potential for stem breakage, harvester operators typically fall trees into the remaining stand so that interaction between the crowns slows the tree's descent. This method also allows any broken stems to be recovered as the harvester progresses through the stand and prevents slash from covering processed logs. Anecdotal evidence suggests that damage to the felled trees and to the remaining stand still occurs. In contrast, feller-bunchers can exert a far greater degree of control over a falling tree and do not need to fell trees into the remaining stand to slow their descent, which may reduce the chance of stem breakage occurring.

The objective of this study was to compare the productivity and degree of stem breakage between a harvester/forwarder ('two machine') harvesting system and a feller-buncher/processor/forwarder ('three machine') harvesting system operating in Australian radiata pine plantations. This bulletin is a preliminary report of the findings of this study.

Study area and research method

The study was conducted in May 2014 in a 29 year old radiata pine plantation 6km north of Morwell, Victoria owned by Hancock Victorian Plantations. Maximum slope on the site was <15 degrees. Remnants of windrows were present in some parts of the site. The study area consisted of two adjacent trial sites of approximately 1 ha each. For each trial site, diameter at breast height over bark (DBHOB) of all trees of at least 130mm DBHOB was recorded (130mm DBHOB was the minimum tree size likely to produce a merchantable product). Heights of approximately 20% of the trees were measured with a Haglöf Vertex and used to derive height-diameter curves to predict the heights of the remaining trees. Details of each trial site are in Table 1.

Table 1. Stand details

Site characteristic	Two machine site	Three machine site
Area (ha)	1.1	0.95
Number of thinnings	2	2
Mean DBHOB (mm)	326	343
Mean height (m)	26	28
Mean tree volume (m^3)	0.88*	0.88*
Stems per hectare (sph)	431	402

* Based on approximately 20% of the trial site trees

On the three machine trial site, a feller-buncher was used to fell all merchantable trees which were then processed into sawlogs and chiplogs using a processor. On the two machine trial site, all merchantable trees were harvested and processed using a harvester (the same machine used to process trees on the three machine site). The same forwarder transported the logs to the roadside from both sites (separate stacks). The machine operators were all experienced in the operation of their machines. Table 2 provides machine details. The cycle times of each of the machines were recorded and used to estimate their productivity (m^3/productive machine hour without delays (PMH_0)). Tree volumes were estimated from their height and DBHOB using the Farm Forestry Toolbox v5 (www.pft.tas.gov.au). Forwarder load sizes were estimated using an onboard weighing scale. During felling, any breakages of felled trees were recorded, along with the length from the tree tip to the breakage point and diameter at the breakpoint.

Table 2. Machine details

Machine	Details
Feller-buncher	Komatsu PC 300 HW base (tracked) with a Rosin 800 swivel head (chainsaw)
Harvester/Processor	John Deere 1470e (wheeled) with a H290 harvester head
Forwarder	John Deere 1910e

Results

The productivities of the feller-buncher, harvester and processor were estimated from approximately 20% of the trees on each trial site (Table 3). The forwarder productivity presented was for the three machine trial site. A later report will address the productivity of the forwarder for the two machine trial site and the productivities of the other machines derived from all the trial trees.

Table 3. Machine productivity and mean tree volume

Machine	Productivity (m^3/PMH_0)*	Mean tree volume (m^3)*
Feller-buncher	108	0.88
Processor	68	0.88
Forwarder	57	0.88
Harvester	67	0.88

* Based on approximately 20% of the trial site trees

The feller-buncher caused considerably less stem damage during felling of the trees on the trial site than that caused by the harvester (Table 4. Note that these figures are for the complete trial area). The reduced breakage reflected the ability of the feller-buncher to be able to guide felled trees between standing trees and to lower trees to the ground rather than let them fall. Some trees outside the study area were damaged by both machines during felling, but it was not possible to obtain accurate observations of the number of damaged trees or the extent of the damage. A study in New Zealand (Lambert 1996) comparing stem breakage by four feller-bunchers operating at different sites found considerably higher rates of stem breakage than were found in the current trial, with all machines recording over 80% of stems broken and two recording 100% of stems broken. The causes of the majority of breakages in this study were unknown. Of the known causes, approximately one third resulted from trees striking stumps or previously felled trees. A possible reason for the greater rate of stem breakage in the New Zealand study may have been the larger trees than in the current trial (across the four NZ sites, mean stem volumes were 1.28-1.95m^3, and mean tree heights were 32-41m). Larger trees are harder for feller-bunchers to handle, strike the ground (or objects on the ground) with more force and generate greater falling speeds at the tree tip. In the current trial, the mean tree DBHOB of the trees that broke on the two machine trial site (370mm) was larger than the mean DBHOB for that site (326mm) which suggests larger trees may have been more susceptible to breakage in the current trial.

Table 4. Stem breakage summary for each trial site

Machine	Broken stems			Harvestable stems
	Number	Mean length at breakpoint (m)	Mean diameter at breakpoint (mm)	
Feller-buncher	2	10	215	382
Harvester	21	7.4	150	474

The mean diameter at the breakage point for the trees felled by the harvester (150mm) is the minimum acceptable diameter for a sawlog, so the majority of the broken stem sections were likely to have been cut as chiplogs if the stems were intact. Broken stem sections were recovered by the harvester where a usable product could be obtained from the section, though some volume loss was still likely to have occurred. Stem breakages also reduce the range of options available to the harvester optimiser which may have reduced the overall value obtained from the broken stems. As part of the next phase of data analysis for this trial, the stem files obtained from the harvester will be used to estimate any value lost from the broken stems.

The productivity of the feller-buncher in the trial was less than that for feller-bunchers in two other Australian radiata pine harvesting trials for the same mean stem volume (Alam et al. (2013): 140m^3/PMH$_0$; Acuna et al. (2011): 150m^3/PMH$_0$). The lower productivity may have resulted from the feller-buncher felling with a chainsaw (the feller-bunchers in the other trials used hotsaws), and from the slow activation of harvester head arms compared with those on the feller-bunchers in the other trials.

The productivity of the harvester was similar when used to fell and process trees or process only. This is likely to result from felling time being a minor component of the overall cycle time. The productivity of the harvester was at the lower end of the range of that of three harvesters felling and processing trees in Australian radiata pine plantations when compared at the same mean stem volume (Strandgard et al. (2013): 65-90 m^3/PMH$_0$). The productivity of the harvester when processing only was considerably less than that for a harvester processing radiata pine in another Australian trial (Strandgard et al. (2014): 94 m^3/PMH$_0$). The greater productivity of the harvester in the other trial may have been because the stand in that trial was unthinned (1057sph), which minimised movement between felled stems, only one product was being produced, and the operator had considerable experience in processing felled stems.

Comparisons of forwarder productivity will be detailed in a later report.

Take-home messages

- Stem breakage was considerably less for the three machine harvest system compared with the two machine harvest system. However, further work is required to determine whether this finding applies to larger trees than were felled in the current study.

- The mean stem diameter at the breakpoint for broken stems on the two machine site (150mm), suggests that in most cases the product affected by the breakage was likely to be chiplogs. Although there was likely to have been some volume and value loss from stem breakage in the trial, this was minimised by the harvester recovering logs from broken stem sections where possible.

- The productivity of the two harvest systems was similar. However, results of other Australian trials suggest that the productivity of the three machine system was less than what was achievable with this system.

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