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Effects of different stocking densities on harvesting of blue gum stands in Western Australia

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Introduction

This bulletin presents the results of a harvesting trial conducted by the CRC for Forestry, Harvesting and Operations Program near Greenbushes, WA in January 2009. The objective of the harvesting trial was to assess the impact of stocking density, tree size and tree form on harvesting efficiency and cost. This trial forms part of a large-scale CRC project focused on the comparison of WA bluegum harvesting systems which is designed to define the optimal harvesting system choices relative to local stand and site conditions.

Study description

- The study site was planted with bluegum (*Eucalyptus globulus*) at 1000 stems per hectare (sph) in early July 1999 and a stocking trial was subsequently established on the site in September 2002 (3.2 years after establishment) to assess the impact of stocking density on tree growth and stand production.
- Eighteen sample plots were laid out randomly in the plantation and were thinned to waste to a stocking of 1000 (control), 700, 500 or 400 stems per hectare. The thinning-to-waste treatment at age 3 targeted those trees of poorer form (resulting mainly from parrot damage) as a priority.
- The harvesting trial occurred during final felling of the site in January 2009 (9.5 years after establishment). Harvesting was carried out using a tracked excavator-based Cat 322L harvester equipped with a 20-inch

Waratah HTH620 head and operated by an experienced operator. Product specification focused on the production of 5.2m logs to a minimum small-end diameter of 50mm.

- CRC staff timed the harvester cycle elements on a tree-by-tree basis during harvesting of all 18 plots. Each treatment plot measured 35m long x 30m (six rows) wide and the operator worked along strips comprised of three rows at a time.
- Every tree in the treatment plots was measured prior to harvest and subjectively assessed by CRC staff as to the expected impact of three major form criteria (branchiness, forking and sweep) on harvester productivity.
- Terrain on the study site was firm and even, and slopes ranged from flat to a gentle side slope (average 6°).
- Generic costs were calculated using ALPACA (Australian Logging Productivity and Cost Appraisal Model) and a model, which will be presented in a later report, was developed to estimate productivity based on volume per tree and tree-form classes.

Study Results

Tree and stand factors

Table 1 summarises the tree growth and stand production for trees within stocking treatments. It is evident that the spacing treatment at age 3 had significant impact on tree growth. Average over bark diameter at breast height (DBHob) increased by 45% when moving from the control 1000 stems per hectare stocking down to 400 stems per hectare, and average tree height increased by 19%. Despite the impressive tree growth in the spaced plots, overall stand production (in tonnes per hectare) did not catch up to that in the control in the six years since thinning. Average final merchantable yield at the 400, 500 and 700 stocking densities was consistently about 7% - 8% less than control.

Table 1: Tree and stand factors

Tree and stand factors	**Target Stocking (trees/ha)**			
	400	**500**	**700**	**1000**
Number of treatment plots	6	6	3	3
Actual stocking (merchantable sph)	393	489	637	978
Average tree diameter, mm (DBHob)	253	226	205	174
Average tree height, m	23.7	22.2	21.4	20.0
Average standing tree volume, m³/tree	0.464	0.366	0.286	0.233
Stem Form (Forking) *, % of trees				
Class 1	77	77	62	62
Class 2	7	6	12	3
Class 3	16	17	26	35
Merchantable yield, tonnes/ha	180.2	178.1	179.9	194.6
Differential	-7%	-8%	-8%	0%

* Class 1: no anticipated impact of factor on harvesting/processing productivity, Class 2: possible impact of factor on harvesting/processing productivity, Class 3: expected impact of factor on harvesting/processing productivity

The spacing treatment at age 3 targeting stems of poor form had a significant impact on overall stand form within the different stockings. In the control 100 stocking, 35% of the stems had major forks compared with only 16% in the 400 stocking and this proved to have a significant effect on relative harvesting efficiency. Note that the spacing treatment at age 3 did not completely eliminate forking in the treated stands as some further forking (including parrot damage) occurred after treatment. Heavy branching was more pronounced in the 400 stocking and sweep was comparable among treatments but these factors were found to have a lesser impact on harvester productivity.

Productivity and cost

Table 2 summarises relative harvester productivity and estimated direct unit costs within the different stocking treatments. Harvester productivity was 66% higher and costs were 40% lower in the 400 stocking compared to the 1000 stocking as a result of both the much larger average tree size and the lower incidence of major forks. Table 3 shows the impact of forks on productivity. Major forks were found to reduce harvester productivity by 28% compared with trees without forking.

Table 2. Productivity and cost comparison

	Stocking (trees/ha)			
	400	**500**	**700**	**1000**
Average time per tree, minutes *	1.06	0.97	0.97	0.91
Average productivity, tonnes/PMH_{15} **	26.2	22.4	18.4	15.8
Average harvesting cost,$/tonne ***	8.40	9.82	11.98	13.93
Differential	-40%	-29%	-14%	0%
Average harvesting cost, $/ha ***	1513	1749	2156	2711
Differential	-44%	-35%	-20%	0%

* The average harvesting cycle was comprised of the following elements: felling (16%), processing (77%), move between trees (4%), clearing of unmerchantable trees and debris (<1%), turnaround at end of strip (<1%) and delays (3%). Delays > 15 min. were not considered productive time and excluded from PMH.

** PMH_{15} considers short delays (less than 15 minutes) as part of productive time.

*** Based on an estimated hourly cost of $220/$PMH_{15}$ for the harvester, excluding overhead, supervision, profit, risk and moving costs.

Table 3. Impact of forks on productivity

	Forking class		
	Class 1	**Class 2**	**Class 3**
Average volume/tree, m^3	0.326	0.307	0.390
Average time per tree, min.	0.85	0.94	1.38
Differential	0%	+10%	+62%
Productivity, m^3/PMH	21.8	19.2	15.7
Differential	0%	-12%	-28%

Cost analysis of spacing treatment

When reducing stocking from 1000 to 400 trees per hectare, tree volume almost doubles (+99%) but overall stand yield reduces by 7%. As such, assuming a thinning-to-waste treatment cost of $400/ha at age 3, a land leasing cost of $500/ha/year, a stand establishment cost of $1450/ha and the harvesting costs presented in this bulletin, a **net loss** of $1.00/tonne in present value is obtained for the stocking at 400 stems per hectare. When growth and cost implications are taken into account, the actual breakeven point of the treatment is achieved when stand yield reduces by no more than 3.8%. The same analysis with the 500 and 700 stocking densities gives a net loss in present value of $2.20/tonne and $3.00/tonne, respectively. Please note that this simple economic analysis does not consider all the possible cost implications of an early stand tending treatment, but merely provides an indication of the economic return.

Take home messages

- Early spacing increased average diameter up to 45% and height up to 19% when moving from standard 1000 stocking down to 400 stocking. Average tree volume was doubled. However, for the study site, final stand yield of the thinned stands did not completely catch up to that of the standard 1000 stocking in the time given (age 3.2 to age 9.5).
- Increased tree volume and removal of poorly formed stems during spacing increased harvester productivity by up to 66% and reduced direct harvesting costs by up to 40% when moving from standard 1000 stocking down to 400 stocking.
- Forking is the form criteria having the greatest impact on harvesting productivity. Major forks decreased harvester productivity by 28% on a per tree basis. Given the significant impact of forks, investment to mitigate forking in severely effected stands may be justified and major forking could be accounted for in the harvest rate.
- The cost analysis showed that all thinning treatments on this site resulted in a net financial loss over the full rotation of 9.5 years. Positive impacts on individual tree growth and form and associated reductions in harvesting costs did not compensate for overall losses in per hectare yield within the time frame of this thinning trial.

Organisations supporting this research

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More information

CRC for Forestry website: http://www.crcforestry.com.au/research/programme-three/index.html