Economic analysis of a Eucalyptus globulus stocking and harvesting trial in Western Australia

Dr. Mauricio Acuna, Senior Research Fellow – AFORA
John Wiedemann, Senior Forester – WAPRES
Martin Strandgard, Senior Research Fellow – AFORA
Rick Mitchell, Senior Technician - AFORA
Overview

• Background & objectives
• Stocking and harvesting trial
• Yield and harvest productivity modelling
• Economic analysis
• Results
• Summary
Background

- Australia has over 1,000,000 ha of Eucalyptus plantations
- Established since 1990, primarily as a source of pulpwood & woodchips
- Plantations planted at a stocking density of approximately 1000 - 1250 stems per ha & a target rotation length of 10 years
Background

Several studies have showed that increasing initial stocking density decreases tree volume and diameter.

Manipulation of plantation stocking density on individual tree size can affect final harvest costs and productivity -> tree size is a major driver of harvesting costs and productivity.

However, harvest costs impacts need to be considered in the context of the total costs and returns for a rotation.
Objectives

• Quantify the effect of stocking density on standing tree traits including DBH, tree height, tree volume, and tree form traits (branchiness and forks)

• Quantify the effect of stocking density on harvesting traits including machine hourly productivity and cost

• Conduct an economic analysis and determine optimal rotation ages and LEV of different stocking densities

• Conduct a sensitivity analysis to determine the factors with the greatest incidence on LEV
Stocking and harvesting trial

- 18 (35x30 m) plots
- 4 treatments
- Thinning to waste at age 3.2 years
Stocking and harvesting trial

- Harvester: CAT 322L tracked excavator base with an 20-inch Waratah HTH620 head
- Experienced operator
- Product specification focused on the production of 5.2 m logs
- Felling across a 3 row face
- Cycle and elemental times: digital video and manual recordings
Yield and harvest productivity modelling

- Trees were measured for DBHOB, tree height, and survival on 6 occasions during the trial period (age 3.2, 3.4, 4.3, 5.4, 7.6, & 9.5 years).

- The volume increment was used to develop a yield model which in turn was used to generate MAI and LEV curves from ages 5 to 12.

- A general harvesting productivity model was developed including the following independent variables: “Stocking treatment”, “tree size”, “branchiness”, and “forking”
Economic analysis - LEV

\[
LEV = \left[ -E + \sum_{t=1}^{R-1} \frac{I_t}{(1+r)^t} + \frac{A \left[ (1+r)^R - 1 \right]}{r(1+r)^R} + \frac{P Y}{(1+r)^R} - \frac{H Y}{(1+r)^R} \right] \frac{(1+r)^R}{(1+r)^R - 1}
\]

where,

- **LEV** = Land Expectation Value per unit area
- **R** = the length of a rotation (in years),
- **E** = the stand establishment cost per unit area,
- **A** = the annual land leasing cost per unit area
- **It** = the thinning-to-waste cost per unit area occurring after plantation establishment and before the final harvest,
- **Y** = the expected yield of pulplogs (m³) per unit area at the final rotation,
- **P** = the mill gate price of pulplogs per m³,
- **H** = the harvesting and transportation cost per m³, and
- **r** = the real interest rate.

Optimal rotation age that maximizes LEV calculated with Excel’s solver
## Results - Tree and stand factors at the time of harvest (age 9.5)

<table>
<thead>
<tr>
<th>Tree and stand factors</th>
<th>Target stocking (trees/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>UTH</td>
</tr>
<tr>
<td>Number of treatment plots</td>
<td>3</td>
</tr>
<tr>
<td>Actual merchantable stocking (tph)</td>
<td>978</td>
</tr>
<tr>
<td>Mean tree diameter (DBHOB), mm</td>
<td>174</td>
</tr>
<tr>
<td>Mean tree height, m</td>
<td>20.0</td>
</tr>
<tr>
<td>Mean standing tree volume, m³/ tree</td>
<td>0.233</td>
</tr>
<tr>
<td>Stem form (Forking), % of trees</td>
<td></td>
</tr>
<tr>
<td>Class 1</td>
<td>62</td>
</tr>
<tr>
<td>Class 2</td>
<td>38</td>
</tr>
<tr>
<td>Merchantable yield, tonnes/ha</td>
<td>194.6</td>
</tr>
<tr>
<td>Differential</td>
<td>-8%</td>
</tr>
</tbody>
</table>
Results - Growth curves
Results - MAI Curves

The diagram illustrates the MAI (m$^3$/ha/y) curves over different age (years) stages, with distinct lines representing various UTH levels: 700, 500, 400.
# Results - Time study

<table>
<thead>
<tr>
<th>Work Element</th>
<th>UTH Mean time per cycle, sec.</th>
<th>UTH % of cycle time</th>
<th>700 Mean time per cycle, sec.</th>
<th>700 % of cycle time</th>
<th>500 Mean time per cycle, sec.</th>
<th>500 % of cycle time</th>
<th>400 Mean time per cycle, sec.</th>
<th>400 % of cycle time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Felling</td>
<td>16.1</td>
<td>17.6</td>
<td>14.4</td>
<td>16.9</td>
<td>14.3</td>
<td>14.8</td>
<td>15.7</td>
<td>15.8</td>
</tr>
<tr>
<td>Processing</td>
<td>71.3</td>
<td>78.1</td>
<td>66.5</td>
<td>78.2</td>
<td>77.3</td>
<td>79.9</td>
<td>77.8</td>
<td>78.2</td>
</tr>
<tr>
<td>Brushing or cleaning</td>
<td>0.8</td>
<td>0.8</td>
<td>0.12</td>
<td>0.1</td>
<td>0.26</td>
<td>0.3</td>
<td>0.20</td>
<td>0.2</td>
</tr>
<tr>
<td>Moving</td>
<td>3.0</td>
<td>3.3</td>
<td>3.8</td>
<td>4.5</td>
<td>4.7</td>
<td>4.9</td>
<td>5.6</td>
<td>5.6</td>
</tr>
<tr>
<td>Travelling</td>
<td>0.2</td>
<td>0.2</td>
<td>0.2</td>
<td>0.2</td>
<td>0.2</td>
<td>0.2</td>
<td>0.2</td>
<td>0.2</td>
</tr>
<tr>
<td>Total</td>
<td><strong>91.4</strong></td>
<td><strong>100.0</strong></td>
<td><strong>85.0</strong></td>
<td><strong>100.0</strong></td>
<td><strong>96.8</strong></td>
<td><strong>100.0</strong></td>
<td><strong>99.5</strong></td>
<td><strong>100.0</strong></td>
</tr>
</tbody>
</table>
Results - Harvest productivity model

\[
\ln(\text{Productivity}) = 3.848 - 0.301 \times \text{Forking} + 0.668 \times \ln(\text{TreeVolume})
\]

- \( R^2 = 0.85 \)
- Productivities:
  - 400 (25.9 m³/PMH)
  - 500 (22.8 m³/PMH)
  - 700 (18.3 m³/PMH)
  - UTH (14.5 m³/PMH)
Results - LEV curves

- UTH
- 700
- 500
- 400

LEV ($/ha)

Age (years)
Results - Sensitivity analysis on LEV

- Mill gate price (65-85 $/m3)
- Yield per ha (-15% - +15%)
- Annual leasing cost (400-600 $/ha)
- Interest rate (6%-8%)
- Harvest productivity (-15% - +15%)
- Establishment cost (1350-1550 $/ha)
- Thinning cost (300-500 $/ha)

LEV ($/ha)
Summary

- Plantation stocking density can affect final harvest productivity and cost.
- The economic analysis showed that at their optimal rotation age, all the stocking treatments resulted in a lower LEV and net financial loss over the full rotation when compared to the unthinned control (UTH) stocking treatment.
- Positive impacts on individual tree growth and form and associated reductions in harvesting costs did not compensate for overall losses in per ha yield.
Thank you!

Wineglass bay, Tasmania