Issue
The Auditor General’s Performance Audit “Sustaining Native Forest Operations: Forests NSW” of April 2009 included an action item (Recommendation 3), requiring Forests NSW to “Undertake and publicly report the results of a review of yield estimates for hardwood plantations”

This report addresses the review of yield estimates for the post-1994 hardwood plantations. Information for this study has been sourced from the analysis contributing to the annual valuation process.

Background

Overview
The post-1994 (1994 and younger) plantation hardwood resource established on the North Coast of NSW by Forests New South Wales was planted to supplement hardwood sawlog supplies from a restructuring native forest resource.

A comprehensive review of North Coast timber supply was undertaken in 2003 following changes to the Forests NSW estate announced by the NSW Government; however, this review did not include the post-1994 hardwood plantations. As a result, yield estimates from these plantations are the subject of this review. The report is underpinned by the analysis undertaken for the 2011 annual valuation process.

Current resource
The northern hardwood plantation resource occurs in a large number of relatively small blocks predominantly on the coastal lowland between Newcastle and the Queensland border. Figure 1.1 shows their location, along with the location of current processing facilities.
Planting began in 1994 under a mandate granted to Forests NSW to establish a new hardwood plantation resource to replace a reduction in future supply caused by removal of native forest from production.

In order to secure sufficient land, Forests NSW made arrangements to access privately held land. Payment for the use of this land is either by way of an annual rental (annuity) or by sharing final harvest proceeds in proportion to the contributions made by each party to the cost of growing and selling the crop (crop share). Approximately 10,200 hectares of plantation is on land managed under these arrangements. A further 18,300 hectares of post-1994 hardwood plantations occur on State Forest land.

Figure 2 shows the distribution of stocked plantation area by these broad tenure classes.
The plantations are widely scattered and many of those on private land occur in blocks of less than 50 hectares. Figure 3 shows the distribution of blocks by planted area.

**Figure 2:** Distribution of hardwood plantation resource by land tenure.

**Figure 3:** Distribution of hardwood plantation block size.
A key feature of this plantation resource is the variety of species planted (a total of 22), and the very uneven and narrow age class distribution, with the majority of the area planted between 1996 and 2004. Figure 4 and Table 1 summarise the age class distribution for the major species planted.

Figure 4: Area by age class and species
Table 1: Stocked area by year of planting at 30 June 2011

<table>
<thead>
<tr>
<th>Year Planted</th>
<th>Blackbutt</th>
<th>Gympie Messmate</th>
<th>Dunns White Gum</th>
<th>Flooded Gum</th>
<th>Spotted Gum</th>
<th>Other</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre94</td>
<td>65</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>67</td>
</tr>
<tr>
<td>1994</td>
<td>38</td>
<td>3</td>
<td>28</td>
<td>50</td>
<td>0</td>
<td>68</td>
<td>186</td>
</tr>
<tr>
<td>1995</td>
<td>52</td>
<td>51</td>
<td>94</td>
<td>9</td>
<td>22</td>
<td>227</td>
<td></td>
</tr>
<tr>
<td>1996</td>
<td>509</td>
<td>52</td>
<td>445</td>
<td>92</td>
<td>356</td>
<td>300</td>
<td>1,753</td>
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<tr>
<td>1997</td>
<td>1,122</td>
<td>45</td>
<td>1,140</td>
<td>198</td>
<td>878</td>
<td>131</td>
<td>3,513</td>
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<td>1998</td>
<td>1,012</td>
<td>236</td>
<td>904</td>
<td>625</td>
<td>2,513</td>
<td>140</td>
<td>5,430</td>
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<td>1999</td>
<td>544</td>
<td>105</td>
<td>839</td>
<td>362</td>
<td>161</td>
<td>105</td>
<td>2,117</td>
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<tr>
<td>2000</td>
<td>763</td>
<td>257</td>
<td>2,118</td>
<td>725</td>
<td>761</td>
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<td>1,592</td>
<td>294</td>
<td>915</td>
<td>111</td>
<td>3,449</td>
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<tr>
<td>2002</td>
<td>228</td>
<td>220</td>
<td>363</td>
<td>68</td>
<td>627</td>
<td>96</td>
<td>1,602</td>
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<tr>
<td>2003</td>
<td>117</td>
<td>22</td>
<td>526</td>
<td>1</td>
<td>520</td>
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<td>2004</td>
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<td>50</td>
<td>7</td>
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<td>5</td>
<td>126</td>
<td>38</td>
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<td>2007</td>
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<td>51</td>
<td>6</td>
<td>10</td>
<td>337</td>
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<tr>
<td>2008</td>
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<td>32</td>
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<td>15</td>
<td>587</td>
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<tr>
<td>2009</td>
<td>1</td>
<td>45</td>
<td></td>
<td>81</td>
<td>127</td>
<td></td>
<td></td>
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<tr>
<td>2010</td>
<td>594</td>
<td>110</td>
<td>14</td>
<td>239</td>
<td>957</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>6,844</td>
<td>1,228</td>
<td>8,612</td>
<td>2,548</td>
<td>7,301</td>
<td>1,919</td>
<td>28,452</td>
</tr>
</tbody>
</table>

The earlier plantings are of variable quality, largely due to large establishment targets being achieved in a short time-frame. The main species planted were Blackbutt, Dunn’s White Gum, Flooded Gum and Spotted Gum. Gympie Messmate has also been identified separately in Table 1 due to its sawlog qualities being similar to Blackbutt and the high demand for these products.

**Silvicultural policy**

The silvicultural objective for these plantations is to produce sawlogs of comparable size and quality to those from the native forests to supply the local sawmilling industry. Rotations of about 30 years are expected to be required, with a single intermediate yield of pulpwood for chip export from thinning in stands within an economically viable zone of markets, and with sufficient stems to support a thinning operation.
Project design
Modelling undertaken as part of this review incorporated:

- Updated definition of available area.
- Yield information from existing growth models, scaled using actual harvest data from clearfelling of older pre-1994 stands.
- Predictions of the proportions of the final yield in logs by product size and quality, made using stand-level equations to estimate product volumes from average stand diameter. These equations also used data from pre-1994 clearfell operations.
- Yield scheduling using Remsoft® Woodstock planning system, with the objective of achieving smoothed long-term sustainable harvest levels in the context of a broader long term hardwood supply strategy for the North Coast.

Historically there has been limited measurement information on which to base the forecast of expected yield per hectare from the hardwood plantation resource across the full range of site, species, stocking and planned silviculture. The growth model developed to simulate the growth and yield of these species is limited by the lack of data representing older ages.

This major review of modelled growth performance was undertaken to improve the reliability of estimates and also forecast future volume from the hardwood plantation resource in the context of supply from the surrounding native forest resource.

Model inputs

Yields
This review is based on yield tables developed from the currently available growth models, described in Muhairwe (2003)1. As these models have limited application for older ages, the yield tables were scaled using actual clearfell yield information generated by the harvesting of pre-1994 stands.

Stands were grouped by species, site productivity class (three Mean Annual Increment (MAI) based classes of > 18 m³/ha/year, 12-18 m³/ha/year, and <12 m³/ha/year) and stocking (two classes of around 750 stems/ha and around 450 stems/ha at age 5) based on the then available inventory plot data.

Using the scaled yield data, thinning regimes were compiled for each combination of site class, stocking class and species group.

Figure 5 shows that the resource is expected to be extremely variable in terms of future volume production, reflecting the variation in species, site and silviculture.

Expected age 40 MAI values of Total Recoverable Volume (TRV) per hectare range from a low of 4.5 to a high of about 14 m³/ha/year. The area-weighted average MAI of TRV at age 40 is around 9.2 m³/ha/year.

![Figure 5: Distribution of age 40 MAI of TRV (m³/ha/year)]

On average, mean annual total volume increment peaks at about age 30, but remains near this level through to age 60 (see Figure 6). This means that an average harvest age of 30 years is the optimum for maximising volume.

![Figure 6: Profile of average Mean Annual Increment]
**Volume by Product**

The yield table volumes were estimated in a range of log types, from high quality logs with small end diameters (sed) of 35 cm and 25 cm to low quality logs of 25 cm sed, and pulpwood.

There is no directly comparable inventory reconciliation data available to verify these estimates.

Product class breakdown was determined by apportioning equations that were developed using product specifications from the surrounding hardwood industries.

**Yield of Thinnings**

Thinning operations to date, covering 157 hectares, yielded an average of 94 tonnes/ha. Assuming that density of the timber is between 1.1 and 1.2 tonnes per green cubic metre, this is equivalent to a volume 78 to 85 m³/ha. For modelling purposes, an area-weighted average yield of 65 m³/ha of pulpwood was assumed for all thinning yields.
Results
The results of the Woodstock modelling are shown in Figure 7. The solid blue line demonstrates a sustainable supply of total recoverable volume (sawlog and pulp) can be produced from the ‘post 94 estate’ in the context of the strategy to deliver a sustainable supply from native forest and hardwood plantations across the region. The basis of this strategy is to supply a constant harvest level of approximately 300,000 m³ for 70 years. This level commences in 2024 to coincide with the transition point set by current wood supply agreements and the corresponding reduction in supply from native forests. By way of comparison, the dotted green line shows the modelled wood supply level for the first rotation of the current crop only.

Figure 7: Results from Woodstock modelling demonstrating sustainable levels than can be maintained in the context of broader regional supply (solid blue line) compared with liquidation of current hardwood resource only (dotted green line).

Figure 8 demonstrates how the non-declining supply level from post-1994 contributes to the combined North Coast supply.

The average age of clearfelling (see Figure 9) gradually increases from around 15 years in the early periods, when all yield expected to be pulp, through to a peak of 44 years in 2045. This is consistent with operations found in the current pre-1994 plantation resource. This graph highlights the rotation lengths that will be needed to achieve the modelled sustainable harvest levels.
Figure 8: Combined North Coast Wood Supply

Figure 9: Average age of clearfelling
The reliability of the modelled predictions was checked in the following way:

1. Comparison of younger age predictions was made with inventory measurements from post-1994 hardwood plantations. This demonstrate a reasonable relationship for the species currently being sold (predominately Blackbutt and Flooded Gum).

2. Comparison of predicted volume at older ages was made with inventory information from the pre-1994 plantation resource, collected in 1997. The plots aged between 30 and 40 years at the time of inventory, show a total standing volume of around 190 m$^3$/ha. Utilising the weak correlation between stocking (number of stems per hectare) and Total Standing Volume (TSV) which is exhibited by many plantation species, adjusting to allow for differences in stocking produced an observed TRV estimate of about 310 m$^3$/ha, compared to the modelled average of 300 m$^3$/ha TSV at age 35.
Conclusion

The results of the modelling reflect an improvement in the yield estimates associated with the post-1994 hardwood plantations.

There are significant management challenges to achieving a sustainable harvest level from the post-1994 hardwood plantation resource. These include: the narrow age class distribution; the variety of species; the widely scattered nature of the resource, often occurring in small, isolated blocks; the varying quality of the resource; and the range of land tenures. However, modelling wood flow in the context of the broader long term hardwood supply strategy for the North Coast, demonstrates that a sustainable supply can be achieved from this resource.

Achievement of forecast yields depends on actual thinning occurring at the simulated ages to the simulated stockings. A delay in thinning, or removal of additional trees, will reduce yields at rotation age.

Rotation lengths of up to 45 years will also be required to achieve the modelled volumes.

Notwithstanding the uncertainties of longer term growth trends for species not well represented in the inventory data, the observed trends for the average growth trajectory of the current yield tables appear consistent with available inventory data.