BLUEGUMS : When to harvest; how many trees to plant ?

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There has been some discussion in recent AFG journals concerning the optimum age to harvest bluegums.

There are many factors which go into making a successful business out of tree farming, As well as good agronomic skills to match genestock, site preparation and fertiliser use to site conditions, tree plantation farmers need to consider how their returns might be affected by stocking density and rotation length for a particular site quality and financial environment, and plan their actions accordingly.

Growth model

This article is a discussion of output from a general growth model I have developed to assist in silvicultural decision making with eucalyptus pulpwood plantations. It is a simplified versions of a model which is examines a forest silviculture where there are mixed product outputs with one or more thinnings during the rotation.

The aim of the model is to be able to answer questions like;

- what is the best stocking rate under various silvicultural and financial circumstances?
- what is the optimum rotation age, ie when should the forest be harvested to generate maximum return on capital for given starting conditions ?

The model shows how bluegum growth may vary on sites of different growth potential ie deep soil -high rainfall- long growing season compared to lower rainfall- shallower soil- shorter growing season, and uses this result together with financial information to formulate an optimal silviculture for the site. Whilst the results should be treated with some caution because it is not entirely based on field data, the individual components ie basal area and height growth in relation to stocking, are at least representative of selected measured sites I have measured in the Green Triangle region.

The model simulates volume production by calculating basal area and height growth for a given site quality, stocking and age. For the technically–minded, the increments in basal area and height, and the interaction of each with stocking rate, are the key factors in the model. A more sophisticated version of the model can also be used to simulate thinning responses.

Stand Basal Area (SBA) is the sum of cross-sectional area of tree stems at 1.3m above ground. SBA is easily, quickly and accurately sampled using an optical prism. A simple tool using a small wooden block, two pins and a piece of string can also be made to do the job.

The volume is calculated by multiplying area x log height x form factor (ff), where form factor indicates the geometric shape of the trunks. ie V= SBA x Ht x ff. The form factor is the log volume proportionate to a cylinder. In the model where merchantable rather than total height is used, form factor ranges from 40-55% and is a function of stocking rate and tree diameter.

Mean Annual Increment (MAI) is the average volume growth over a given period of time, and is a familiar measure to most forest managers. I have used MAI as a means of defining site quality SQ, such that SQ is the MAI at age 10 of a plantation with 1000 trees per hectare.

Figures 1 and 2 illustrate the changes over time, on a given quality site (SQ30) and with a range of initial stocking rates (trees per hectare [tpha]), for MAI, and for Merchantable Height (ie to 6cm small end diameter under bark [sedub])

In Figure 1 only, the vertical axis is scalar, that is for any SQ other than 30, the axis values can simply be multiplied by the appropriate factor, eg for SQ 20, the values on the left axis would be 20/30 (two-thirds) of that shown, and the position and shape of the curves do not change.

Figure 3 illustrates the Height for Age curve at a given stocking rate for a range of SQ.

Comments on the Figures;

1. As the vertical axis can be rescaled as noted above, the curves can be used to estimate SQ in an existing forest. One could, for any given site with existing well-managed trees, measure standing volume and stocking, compare this to the value on the standard curves, and calibrate the scale to give an inferred SQ rating . Estimating SQ from base parameters such as soil and climate is more complex and a matter for experienced foresters.
2. Merchantable Height to 6cm sedub, is about 80% of total height. Note how height growth is slightly higher in dense stands at a young age, but that as the stand ages height increment is less in the higher density stands because of competition effects. Also log form (shape) is assumed to be more conical in young stands with low stocking and therefore merchantable length is shorter. However as the trees age, the more dense stands will have the shorter merchantable length relative to lower stockings, because (a) the trees in the dense stands are thinner (6 cm sedub is lower down the stem), and (b) on average a dense stand has more

trees with crown defect. In practice, actual observed heights may be higher than those indicated on the chart; the model makes allowance for some defective upper stems by "averaging down'.

3. These curves indicate that height growth is related to site quality for a given stocking rate. The height curve for combination SQ 30 and 1000 tpha is also shown in Figure 2. A family of curves of this nature (ie when all stocking rates are shown) could in theory be used to infer a particular SQ. However it will be more reliable to also measure SBA, as the differences are usually more pronounced for SBA with varying SQ than they are for height, especially at an early age. SBA is also very easy to sample using an optical prism.

An important assumption is that the field management and genestock are already optimum for the site, eg the land has been well prepared, trees receive adequate fertiliser and weed control to use the available sunlight and water, and high quality planting stock is used.

Having thus modelled the silvicultural interactions to come up with projected final harvest volume under various silvicultural circumstances (site quality and stocking), it is relatively simple to add the financial information to determine outcomes under different circumstances. This enables the modeller to test whether changes in various financial parameters (eg costs, sales value, real increase in stumpage etc) will have any significant influence on management planning such as optimum stocking rates and rotation length for different SQ.

Finances

On the financial side, I have used IRR (internal rate of return) as the simplest and most appropriate measure of financial benefit. The optimum rotation for a given set of starting conditions, ie stocking and site quality, is the one which maximises IRR when the forest is harvested at any age from 1 to 24 and sold for pulpwood at the assumed price. This is the key outcome from the model.

For each possible stocking density on each possible SQ, I have calculated the IRR for harvest at any age from 1 to 24. Each stocking rate thus has an optimum harvest age, and the highest IRR from all these various stocking rate "local" optima, is the best combination of stocking rate and harvest age for a given SQ. The optimum stocking and rotation for a given SQ can be determined from Figures 4 and 5, which show the "local" optimum IRR graphed against harvest age for a range of SQ and stocking density (The intermediate unlabelled lines are for SQ 25,35,45). Note that, given the uncertainties in both the model and forecasting conditions in the real world, differences of less than say 1% in IRR may not be sufficient reason to adjust field management practices.

Cost & revenue assumptions

- Figures 4 and 5 represent two different cost scenarios; Fig 4 is a fully managed plantation with costs similar to recent public prospectus offerings with costs at $2800/ha plus 80c/tree establishment and $120/ha annual maintenance. Fig 5 is for an owner-grower with fewer overheads, and costs at $1500/ha plus 40c/tree establishment and $100/ha annual maintenance.
- A base stumpage rate of $35/m3 is used for harvest of 900 trees/ha with basic density of 560kg/m3. This is derived from a world price of $155/bdt fob. Variables other than transport costs which may affect stumpage are wood density and harvest cost. Wood density is assumed to vary with age. A logarithmic model has bone-dry density going from 460 kg/m3 at age 6 ,to 560 kg/m3 at age 10, and 600 kg/m3 at age 20. In a competitive market, stumpages will vary in direct proportion to density (ie increased fibre yield). Harvest costs should be somewhat lower in open stands; a change +/- of 100 trees/ha is assumed to affect the residual stumpage by $0.50 per m3 sold. The combined effects of wood density and harvest cost variation create a range of stumpages from $25-$40 per m3 for young dense, to old open stands respectively.
- Inflation is 3% per annum on costs and 3.5% per annum on revenues
- There is no net holding cost for land, and tax effects are neutral, ie an investor can deduct all costs as incurred at the same marginal rate as when revenues are received. Land costs can included for specific scenarios. Tax considerations will need to be revisited if an investor borrows or pays different rates at different times etc.
- The effect of a possible second harvest from coppice regrowth has been ignored to keep the outcomes and analyisis relatively simple.

Conclusions

Some important conclusions can be drawn from the model. Refer to Figures 4 and 5, and Table 1 which shows some parameters which were used for the analysis.

- The most surprising conclusion, is that the optimum planting density, almost irrespective of SQ and initial overhead costs, should be much lower than conventionally assumed. In most cases 600-700 trees per ha is about right.
- the level of costs has a more significant impact on optimum rotation age than does SQ. Short rotations of as little as 8 years are feasible on high quality owner-managed sites despite some loss of wood density, provided that establishment and harvest costs are kept down by lower density plantings.
- Changes in world price levels which impact on stumpage, will have a similar effect to change in costs, ie with increasing price or lower costs, the "envelope" of curves moves upward and to the left and the individual SQ curves rotate clockwise slightly; this movement indicates that higher returns are possible with a shortened optimum rotation using somewhat higher stocking rates.
- In the higher cost scenario, optimal rotation ages are 11-13 years for SQ 25-40, with low stocking rates, though shorter rotations of 9-11 years provide a "local" optimum if higher stocking rates are already in place. On low quality sites, a longer rotation is required to generate maximum return from investment capital.
- In the lower cost scenario, optimal rotation is less than 10 years except on the poorest quality site.

These conclusions would suggest some changes to current practices. Conventional wisdom has been that high stocking rates will generate high biomass yields at an early age, and this is certainly borne out in the model. However as we have seen, this outcome is not necessarily going to generate the best return on scarce investment capital. Where there is a price discount for young trees with lower wood density and establishing managing and ultimately harvesting the extra trees is brought to account, lower stocking rates are indicated. However growers would have to be reasonably certain of being able to capture the economic benefits of increased wood density and reduced harvest costs before moving to a lower stocking rate regime.

Other rationales in favour of reduced stocking rates include reduced susceptibility to foliage fungi and drought stresses, better access for insect and fire control, and more flexible marketing options (eg small sawlogs) at maturity.

I would welcome any enquiries for practical commercial applications of this model, and can be contacted on 04 0725 7545. I would like to express my thanks to Jan Newport ForestrySA, and Bruce Mattinson ITC for their helpful and constructive comments on the draft.

Charts and Tables link