Sustaining productivity of blue-gum plantations: using process knowledge to reduce risk while maximizing net benefits

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In the early to mid-1990's Australia embarked on an expansion program of eucalypt plantations that was geographically widespread and extensive. The main species planted was *Eucalyptus globulus* grown on a relatively short rotation (10-15 years) for pulpwood. A part of this estate has now reached a harvestable age. Production across this plantation estate has been high but variable. Peak productivity can be as high as a mean annual increment of 40 m3/ha/yr but across the Australian-estate average productivity is about 20 m3/ha/yr, though it seems likely that the later plantings may be more productive.

Development of this resource has not been without challenge. Particularly challenging has been the dynamic interaction between tree and site conditions, and the effects of weather and changing climate in varying production; both factors calling into question the notion of site index and the appropriateness of yield prediction without an estimate of risk or a variance attached. Confronted with this challenge Ensis (and its joint ventures such as the CRC-Forestry) in partnership with industry has developed tools and prescriptions based on the biophysical principals of growth and an understanding of the carbon, water and nutrient cycles to define the fundamental interactions of plantations and conditions and allow prediction in the face of changing conditions and management. Furthermore, the success and extent of the plantation expansion has meant that in some catchments a significant proportion of the area has been developed as plantation. Consequently these plantations have a landscape-level role in carbon, water, salinity and biodiversity management. A result of this is the need for a new set of evaluation tools that allow the net economic and environmental impacts of plantations to be assessed and multiple benefits to be evaluated.

This paper, through some key examples, illustrates the application of forest process knowledge and its embodiment in tools for industry to meet the challenges of changing conditions, evaluating risk and multiple-benefit evaluation. In doing this we show the migration of industry away from broad-acre prescriptive management to, what we term, "precision forestry", and the increased involvement and centrality of forestry in water management, salinity control and biodiversity conservation.

Water is arguably the most limiting resource to plantation development and growth in Australia. Detailed experimental research and modeling has shown that supplies of soil-stored water maybe influenced by tree cropping and productivity may change. Even within the first rotation drought death may result when ground stored water reserves are depleted. The combination of eco-physiological studies and model development has enable industry to design robust silvicultural systems based around the control of leaf area that maximize production and financial returns while minimizing the risks associated with growing trees in a water-limiting environment.

Many plantations have been established on sites where nutrient availability has been built up under a long period of agricultural (often legume-based) production. Productivity was increased in the first rotation with the addition of fertilizers in some cases but many sites were unresponsive. However, following plantation development the quality and quantity of organic matter inputs has changed and we have observed through the first rotation, and into the second rotation, a change in the supply of available nutrients. Moving away from limiting and static concepts such as fertility ratings or site indices we have developed diagnostics based on measured and modeled supply and demand that capture the dynamic nature of the tree, nutrient cycle and site interaction.

Within these environments that are limited by available resources we have explored how improved germplasm provides gains for industry. Genetic gains trials and modeling suggest that gains from breeding come not just from increased volume production but improved uniformity and wood quality. We have extended this analysis to explore the likely magnitude of trait variation necessary to lead to significant volume gains. A better understanding of the environmental and silvicultural correlates of wood properties, and developing models of wood properties, can now be used to guide management and develop regimes to maximise value and not just volume.

Finally, these forest activities within Australia operate in an increasingly complex policy environment where the net economic and environmental impacts of plantation development need to be assessed. For example, timber quality and quantity need to be maximized whereas the impacts on streamflow and groundwater recharge need to be minimized. We have developed the Scenario Planning and Investment Framework (SPIF) software, and its underpinning process-based models, to enable targeting of plantations in landscapes for multiple benefits outcomes.