



Project news from 1.3: modelling and information integration

From the desk

There was a good response to the initial *understorey* newsletter, released earlier in the year, so I'm keen to keep this format going as a means of keeping those interested in the project up-to-date with project activities. Looking back at the last newsletter I didn't really do a good job of outlining the project or its objectives and activity so I thought a short overview of the project background would be a good place to start in this newsletter. Also, we've made significant progress on our first major deliverable, a process based approach to predicting size class distribution in even aged stands so it is a good time to describe how we've been tackling this problem

In terms of the project team there have been a couple of changes since the last Newsletter. Daniel Mendham and Keith Churchill, both from CSIRO Sustainable Ecosystems have joined the project. Keith is making a significant contribution to our vegetation surveys, which form the basis of developing an understanding of the "functional types" within our plantations. Daniel Mendham has also joined the project and brings with him significant model development capacity and insights into the workings of the CABALA framework. Furthermore Karina Potter (CSE) has returned from maternity leave and will also be making contributions to our understanding of weed ecology

You may notice also that the format of this newsletter has changed somewhat and this is thanks to Prue Loney and Vern Field the communications team in the CRC. Remember

this newsletter aims to be more than a one way transfer of information. I invite any of our CRC partners to use this forum to contribute their thoughts on the projects goals or objectives or to raise points of interest and stimulate discussion within the program. Given that a major focus in the last three years will be on adoption I'd be particularly interested in hearing thoughts on how the projects outputs would be incorporated into planning and operations

Tony O'Grady



Photo: *Eucalyptus nitens* in the Florentine valley Tasmania.

What is Project 1.3 about?

A large component of the work that is being conducted in program one is aimed at improving our understanding of the processes that constrain forest function and integrating this understanding into mechanistic models. Our project in this program, Project 1.3 has two defining objectives:

1. to produce a process-based size class distribution model
2. to incorporate the effects of competing vegetation (be that other tree species, weeds or understorey species) into the existing process based models.

The development of the tree size class distribution and survival model has largely been an extension of the detailed process based work conducted at the Pittwater research plantation in Tasmania. Our research has been focused on applying complexity theory in particular the theory around ‘cellular automata networks’ to model the interactions between trees within the stand (see below) and predict tree growth and survival in stands.

The second major area of research is based on trying to incorporate an understanding of the roles that other vegetation communities play in determining forest productivity. Vegetation management in forests consumes considerable resources. But quantifying the impact of weeds or other vegetation communities on plantation productivity is complicated by the diversity of vegetation communities and the range of management options employed to address the issue. We’re tackling this problem on a number of fronts. Karina Potter has conducted extensive surveys of industry partners coming the terms with critical issues such as what weeds are important and where are the research gaps. Other initiatives within Project 1.3 include extensive vegetation surveys in plantations across Tasmania and the green triangle to develop a ‘functional’ understanding of the types and spread of common vegetation communities. We are also managing, in consultation with our partners, an extensive network of paired plots to better quantify the impacts of these vegetation communities on production. These studies in combination with our work quantifying the roles that these vegetation communities play in the carbon and water cycles in our forest will provide a more detailed understanding of forest function

and productivity. This understanding will become even more critical in an environment where forests are increasingly being managed for multiple outcomes (e.g. water carbon, biodiversity and social objectives).

Cellular automata and tree sizes?

Our understanding of forest function has come a long way in the last 20 years and much of this understanding has been incorporated into mechanistic models of forest function. However, as they stand at the moment, these models are simplistic in their treatment of forest structure and model “average” stand conditions. In reality, we know that forests are rarely ever uniform. Rather, forests are complex and highly linked systems. Stand structure is an emergent property that represents the integration of, among other things, site, climatic and genetic factors.

But why do we need to model forest structure?

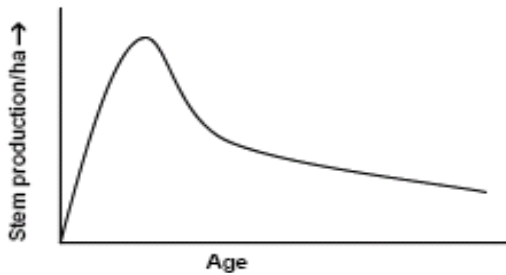
Well firstly two stands with the same average production rate can have greatly different value and cost very different amounts to harvest because they are made up of trees of different sizes. While we can presume a standard size class distribution function this doesn’t incorporate the effects of stand history (weeds pests) nor management (seedling uniformity site preparation, thinning). If models are to be useful in support of routine management these are substantial issues.

Two of the most recognizable features of forest growth are:

- the commonly observed “later-aged decline in forest productivity” and;
- the differentiation of trees into a range of dominance classes.

Despite being well recognised, capturing these processes into models has proven elusive. Later-aged decline in productivity in particular has been the focus of considerable research and while this research has provided considerable insights into forest function, it is still difficult to capture this process in models. Recent thinking suggests that later aged decline and forest structure are intimately linked.

Forest structure is intimately linked to forest productivity



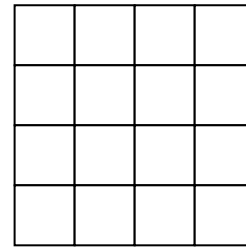
A conceptual model of forest growth from Binkley 2004 Forest Ecology and Management

In Project 1.3 we've been applying the emerging theory of "cellular automata networks" (CA) to the problem of predicting the emergence of size class distributions and survival in forest stands. CA models have been around for some time and have been used in many applications including, modeling fire behavior, snow transport or traffic flows. CA models are dynamic models where space time and state are discrete variables. Space is subdivided into cells that can take on a range of states.

Cellular automata networks model the forest as a neighbourhood of cells using simple rules to determine how trees within a neighbourhood interact with each other

In forests, the space states are relatively simple as the forest can be represented as an array of squares or rectangles, and trees don't move between grid cells (although they may occupy some of that space). Simple rules can then be defined that govern the way that the cells interact. For example in the model that we have developed, the proportion of stand primary production

A canopy surface predicted using the CA model with outputs derived from CABALA

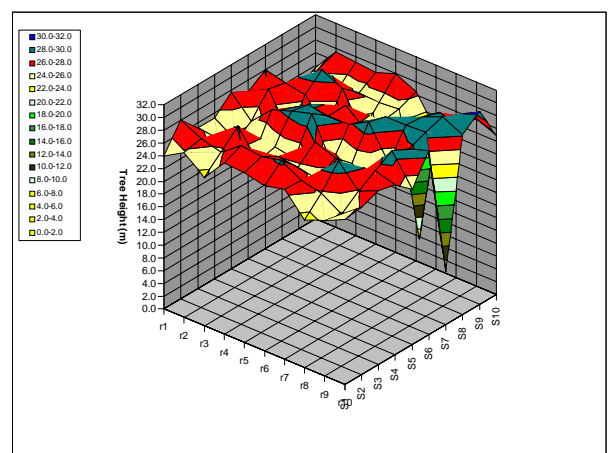


An example of a simple 25 cell CA network

an individual tree receives is a function of its leaf area and the amount of shading from the surrounding canopies. One advantage for us going down this path is that we can continue to use our very robust stand level relations to predict stand level outputs such as volume or leaf area. Often when these are predicted as the sum of individual trees in models the complexity of the interactions for nutrients, water, light and how these are structurally and functionally related to tree dimensions and leaf-shoot ratios leads to strange model results and models that can be tuned to one site but are not easily applied in novel situations. We are trying in our approach to retain the generality and simplicity of modeling at the stand level with simple scaling rules to allocate stand level outputs among our tree array

So how does it work?

Models such as CABALA do a good job of producing stand level estimates of production, respiration and biomass. The challenge is to distribute these pools of primary production and biomass to individual trees within a "notional array" of trees (i.e. the CA network) in a manner that reproduces commonly observed features of stand growth, for example self thinning, the differentiation of trees into a range of size classes and later aged declines in stand productivity.



At the moment the allocation of production to individual trees is largely a function of the a trees leaf area, principally determined using allometric relationships and the amount of competition for light among trees in the neighborhood (i.e. the average height of the trees surrounding the target tree.

Although relatively simple at this stage we have been successful in reproducing some well recognised features of stand growth for example:

- Low productivity sites tend to be more variable than high productivity sites
- Later-aged decline commences earlier in stands that are more variable (or on sites of lower productivity)
- Higher productivity (more uniform) stands tend to be resource use efficient than lower productivity stands (more variable)
- Realistic prediction of tree size distributions.

The CA model predicts well recognised features of stand growth such as later-aged decline in production and tree size class distributions

The model has been developed based on our research at the Pittwater research site but key challenges remain:

- Can we produce realistic predictions of diameter and height distributions?
- How does the model perform when resources other than light are limiting ie water and nutrients?
- Can this understanding/approach be used to capture the roles of understory competition for resources?
- Can we use this approach such as this to “visualise” the outcomes of our management interventions?

Work is currently focused on incorporating the CA model into CABALA for further evaluation and feedback from the CRC’s partners.

Got a suggestion?

Remember contributions including feedback, opinions or descriptions of related activities are always welcome

Other Current Activities

- Work is continuing in collaboration with Sandra Roberts at FT to quantify the contribution of understory water use to ET in the Florentine Valley in Tasmania
- We now have an extensive network of paired plots (with/without) weed control. These are focused mainly in Tasmania but span a broad gradients in site types, productivities and land use histories and require ongoing maintenance and monitoring
- Currently processing a large number of vegetation surveys and incorporating these surveys in a data base. This time consuming task is an essential step in developing a framework of developing a classification of vegetation functional types that can be incorporated into future modeling and management frameworks.

Some Recent Publications

- Drew, D., O’Grady, A.P., Downes, G., Read, J. and Worledge, D., 2008. Daily stem growth patterns in irrigated and non-irrigated *Eucalyptus globulus*. *Tree Physiology*, 28: 1573-1581.
- Drew, D.M., Downes, G.M., O’Grady, A.P. and Read, J., 2009. High resolution temporal variation in wood density, microfibril angle and wood anatomical properties in irrigated and non-irrigated *Eucalyptus globulus*. *Annals of Forest Science*, 66: 406-415.
- Eyles, A. et al., 2009. Role of corticular photosynthesis in recovery following defoliation in *Eucalyptus globulus*? *Plant Cell and Environment*, 32: 1004-1014.
- Macinnis-Ng, C.M.O. et al., 2009. Root biomass distribution and soil properties of an open woodland on a duplex soil. *Plant and Soil*.
- O’Grady, A.P. et al., 2009. Convergence in water use within an arid-zone woodland. *Oecologia*, 160: 643-655.
- O’Grady, A.P., Worledge, D. and Battaglia, M., 2008. Constraints on transpiration in *Eucalyptus globulus* in southern Tasmania. *Agricultural and Forest Meteorology*, 148: 453-465.
- O’Grady, A.P., Worledge, D., Wilkinson, A. and Battaglia, M., 2008. Gradients in photosynthesis and respiration within dominant and suppressed *Eucalyptus globulus* trees. *Functional Plant Biology*, 35: 439-447.
- Quentin, A. et al., 2009. Do artificial and natural defoliations have similar effects on physiology of *Eucalyptus globulus* Labill. seedlings? *Annals of Forest Science* (In Press).