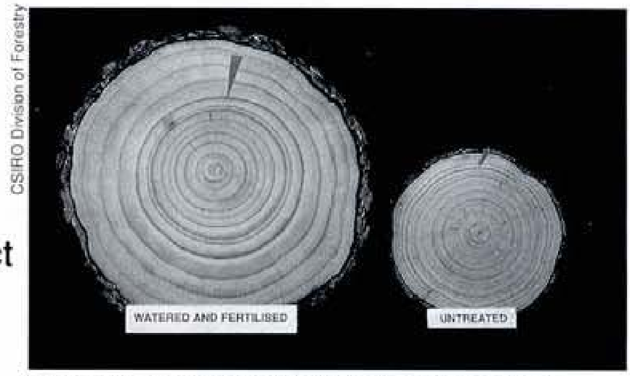
More wood from plantation trees

Ways of working out how climate change may affect tree growth and what impact forests may have on the build-up of atmospheric carbon dioxide are among spin-offs from a major study of the biology of forest growth



Stem sections from an untreated and an irrigated and fertilised tree. The arrows show similar tree size before treatment began 4 years earlier.

Australia's imports of timber and wood products exceed our exports by about $2 billion a year. If existing plantations can be coaxed to produce more wood, this will have the important economic benefits of reducing that trade imbalance and increasing the return on investment in the plantations. It will also reduce demand pressures from Australia on overseas timber supplies.

So research that is showing what levels of productivity are possible in plantations and what approaches should produce the best results has some important implications.

Two major reasons why plantation trees don't grow as fast as they could are fairly obvious — shortages of nutrients and water. Solutions are not so easy, largely because we don't know enough about the intricacies of how trees respond to their environment. Without that knowledge, forest managers can't predict with any certainty how stands will respond to the main options available for boosting growth — thinning (to make more water available to the remaining trees) and application of fertiliser. The result is less-than-optimum plantation production.

Over the past 10 years a research team from the CSIRO Division of Forestry, collaborating with scientists at the Division of Soils and the Australian National University, has come a long way in filling the knowledge gaps. Working in a radiata pine (*Pinus radiata*) plantation near Canberra, the team has observed in detail what happens to stands subjected to a range of treatments. They have used their findings to develop a complex tree-growth model and are now working on the development of simpler models that plantation managers will be able to use to help plan operations.

The project, called the biology of forest growth study, began in 1983, when the researchers marked out a series of very similar quarter-hectare plots in a pine forest planted in 1973 following the harvest of radiata pine established on the site in 1935. Summer drought and soil low in organic matter and nutrient reserves make the area far from optimal for tree growth.

To enable them to find out how trees respond to different growing conditions, the team applied a varied range of treatments. Plots received one of the following:

- two applications of solid fertiliser, 6 weeks apart, totalling about double the quantity of nitrogen and phosphorus applied in routine plantation management — aimed at removing inadequate nutrition as a factor limiting growth for several years and then enabling study of the effects of redeveloping nutrient stress
- irrigation, applied by sprinklers when needed, to remove lack of soil moisture as a factor limiting growth
- irrigation plus the solid fertiliser treatment
- irrigation plus liquid fertiliser supplied through the irrigation system, aimed at removing both soil-water and nutrient deficiencies as constraints to tree growth

In addition, the team left a control plot unirrigated and unfertilised.

Showing just how much difference added water and nutrients can make, the researchers recorded an increase from 13 to 44·3 sq. m in the basal area of trees in the plots given irrigation plus liquid fertiliser in the 5 years to winter 1988 — compared with a much smaller increase from 12·5 to 25·6 sq. m in the control trees. This translates to more than double the rate of wood production in the treated plots.

The trees given solid fertiliser and irrigation did nearly as well — in fact, both fertiliser-plus-irrigation treatments produced levels of productivity higher than those previously recorded in radiata pine in Australia and near the upper limit for forests world-wide. Irrigation and fertilisation on their own each gave some boost to growth, but the effect of the combined treatments was much larger than the sum of the effects of both on their own.

While these results show that great potential exists for increasing plantation productivity, in the real world it is seldom possible to provide irrigation or to supply all of the nutrients a stand needs. So for practical purposes the detailed measurements made of how trees respond to added water and nutrients at different times of the year and under different growing conditions are more important. Such information can help foresters plan fertilisation, thinning and other activities to achieve the maximum growth benefits.

Illustrating what's possible, Dr David Flinn of the Victorian Department of Conservation and Environment and Dr John Turner of the New South Wales Forestry Commission concluded in a 1990 study that more intensive management involving thinning, fertilisation and genetic improvement could yield an additional 1·7 million cubic metres of wood each year from Australia's 650 000 ha of radiata pine plantations. That is equivalent to the production from 94 000 ha of new plantations at current yields.

The detailed information gathered in the biology of forest growth project came from intensive monitoring of the experimental stands. For example, to keep track of water stress, researchers measured pine-needle water tension before dawn at 2-week intervals for 4 years. This required a fortnightly 4 a.m. tree climb, because measurements need

The automatic dendrometer measured day and night changes in stem growth.

to be made when water in the tree is in balance with that in the soil — a state reached during the night as trees do not transpire then.

Other fortnightly measurements tracked soil water content, patterns of stem growth and the development of new foliage. The scientists also measured many other variables, including rainfall interception by the trees, stem flow, plant uptake and leaching of nutrients, growth of pine cones and flowers, needle growth, litter fall and the concentration of nitrogen in different parts of the tree.

They found that on the study site nitrogen availability was the key nutritional factor limiting tree growth. As a result, they put a great deal of effort into following what happens to nitrogen as it moves between soil and tree and within the tree, and into working out the most effective ways to satisfy demand for the nutrient.

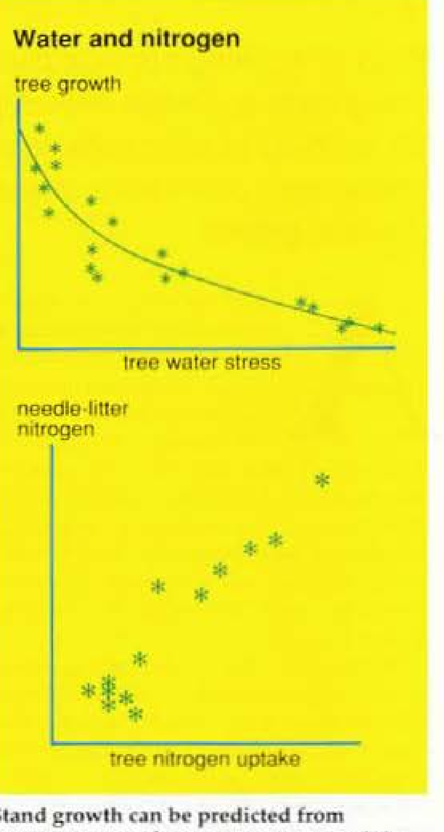
One interesting finding, by the late Dr Wilf Crane of CSIRO and Dr John Banks of the Australian National University, was the extent to which nitrogen 'translocating' from older foliage can contribute to the needs of new growth. The researchers found that during the first year after heavy fertilisation trees took up nitrogen from the soil very rapidly and 'retranslocation' from older foliage was negligible. However, in following years, even when further substantial quantities were added to the soil, nitrogen flowed from older foliage in large amounts — often providing more than half the total taken up in new growth.

The team's demonstration of the importance of nitrogen in boosting tree growth has clear implications for plantation managers; for instance, it reinforces the value, shown in other CSIRO research, of 'slash retention' (leaving harvest residues to decay in the forest) and of growing nitrogen-fixing legumes between tree crops. Their detailed findings on what happens to added nitrogen can be used to modify fertilisation practices to increase efficiency.

As soil moisture is a major factor affecting trees' response to nitrogen fertiliser, the goal should be to fertilise in seasons when it allows rapid uptake of nitrogen. Once stored in the tree, the nutrient can be utilised over a period of several years. Late winter is the best time to fertilise in areas likely to experience dry summers; this increases the chances for significant nitrogen uptake before the onset of water stress.

How do you tell whether a plantation is short of nitrogen and would benefit from fertilisation? This has been quite a problem, largely because of the extent to which the element moves around within a tree, making sampling of foliage for testing extremely difficult. The practical solution proposed by CSIRO's Dr John Raison is to measure the concentration of nitrogen in pine needles when they are shed, or that in fresh needle litter on the forest floor. Tests have shown this gives a reliable measure of the nitrogen status of a pine plantation.

Another practical outcome of the research is the development, by Mr Brian Myers of CSIRO, of an index of water stress — a means of smoothing out water-stress measurements taken over a period to obtain a reliable picture of the state of the plantation. The index is negatively correlated with tree growth.



Stand growth can be predicted from measurements of tree water stress, and the nitrogen in needle litter provides a measure of the nitrogen status of stands.

Irrigating with sewage effluent

Information from the biology of forest growth study on how plantations respond to added water and fertiliser has uses beyond helping boost wood production. An increasingly important application will be in planning plantations whose primary purpose is sewage treatment. Disposal of municipal and industrial effluents in rivers is a major source of environmental pollution in Australia, and the use of effluents to irrigate tree plantations is becoming an increasingly popular alternative.

What the planners need to know is how much effluent a plantation of a particular size at a given location can treat. This information will put them in a position to plan an effluent-irrigation system that eliminates the need for nutrient discharges into rivers or the ocean. How much wood the plantation will produce is a secondary consideration; to achieve maximum nutrient take-up, managers will harvest trees early — at the end of their period of maximum foliage growth — when the wood is unlikely to be good for anything except pulp, fibre products such as chip boards or firewood.

Mr Brian Myers of the Division of Forestry has drawn on the study findings to develop a model, called WATLOAD, that enables planners to calculate the amount of effluent that can be applied to a plantation in a particular climate without causing nutrient contamination of nearby waterways. They can calculate the area of plantation needed to treat a given volume of effluent and how much effluent will have to be stored during winter, when the trees are not growing, for application in spring.

The recently launched Wagga effluent plantation project, run by CSIRO and supported by the Land and Water Resources Research and Development Corporation, Murray–Darling Basin Commission, New South Wales Public Works Department and Wagga Wagga City Council, will throw more light on the prospects for large-scale use of plantations for sewage disposal. It will also provide the opportunity to validate and further develop WATLOAD.

Plantation managers may be able to use the information derived to assess the susceptibility of stands to insect attack, because trees under stress are the ones at most risk.

Another member of the Division of Forestry team, Dr Ross McMurtrie, who is currently at the University of New South Wales, developed the model that brings all the findings together. Called BIOMASS, its uses include predicting the impacts that forest management practices such as thinning and fertilising, and disturbances such as disease and insect attack, will have on growth or on water use. Researchers can also use it to evaluate the likely effects on tree growth of climate changes — such as possible temperature rises and rainfall changes due to the enhanced greenhouse effect.

The model simulates tree growth in general — not just the performance of radiata pine — and is now undergoing an international evaluation under the auspices of the Scientific Committee on Problems of the Environment. The assessment team is comparing its performance with that of five other forest-growth models using data from two sites — the experimental one near Canberra and a cold forest site in Sweden.

One use for BIOMASS, as a research tool, will be to evaluate simpler forest-growth models that plantation managers can use. Research at CSIRO and the University of New South Wales on such models has received funding from the National Greenhouse Research Advisory Committee. Accurate models will have many potential applications; one of the most important may be determining the contribution that plantation and native forests could make to mopping up excess carbon dioxide in the atmosphere.

Robert Lehane

More about the topic

'The Biology of Forest Growth Experiment.' Ed. R.J. Raison and B.J. Myers. Special issue of *Forest Ecology and Management*, 1992, **52** (in press). The issue contains 14 papers describing the major results of the biology of forest growth study.

Opportunities for increased softwood production through intensive site and nutrient management. D.W. Flinn and J. Turner. In 'Prospects for Australian Forest Plantations', ed. J. Dargavel and N. Semple. (Centre for Resource and Environmental Studies, ANU: Canberra: 1990.)

More plantations?

A major reason for looking to increased output from existing plantations as a way of boosting Australia's wood production is the shortage of suitable land for new plantations. A report prepared last year for the National Plantations Advisory Committee, a federal government advisory body, gives an indication of how much land may be available.

Prepared by Dr Trevor Booth and Mr Tom Jovanovic, of the CSIRO Division of Forestry, the report looks at the potential for establishing plantations on cleared agricultural land. Excluding existing forested areas and land in national parks and reserves from consideration, the scientists assessed plantation potential in terms of rainfall, soil fertility and topography. They focused on eucalypt plantations, but their findings also broadly apply to other species, including radiata pine.

Not surprisingly, it turned out that the best land for plantations was also generally the most productive for agriculture. As new plantations take many years to begin to provide any return to an investor, the chances of any such land being turned over to trees are minimal. Marginally productive agricultural land that is also suitable for tree plantations offers the best prospects.

The researchers mapped land in terms of plantation capability and intensity of agricultural use. Of a total of about 18·5 million ha, they rated 5·59% — just over 1 million ha — as having high plantation capability and low agricultural intensity. This is the combination of categories most likely to lend itself to plantation development. A further 2·14% — nearly 400 000 ha — had medium capability and low agricultural intensity.

These areas are quite large compared with the 650 000 ha now under radiata pine and less than 100 000 ha in eucalypt plantations. Economic and social factors will determine their availability. Whether a 1987 forest industry proposal to increase the area under plantations by nearly 600 000 ha is achievable remains to be determined. Meanwhile, increasing the productivity of suitable land already under plantations is a logical way to increase Australia's wood supply.

How good is the wood?

A potential problem with the use of nitrogen fertiliser (or sewage effluent) to boost plantation growth is that the fast-growing trees may develop growth deformities that will downgrade their value for timber production. Excess nitrogen can lead to the development of large persistent branches and other examples of 'poor tree form'; this problem has made itself felt in some plantations established in nutrient-rich former pasture land.

Researchers from the biology of forest growth study are confident that the problem can be avoided through careful selection of planting stock and management of fertilisation. They also believe that another potential problem, a loss of wood density due to rapid growth, should not be a major concern.

They have found that wood produced when the trees are growing fastest in spring and early summer is indeed less dense than the equivalent wood in unfertilised trees, as the cells that make it up grow to a larger size. Balancing this, though, an increased quantity of denser 'late wood' forms in late summer and autumn.

Forestry Division researchers Mr Martin Benson and Mr Brian Myers are collaborating with Dr Robert Evans of the CSIRO Division of Forest Products in Melbourne in a study of plantation wood quality. At this stage it appears that fast growth does not mean a loss of pulping quality.

CSIRO Division of Forestry

This branch, from the control stand, shows the contrasting needle lengths produced in years of differing rainfall.