Taming f

Eucalyptus diversicolor, karri forest.

orest fire

Liana Christensen traces the interplay of nutrients and fire in Western Australia's thinned regrowth karri forest.

Australia stands to benefit if recognised internationally as an ecologically-sustainable producer of timber. However, reaching this goal requires continual assessment of environmental, economic and social factors associated with the industry.

As part of this process, it is essential to expand our scientific knowledge of forest management to provide a solid database to underpin operational, social and political decision-making.

Understanding the effects of fire in karri (*Eucalyptus diversicolor*) regrowth stands will lead to more efficient forest management practices. Research in this area is being conducted by Dr Tony O'Connell, of CSIRO's Division of Forestry, and Lachlan McCaw, of Western Australia's Conservation and Land Management Department (CALM).

An outcome of their work so far has been the development of options for hazard reduction burns which will minimise the risk of wildfires while also limiting disturbance to the forest nutrient cycle.

Even-aged eucalypt stands that regenerate after wildfires or clear-felling are an important part of the forest estate in Western Australia, Victoria, Tasmania and south-eastern New South Wales. In such stands, commercial thinning is becoming more widely practised, even in young stands.

Fire management has always been a part of forestry in Australia. In WA especially, regular fuel reduction or 'prescribed' burns have been used for many years. The aim of this strategy is to limit the build-up of litter and other fuels to reduce the possibility of uncontrolled wildfires which may damage the forests and endanger human life and property. Because of the sensitivity of young trees to fire, however, burning operations in regrowth stands have usually been delayed for at least 20 years after regeneration.

Principles for fuel reduction burning in these young (20-25 years old) stands have been developed and tested on an operational scale in several States, but are not yet routinely applied. Research aimed at integrating silvicultural and fire protection objectives in regrowth stands is therefore of interest to managers of eucalypt regrowth Australia-wide.

In WA's karri forest, Lachlan McCaw has been carrying out experimental burns of slash left after thinning to find the optimum timing for prescribed burning in thinned regrowth stands. To do so, he must assess fuel quantity, fuel dryness, wind speed, tree size and air temperature in order to reduce the fuel hazard, while preventing damage to retained crop trees. It is a delicate balance, requiring a thorough knowledge of the forest's characteristics.

Lachlan McCaw

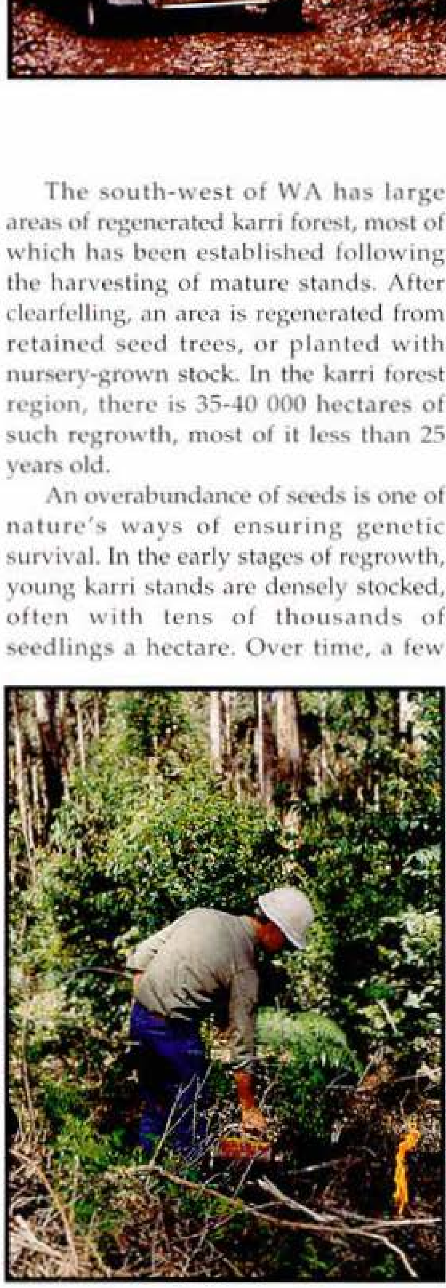
The south-west of WA has large areas of regenerated karri forest, most of which has been established following the harvesting of mature stands. After clearfelling, an area is regenerated from retained seed trees, or planted with nursery-grown stock. In the karri forest region, there is 35-40 000 hectares of such regrowth, most of it less than 25 years old.

An overabundance of seeds is one of nature's ways of ensuring genetic survival. In the early stages of regrowth, young karri stands are densely stocked, often with tens of thousands of seedlings a hectare. Over time, a few establish dominance, and the remainder – weaker or less favourably positioned – gradually decline and die. Mature forest often consists of fewer than 100 trees per hectare.

When managed regrowth forests are thinned at about 20 years, this mimics and accelerates the natural process, thus increasing the rate at which retained dominant trees grow. This 'time management' effectively allows a greater amount of usable wood to be produced in a smaller area. It does this in two ways: the rotation time is shortened and sawlogs are produced more quickly. Also, small suppressed trees, which would otherwise die and decay, are salvaged during thinning.

Even before thinning, regrowth stands have large amounts of fuel. At 20 years, about 30 tonnes per hectare of litter have accumulated from karri and the dense understorey species which commonly grow in the forest, for example, hazel (*Trymalium floribundum*) and the native legume shrubs (species of *Acacia* and *Bossiaea*).

After thinning, the small branches and leaves left on the forest floor add to forest floor fuels. Because the forest canopy is more open, this fuel dries out more quickly, increasing the fire hazard.



Lachlan McCaw

Lighting a prescribed fire with a drip torch. During trials to be carried out in spring, helicopters will be used to improve the efficiency of fire ignition.

Young karri are vulnerable to fire. Until the tree is protected by a sufficient thickness of bark (usually when the stem is at least 20 cm in diameter) even low intensity fires may prove fatal. Fire damage to tree stems can increase their susceptibility to insect attack and wood-decaying fungi, both of which degrade the timber. How, then, can you maximise wood production while minimising fire hazard and maintaining other forest values?

You cannot do so without a broad focus. Dr Tony O'Connell has been investigating the subtle interplay of forest management, especially fire, and nutrient cycling. He has found that a lot of the thinning slash is nutrient-rich compared with the normal leaf litter that falls each summer. (With ordinary senescence, nutrients are withdrawn from leaves before they abscise.) In particular, leaves in slash have a high concentration of nitrogen and phosphorus, the two most important nutrients for forest growth (Figure 1). As the leaves decompose, these nutrients are recycled in the soil and used by the retained trees.

O'Connell's work has shown that the rate at which leaves in thinning slash decay and release their nutrients is relatively rapid compared with the rates for normal litter. This is particularly so for understorey species, which have both high nutrient content and rapid rates of decomposition.

Far left: Fifteen-year-old karri regrowth before thinning.
Left: A 23-year-old karri regrowth stand after thinning. Thinning allows a greater amount of useable wood to be produced in a smaller area.

When litter and slash are burnt during fuel reduction burning, much of the nutrients they contain are deposited on the soil surface in ash. However, some nutrients – notably nitrogen – are converted to gas, the amount of which can be predicted precisely from the amount of fuel consumed (Figure 2).

Although the amounts of nitrogen volatilised during any single fire are small compared with the amount of nitrogen in the soil, the cumulative effects of many fires may affect the total store of nutrients in the ecosystem. It is this aspect which claims the attention of O'Connell. Together with McCaw, he is researching ways to understand this process, and thus manage the nutrients (especially nitrogen) on site.

Experiments during 1991 and '92 provided baseline data about the effects of fire on nutrients and on trees. After an experimental fire, O'Connell found nutrients and fuel may be:

- redistributed from one part of the litter layer to another, (for example, some nutrients end up in the leaf and twig fraction in the lower strata of the fuel bed);
- transported to the soil surface, in the form of ash;
- moved outside the sampling area, in the form of ash or smoke; or
- volatilised and released to the atmosphere as gas (particularly nitrogen and sulfur).

What, then, are the options for hazard reduction burns that minimise the risk of wildfires while also limiting disturbance to the nutrient cycle?

Fire options

One possible solution is to defer burning until most of the thinning slash has decomposed: O'Connell's research has shown that 60-90% of the nutrient-rich leaf mass decayed within two years (Figure 3). Once the leafy component of the slash has decomposed, the fuel bed is less volatile, and not so likely to scorch the crowns of the trees. However, woody fractions that remain in the slash decay slowly, delaying the release of nutrients into the forest soil (Figure 4).

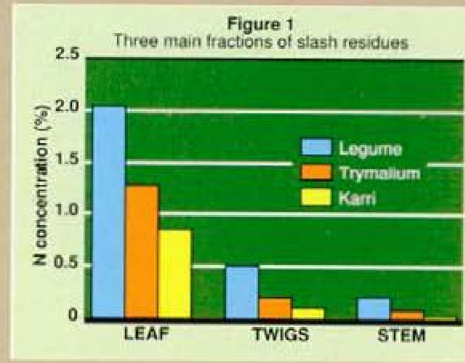
These woody remnants – branches larger than 50 millimetres in diameter – can remain in the fuel bed for up to 10 years (unless it is burnt, of course). Because of this, a fire during dry conditions (even at fairly low levels of fire danger) will almost certainly damage retained crop trees severely. Although postponing burning after a thinning operation helps retain nutrients on site, it can only be used where the risk of wildfire is low, and never in stands that are near towns or valuable assets.

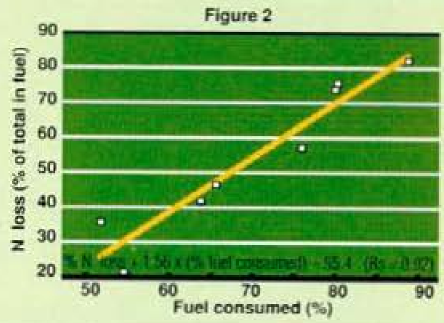
The other possibility is to burn under very specific conditions. You can safely burn in thinned karri regrowth and minimise nutrient loss, provided you know how and when.

Mild spring conditions are optimal. The fuel must be sufficiently dry in order to sustain fire spread, but not so dry as to allow a high level of fuel consumption. There must be no strong winds. These conditions favour both controlled burning and reduced nutrient losses.

The reason for this is that the fine, partly decomposed litter that occurs towards the base of the fuel bed is a rich store of nutrients, especially nitrogen and phosphorus. For example, although (on average) the fine litter and twigs make up only about 30% of fuel weight they contain more than 60% of the nitrogen (Figure 5). Fire regimes which leave this layer undisturbed help to maintain nutrients on site.

During spring this fine material remains moist and with suitable fire prescriptions will remain largely unburnt during fuel reduction





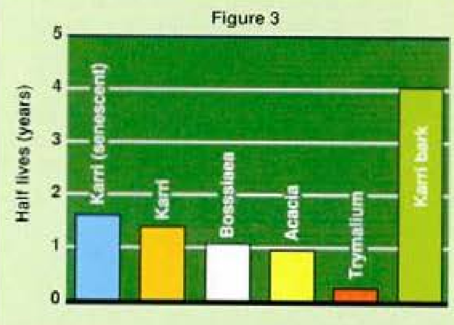
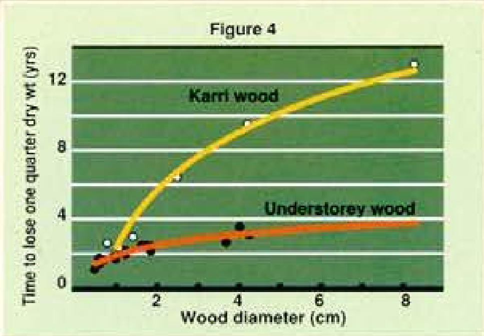
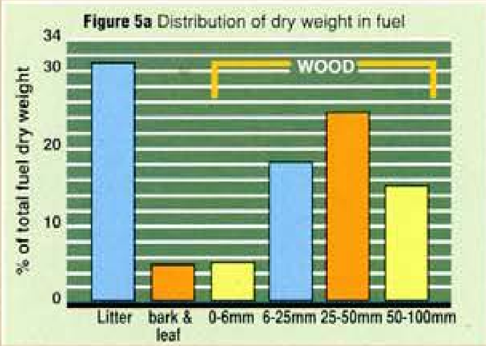


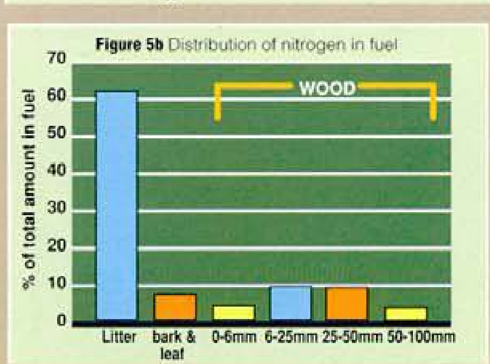
Figure 1: The concentration of nitrogen in different components of thinning slash from karri and understorey species (*Trymalium* and native legumes).

Figure 2 : The relationship between the proportion of fuel consumed and the proportion of nitrogen in fuel that was lost in volatile forms during eight experimental fires conducted under a range of different burning conditions in regrowth karri forest.

Figure 3 : Comparison of the rates of decay (time to lose half of initial weight) of leaves and bark of karri and leaves of the main understorey plants in regrowth karri forest. Senescent karri leaves are those that occur during normal summer litterfall. Other leaf and bark samples came from trees and shrubs removed during thinning operations.







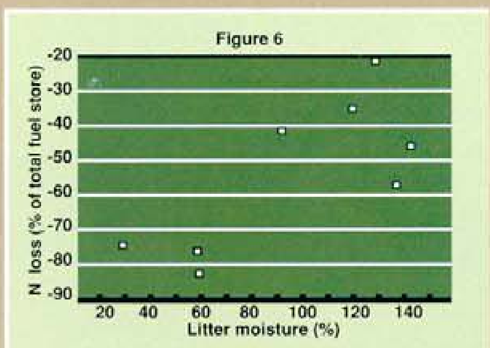


Figure 4: Comparison of rates of decay (time to lose one quarter of weight) of woody residues from karri and the main understorey plants in relation to the diameter of the woody material.

Figure 5: (a) The distribution of weight between different fuel fractions, expressed as a percentage of total fuel weight. (b) The distribution of nitrogen between different fuel fractions, expressed as a percentage of total nitrogen in fuel.

Figure 6: The relationship between the proportion of nitrogen lost from fuel and the moisture content of the litter layer during eight experimental fires conducted under different weather conditions in regrowth karri forest in 1991-2.

operations, thus minimising nitrogen removal (Figure 6). It would be unusual, however, to get ideal burning conditions for more than ten or fifteen days in a year. Therefore, considerable effort is now focused on how best to use this limited time.

McCaw's research has established that low intensity fires in spring will significantly reduce the amount of fuels up to 25 mm in diameter, without scorching the crown or damaging the butts of retained crop trees. Trouble will arise, however, if the fire takes hold of slash greater than 25 mm, or large logs or stumps are ignited. For this reason, the pattern of lighting must be carefully planned and scrupulously supervised to avoid flare-ups in heaped slash, or extensive upslope fire runs.

In short, post-thinning burns are constrained for three reasons: the need for ideal weather conditions; a requirement for carefully controlled ignition; and an awareness of the need to maintain the nutrient balance.

Larger-scale trials carried out in the spring of 1993 attempted to overcome the problem of controlled ignition, by using helicopters. Twenty hectares were successfully burnt. As the trials are scaled up this spring, the use of helitorches means that favourable weather conditions can be fully exploited.

Eventually the trials will provide sufficient data to generate suitable burning prescriptions for thinned regrowth karri. During that process, the scientists will be looking for answers to several questions:

- Is the full complement of nutrients being conserved on site?
- Can we refine fuel descriptors so that they more accurately reflect fuel flammability with time after thinning? For example, breakdown of elevated fine fuels greatly alters the ease of ignition of slash fuels, but is not currently reflected in measurements of total fuel, or even of more specific fuel fractions.
- Do live fuels, such as shoots from a stump developed after thinning, affect the overall flammability of a stand?
- How effective are different levels of fuel reduction in mitigating the potential damage of wildfire in thinned stands?

A 23-year-old thinned stand following low-intensity prescribed fire. When litter and slash are burnt during fuel-reduction burning, much of the nutrients they contain are deposited on the soil surface as ash.

Lachlan McCaw

Lachlan McCaw

Thinning slash following burning. Post-thinning burns are constrained by the need to maintain nutrient balance.

- Can we monitor the moisture content of woody residues which persist in the litter layer for many years, whether it is burnt or not?
- How, exactly, does fire behave in thinned regrowth conditions? It will be different in significant ways from fire in other forest types.
- What effects do fires of different intensity and frequency have on soil biological processes important for nutrient cycling and forest growth?

Continued research is intended to answer these questions.

More about forests and fire

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From physics to forests

Dr Tony O'Connell, originally a physicist, joined CSIRO in 1973 when he came to install a an x-ray fluorescence spectrometer for the Division of Soils. In 1975 he became part of the forest soils group in the newly-formed Division of Resources Management.

O'Connell's research has focused on nutrient cycling in the karri and jarrah forests. In 1991, in line with the increase of plantation forests, he turned his attention to nutrient cycling in *Eucalyptus globulus* plantations.

His present work began in 1989 with an investigation into the composition and decomposition of slash residue. This was followed in 1991 by the joint research with the Western Australian Department of Conservation and Land Management into the effects of fire on nutrient cycling in regrowth karri.

Lachlan McCaw has been with the Department of Conservation and Land Management since 1981. During that time his work has concentrated on on various aspects of fire-related research in forests and shrublands. He has been working on the forest project with O'Connell since 1991.

Dr Tony O'Connell

Lachlan McCaw

Lachlan McCaw

Low-intensity prescribed fire in karri thinning slash. Scientists are researching the effects that fires c different intensity and frequency have on soil biological processes.