

FIRE NOTE

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QUANTIFYING THE IMPACT OF FIRE ON TREE WATER USE

SUMMARY

Some eucalypt forests regenerating after fire use more water than their undisturbed counterparts. This means that fire can directly reduce water yield from forested catchments, posing a direct threat to the supply of water to urban and rural areas. This *Fire Note* describes the approaches that have been used to assess how different species of eucalypts use water as they regenerate after fire. This information is being used to predict the volume of water that is needed as forests recover over time, and understand the impact of a bushfire on catchment yield. Research shows that after three years mixed-species eucalyptus forests that regenerate by sprouting do not use more water than similar unburnt forests. Since the canopy in the regenerating forest closely resembled a mature, undisturbed forest, it is proposed that water use in the regenerating forest should not increase dramatically as the forest continues to move towards maturity.

ABOUT THIS PROJECT

This *Fire Note* is from *The Fires and Hydrology of South Eastern Mixed-Species Forests* project. It has built upon existing methods of calculating overstorey water use, enabling these methods to be applied to measure water use of resprouting mixed-species forests. This required the research team to characterise the physiology of resprouting for a range of species of *Eucalyptus*, and to use this information to model tree water-use in regenerating mixed-species forests.

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▲ Figure 1: Micro-metrological stations were set up at research sites in north east Victoria to enable continuous measurements of the environmental variables that drive water use by plants.

CONTEXT

The greatest water loss in trees occurs through the leaves. As such, this project has investigated the nature and extent of changes in the structure and physiology of leaves from regenerating eucalypts of mixed-species forests so the properties that exert the most control over tree water use can be determined.

BACKGROUND

The 2009 bushfires in Victoria's north east have undoubtedly changed the hydrology of the forests and by consequence, their water yield. As yet, it is not known how much the hydrology has changed, or how long the effects will last. Research has been conducted in Ash-type forests covering high-yield water catchments such as those in the Central Highlands of Victoria, or

the sub-alpine headwaters of the Murray River (Buckley *et al.*, 2012b). This research has shown that it is the structure and physiology of the regenerating Ash forests that causes more water to be used. After fire, the forest regenerates with a dense, even-aged stand of young leafy seedlings. The water yield is strongly coupled with water use of the vegetation, and for every 1% of catchment burnt, water use 30 years after a fire removed tree crowns reduced stream flow by 6 mm per annum (Kuczera 1987).

In contrast, very little is known about the post-fire water use of mixed-species eucalypt forests, the most extensive forest type in south east Australia. Unlike Ash-type trees, individual trees in these forests are more likely to survive fire and a burnt



▲ Figure 2: An old fire truck with a cherry picker allows researchers to easily access leaves from the canopies for measurements.

canopy doesn't mean the death of the tree. Instead it stimulates new branches to sprout from epicormic buds lying protected under bark soon after the fire. It is likely that a catchment composed of species that can regenerate in this manner would not follow the same pattern of water use as measured for Ash-type forests.

BUSHFIRE CRC RESEARCH

The key area investigated is related to how resprouting eucalypts differ in water use from eucalypts that regenerate from seed, such as Ash-type eucalypts. In general, tree water use depends on features in the local forest environment that control movement of water through a plant, such as how dry the air is (Gharun *et al.*, 2013a, b) and how moist the soil is (Leuning *et al.*, 2005). On a landscape scale, features that describe the type of trees

present, how dense the forest is and the size of the forest involved are important (Mitchell *et al.*, 2012). The degree of control of water loss from leaves is determined by the physiology of the leaf including the leaf structure, age and total leaf area.

There has been limited catchment-related research in mixed-species eucalyptus forests (including Mitchell *et al.* 2012), and as a consequence, there is little data on the water use of resprouting eucalyptus. The approach used in this study was to measure a range of variables that are known to be important regulators of plant water use (e.g. Buckley *et al.*, 2012a):

- Weather and soil water content.
- Forest and tree structure.
- Leaf anatomy.

END USER STATEMENT

Much is known about the water use of Ash-type eucalypt forests that are killed by fire, but land managers currently have a limited understanding of the water use of eucalypts that recover by resprouting. The mixed-species eucalypt forests targeted in this project represent the type of forest that forms important water catchment areas in New South Wales and Victoria that provide clean water to Sydney and Melbourne. By using the range of techniques described, this project will fill a significant gap in the current knowledge of water use by trees after fire and will help inform future management and protection decisions made about these forests.

- Tim McGuffog, Corporate Fire Manager, Land Management and Forestry Services, Forests NSW

These variables were used to test how well tree water use of eucalypts in mixed-species forests can be modelled.

WEATHER AND SOIL WATER CONTENT

The flow of water through soil, into a plant and out through its leaves (transpiration) is controlled by the environment within the soil (soil water content), the structure of a leaf and the atmosphere around the tree crown.

Water moves from wetter environments to drier. As a result, soil moisture content and structure (the capacity to retain moisture), air temperature and relative humidity are all important factors in tree water use. Additionally, as water moves from soil, through a plant and into the atmosphere it meets resistance along the way. The greatest resistance arises in the leaf; at the pores (stomata) in the leaf surface through which water exits, and at the layer of air directly adjacent to the leaf surface. Bright sunlight, warm, dry air and moist soil cause the stomata to open. In contrast, darkness, cool air, wet weather and dry soil can all cause stomata to close.

Micro-meteorological stations were established at each research site. This enables continuous measurement of the environmental variables that drive plant water use (figure 1, page 1).

FOREST AND TREE STRUCTURE

The structure of a forest influences the amount of water it uses. Older forests use less water than younger forests, and burnt Ash-type eucalypt forests use more water than the older forests they replaced (Buckley *et al.*, 2012b).

Within the trunk and stems of a tree, water moves through tissue called sapwood. Water moves through the sapwood of both old trees and young trees at the same rate (Dunn and Connor 1993). The difference in water use between burnt and unburnt forests depends on the total amount of sapwood in the forest. To calculate how much water is used by trees, the number of trees in a given area needs to be known, along with what proportion of their trunk consists of sapwood. Sensors installed into the sapwood of individual trees of a range of sizes to measure the rate of movement of water through the stem (figure 3, right). Sap flow is recorded at half-hourly intervals, and patterns of water movement are interpreted using micro-meteorological data.

LEAF ANATOMY

The rate at which water flows from soil to the atmosphere through a plant is influenced by the demand for water by leaves in the canopy. The 'leafiness' (leaf area) of a forest is measured, along with the structural properties of leaves to assess how much water is used by the canopy throughout the day and during different times of the year.

The leaf area of a forest is measured by photographing the canopy from the ground (Bréda 2003). From these images, the leaf area index (leaf area per unit ground area) can be calculated. In forests that regenerate via sprouting, this method does not work particularly well as leaves are clustered tightly around the trunk and stems and images are difficult to interpret (figure 4, bottom right). In situations like this, leaf area index photography is supplemented with actual measurements of leaf area. The number and size of branches are mapped along the tree trunk and stems, and the relationship between branch size and leaf area is determined. From these measurements, the total area of leaves for each tree can be calculated.

Additionally, other sources of resistance to water loss within an individual leaf need to be investigated. The 'porosity' of leaves is determined by counting the number of stomata, measuring their size and the maximum aperture of the stomatal pore or how wide the stomata can open (figure 5, page 4).

Patterns in leaf anatomy need to be further examined in order to calculate how water is conducted through a leaf. This involves measuring the perimeter of 'wet' cells (that is, types of cells known to evaporate water) in relation to the volume of airspace within a leaf, and coupling these measurements to other anatomical features of leaves including the density of water-supplying veins.



▲ Figure 3: Sensors measure the rate of movement of water through a stem.



▲ Figure 4: The leaf area of a forest is measured by photographing the canopy as viewed from the ground. At left, resprouting eucalypts make this difficult, so the number and size of branches need to be mapped to determine leaf area.

- ▶ **Figure 5.** Water escapes from plants through leaves. Here, the pores (stomata) of a leaf are shown; two are open. Sunlight stimulates the pores to open.

RESEARCH OUTCOMES

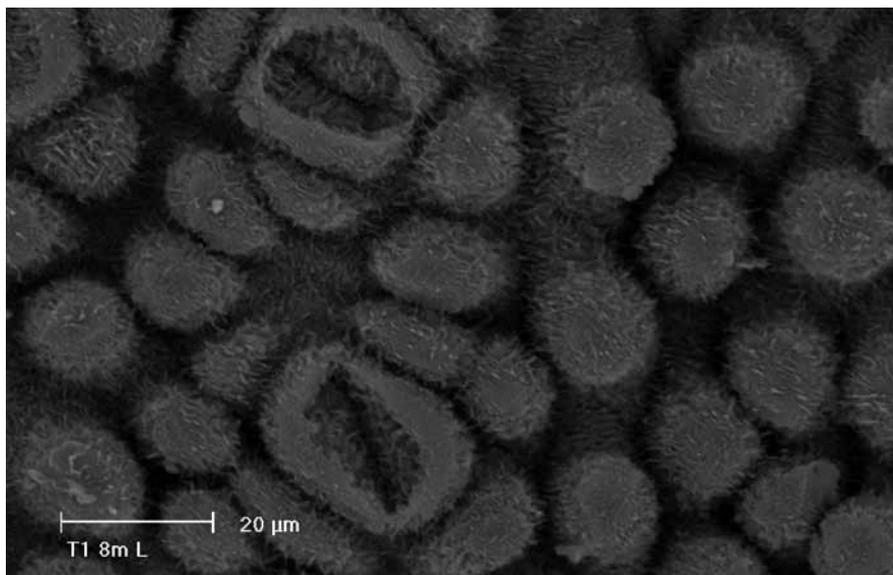
A simple model of accurately predicting sap flow in eucalypts based on variables known to control stomatal conductance has already been published as part of this project (Buckley *et al.*, 2012a). Tests have also been conducted to understand how well water use in mixed-species eucalypt forest can be predicted using an existing and well-known empirical eco-hydrological model (Gharun *et al.*, 2013a).

The next logical step was to measure *in situ* the volume of water used by mixed-species eucalypt forests as they regenerate after a fire. By undertaking this, it was discovered that after three years, forests that regenerate after fire by sprouting do not use more water than unburnt forests (Gharun *et al.*, 2013b). Furthermore, since the canopy in the recovering forest closely resembled mature, undisturbed forest, the research team proposes that water use in this regenerating forest should not increase dramatically as the forest continues to move towards maturity.

Based on this research, knowledge of water use by trees will enable land managers to predict how much water forests use post-fire, and how long the effect might continue. To protect the water supply from forested catchments, these findings can be used when planning the location and extent of prescribed fires within mixed-species forests and determining the effect of bushfire on water yields.

FUTURE DIRECTIONS

The next step is to combine data from the physical environment, physiological measurements of leaves and sap flow measurements of individual trees to predict landscape-level impacts of fire on catchment water yield in mixed-species eucalypt forests.



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