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Stand water use status in relation to fire in a mixed species eucalypt forest

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ABSTRACT

Previous research on seed-regenerating eucalypt species (e.g. ash-type eucalypts) posits that water use by regenerating forests increases quickly after fire and may exceed that of mature forests (by as much as 100%) for periods of many decades. This hypothesis has not been tested in forests dominated by resprouting eucalypts. We examined the effect of fire on tree and stand-level water use in a resprouting mixed species eucalypt forests close to Stanley in north-east Victoria, Australia.

In general, rates of water use in regenerating mixed-species eucalypt forests 3 years after fire were very similar to those for adjacent unburnt mature forests (0.48 ± 0.14 in regenerating vs. 0.66 ± 0.17 mm day^{-1} in unburnt forest, mean ± 0.95 CIs). This clear difference between resprouters and seeders corresponds to: slower sap flow in resprouting trees; a comparatively limited increase in sapwood area index (22% compared to 70% in Alpine ash forests); and a 20% decrease in total leaf area index after the fire. While the general climate differed little amongst study forests due to their close spatial proximity, vapour pressure deficit within unburnt was greater than regenerating forest and was the main control of tree water use, irrespective of species. Midday leaf water potential and measures of leaf physiology (except stomatal conductance) derived from gas-exchange measurements were similar between mature and resprouting trees, but the stomata of resprouting trees maintained a greater conductance to water vapour than mature leaves.

A few years after crown-removing fires, water use by resprouting mixed-species eucalypt forests was little different to nearby mature forests. These results strongly contrast post-fire patterns in water use for the seeder (ash-type) eucalypt forests.

1. Introduction

The mixed-species eucalypt forests of south-east Australia's low-elevation foothills meet much of the water needs of rural communities within the Murray Darling Basin. These mixed-species forests are dominated by eucalypts that mostly regrow vegetatively after fire via sprouting from stems and large branches (epicormic buds). Fires that are of sufficient intensity to destroy forest canopies also promote the sprouting of epicormic shoots from bud tissues located below the bark. Dominance of forests by such resprouting eucalypts is generally considered to be intimately associated with fire regimes. For example, more frequent fires of lower intensity in drier forests are associated with dominance of resprouters, while seeders are dominant in wetter forests where fires are less frequent but of much higher intensity. Regenerating via epicormic sprouts is the norm for eucalypts inasmuch as less than 10% of the more than 700 eucalypt taxa are obligate seeders (Nicolle, 2006). Even so, the published literature on fire effects on hydrology of eucalypt forests is overwhelmingly focused on ash forests where seeders dominate.

Catchment management, including guiding hydrological models, has thus often been based on conceptual understandings that are based on responses to fire by ash-type forests. Currently, management relies on generalizations based on the response of ash-type forests (e.g. Watson et al., 1999) where the landscape is transformed into mosaics of even-aged regenerating forest (Kuczera, 1987; Langford, 1976). These conceptual (and empirical and mechanistic) models predict a reduction in yield that can persist for many decades (Dunn and Connor, 1993; Vertessy et al., 1995, 1997, 2001). Recently, Buckley et al. (2012) showed that within 7 years of a major bushfire in Alpine ash (*Eucalyptus delegatensis*) forest, evapotranspiration (E_t) had increased more than two-fold, suggesting a major reduction in water yield (consistent with the Kuczera-type response).

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With the exception of Alpine ash forests (Buckley et al., 2012), we know little of the dynamics of forest water use in the first few years after fire in seeder eucalypt forests and almost nothing about fire effects for resprouting mixed-species forests. Changes in E_t following bushfires may be due to many factors, including the structure and density of forests. Stream flow from eucalypt-dominated catchments is strongly leveraged to tree water use given that as much as 80% of incoming rainfall is returned to the atmosphere via E_t (Adams and Attiwill, 2011) and small changes in E_t at the landscape scale result in large proportional changes in run-off. As recently highlighted by Roderick and Farquhar (2011) in their development of the utility of Budyko approaches to predicting water yield, there is a profound lack of a broadly based knowledge of the effects of fire on E_t, especially in forests other than ash type where large areas were burnt by high intensity wildfires over the last decade (Attiwill and Adams, 2013).

Past hydrological research in mixed-species eucalypt forests has focused on drought (Mitchell et al., 2012) and silvicultural regime (Cornish, 1993; Cornish and Vertessy, 2001; Lane and Mackay, 2001) effects on catchment water yield. While the water yield effects of regeneration processes in mixed-species forests have not been documented, they seem unlikely to mirror those of ash-type forests. Trees that regenerate by seed tend to create even-aged forests whereas forests of trees that regenerate vegetatively are characteristically multi-aged (Attiwill, 1994). This complex structure means that generalisations about stand water use based on ash-type forests cannot be applied with confidence. Further complications arise from the multiple eucalypt species that form the forest canopy, and the variation in soils upon which these forests grow. At least eight species of peppermints (e.g. *Eucalyptus radiata*, *Eucalyptus dives*), stringybarks (e.g. *Eucalyptus obliqua*, *Eucalyptus macrorhyncha*, *Eucalyptus baxteri*) boxes (e.g. *Eucalyptus goniocalyx*, *Eucalyptus polyanthemos*) and gums (*Eucalyptus mannifera*, *Eucalyptus globulus*), each with its own structure and physiology, contribute to mature canopies in mixed species forests in south-eastern Australia. In contrast to adjacent ash-type forests that grow on deep, mostly homogenous and well-structured soils (Lacey and Grayson, 1998), mixed-species eucalypt forests grow upon heterogeneous substrates of varying structure and moisture-holding capacities. Typical soils range from shallow duplex profiles, with high proportions of sand and rock that typify steep slopes and higher peaks, to weakly bleached yellowish gradational soils or friable reddish gradational soils that are found on low-elevation sites (Clutterbuck and McLennan, 1978).

In the context of climate change, and increasing frequency of high intensity bushfires and longer fire seasons (Lucas et al., 2007), the effects of fire on water use by mixed-species forests, and consequently catchment water yield, are of increasing scientific interest. The effects on water yield for the first 10 or so years post-fire have not been studied in detail. We sought to address the serious lack of knowledge of the stand-level hydrology of mixed-species eucalypt forests for the post-fire period in which they contain leaves of juvenile form growing on epicormic branches along the entire height of the tree. Study sites were located in north-east Victoria, Australia, in forest that was burnt in 2009. We hypothesised that water use in the mixed-species forest would not increase significantly after fire.

2. Methods

2.1. Site description

The study area is located within the Stanley State Forest, approximately 10 km to the south of Beechworth in north-eastern Victoria (36°25′S, 146°43′E). Mean annual rainfall (1971–2000) is 1014 mm with 90 days rainfall > 1 mm (Australian Bureau of Meteorology). The geology of the area is characterised by Ordovician aged sediments with sandstone, shale and mudstone horizons within fractured bedrock (Hough, 1981). Much of this forest was severely burnt in 2009 by the series of fires known collectively as the Black Saturday fires. These fires started on January 7th 2009 when temperatures reached >46 °C and wind-speeds >100 km h^{-1}. The fires were precipitated by an intense heat wave and almost 2 months of little or no rain (Pfautsch and Adams, 2012).

The site studied here was dominated by at least five eucalypt species and is typical of the greater region's dry sclerophyll, open forests. The composition of canopy species varies greatly depending on aspect (and exposure), soil depth and altitude. Consequently, we identified patches (>5 ha) in both burnt and nearby unburnt stands where one of the three most common species (*E. radiata* Sieber, *E. dives* Schauer, and *E. mannifera* Mudie) dominated the canopy. We then selected three pairs of study plots (0.25 ha) within these patches (i.e. six plots in total) such that for each species, we had a pair of adjacent (within 500 m) plots in burnt or unburnt condition. Each 0.25 ha plot was selected such that the selected species was the only overstorey species present in the plot. In the burnt plots, the entire understorey and overstorey crown was consumed. In each plot we measured sap flow of the overstorey (three trees of each species), climate, and soil moisture as well as completing a forest inventory. A general description of the selected species is provided in Table 1.

2.2. Soil and meteorological measurements

Soil water content was measured every 6 h within each plot using standing wave soil moisture sensors (MP406, ICT Interna-

Table 1
Characteristics of eucalypt species studied. Descriptions are from Costermans (1981) and Boland et al. (2006).

Species	Climatic distribution	Growth	Annual rainfall (mm)	Species edaphic conditions	Fire response[a]
Eucalyptus radiata Sieber ex DC.	Occur largely on tablelands, more on hill and mountain slopes and sheltered aspects, north east Victoria to NSW	Varies from bushy to tall, 10–50 m	650–1100	Wide range of soils derived from a range of shale and granite parent materials	Resprout from epicormic shoots
Eucalyptus dives Schauer	From edges of plains to foothills of mountain ranges, particularly on drier northern aspects	Medium size, 12–25 m	600–1100	Rock substrates, particularly metasedimentary types, commonly found on poor shallow and stony soils of low fertility	Resprout from epicormic shoots
Eucalyptus mannifera Mudie	Woodland species, common in NSW tableland regions and foothills of north east Victoria	Small or medium size, 6–25 m	600–1600	Skeletal soils of lateaux and hillslope of Triassic and Permian sandstone parent rock	Resprout from basal stem buds

[a] Gill, A.M., Bradstock, R.A., 1992. A national register for the fire responses of plant species. Cunninghamia, 2(4), Fire biodiversity in the Australian Alps national parks, Workshop Proceedings, Albury 2005.