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Post-wildfire recovery of water yield in the Sydney Basin water supply catchments: An assessment of the 2001/2002 wildfires

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SUMMARY

Wildfire is a recurring event which has been acknowledged by the literature to impact the hydrological cycle of a catchment. Hence, wildfire may have a significant impact on water yield levels within a catchment. In Australia, studies of the effect of fire on water yield have been limited to obligate seeder vegetation communities. These communities regenerate from seed banks in the ground or within woody fruits and are generally activated by fire. In contrast, the Sydney Basin is dominated by obligate resprouter communities. These communities regenerate from fire resistant buds found on the plant and are generally found in regions where wildfire is a regular occurrence. The 2001/2002 wildfires in the Sydney Basin provided an opportunity to investigate the impacts of wildfire on water yield in a number of catchments dominated by obligate resprouting communities. The overall aim of this study was to investigate whether there was a difference in water yield post-wildfire. Four burnt subcatchments and 3 control subcatchments were assessed. A general additive model was calibrated using pre-wildfire data and then used to predict post-wildfire water yield using post-wildfire data. The model errors were analysed and it was found that the errors for all subcatchments showed similar trends for the post-wildfire period. This finding demonstrates that wildfires within the Sydney Basin have no significant medium-term impact on water yield.

1. Introduction

Wildfire can lead to considerable changes in the hydrological cycle within a catchment which ultimately affects water yield (total flow for a given time period) at its outlet (DeBano et al., 1998). Loss of vegetation and litter, a decrease in decomposed organic matter and changes in soil properties (formation of water-repellent soils) cause a decrease in infiltration rates and an increase in runoff. Robichaud et al. (2000) suggested that if vegetation cover and litter are reduced to less than 10%, surface runoff may increase by more than 70%. Increased runoff will increase stream flow causing higher water yields immediately post-wildfire. Once vegetation begins to recover post-wildfire more water is consumed as the evapotranspiration levels are increased. Evapotranspiration rates are higher for saplings (1–5 years of age) causing a decline in water yield (Kuczera, 1987). Older trees have a lower evapotranspiration rate due to a slowing of growth meaning catchment water yield begins to equilibrate to pre-wildfire conditions over time (Andréassian, 2004).

Within Australia, a number of published studies have demonstrated the decline in water yield in forested catchments after severe wildfire across a range of environments. Examples include: from Victoria (Chessman, 1986; Kuczera, 1987; Lane et al., 2004, 2006; Langford, 1976), from New South Wales (Brown, 1972; Prosser and Williams, 1998) and from the Northern Territory (Townsend and Douglas, 2000, 2004). The majority of these studies found that change occurred in post-fire water yield, with recovery towards pre-fire conditions occurring between 3 months and 150 years after fire. A summary of the main findings from these studies can be found in Table 1. Generally the studies were somewhat limited by the long recovery period of the catchments, paucity of pre-wildfire data, spatial heterogeneity of environmental factors such as topography and vegetation, wildfire severity and wildfire history (Lane et al., 2006; Miller et al., 2003; Shakesby and Doerr, 2006).

Most of the Victorian studies referenced above assess the relationship between water yield and the regrowth of catchments dominated by *Eucalyptus regnans* (Mountain Ash). *E. regnans* is

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classified as an obligate seeder; i.e. a perennial plant which regenerates post-wildfire through propagation from the seed bank. Regeneration in this species can be delayed for months depending on the intensity of the wildfire and the environmental conditions, ultimately affecting a catchment's hydrology. Once regrowth begins to occur, *E. regnans* repopulate the area in densities in the hundreds of thousands per hectare (Vertessy et al., 2001). Langford (1976) showed that after the 1939 wildfires, regrowth of *E. regnans* did not cause a decline in water yield levels until three to five years post-wildfire. Langford's study found that post-wildfire flow levels over the 21 year study period were only equal to around 24% of pre-fire flow conditions. Kuczera (1987) reassessed the 1939 wildfire using a model based on long term hydrographs (Kuczera's model) and established that Langford's findings were correct and showed a significant decline in water yield post-wildfire. From this model Kuczera developed a curve (Kuczera's curve) which shows the relationship between water yield and vegetation growth post-wildfire. It recognises there is a decline in post-wildfire water yield followed by an increase in water yield which begins to take place approximately 25 years post-wildfire (Fig. 1; Kuczera, 1987). The recovery in water yield should return to pre-wildfire levels by the time the ash stand reaches maturity; l20–150 years after regeneration. The water yield changes within these catchments consequently conform to the life cycle of the seeding species (Kuczera, 1987; Vertessy et al., 2001). This is an important issue as there are over 900 eucalypt taxa within Australia and less than 10% are classified as obligate seeders meaning those studies only represent a small percentage of the Australian landscape (Waters et al., 2010).

Obligate resprouters are perennial plants which regenerate post-wildfire from either epicormic or basal shoots (Waters et al., 2010). Little to no research has been published on post-wildfire water yield within catchments dominated by obligate resprouting species so the flow pattern experienced in a post-wildfire catchment dominated by resprouters is largely unknown within the Australian landscape. As obligate resprouting eucalypts dominate the area around greater Sydney, New South Wales (Keith, 2006), the hypothesis of this study is that the hydrological findings obtained from the Victorian catchments are not representative of the catchment response in the Sydney Basin due to different vegetative communities.

The 2001–2002 wildfires that occurred in outer Sydney Basin from the 24th December 2001–16th January 2002 were extensive (Chafer et al., 2004) and provided the opportunity for investigating the impacts of severe wildfires on water yield for several subcatchments where medium term water yield records were available pre- and post-wildfire. Recent studies have only had a focus on one subcatchment or paired subcatchments when analysing wildfire impacts on water yield (Moody and Martin, 2001; Rosso et al., 2007; Townsend and Douglas, 2000). Therefore the aims of this research are to see if the 2001–2002 wildfires had an impact on the water yield of catchments in the Sydney Basin.

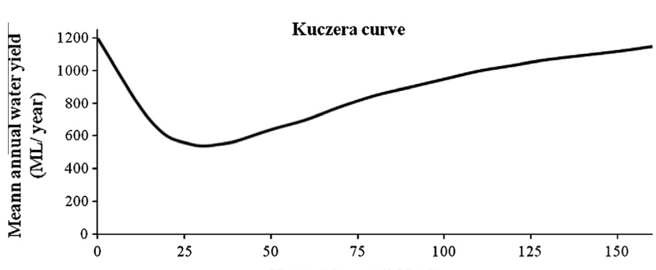

Fig. 1. The Kuczera curve of mean annual water yield since wildfire (based on Kuczera, 1987).

2. Methods

2.1. Study area and datasets

2.1.1. Study area

The study area is located in the Hawkesbury-Nepean catchment in south-eastern New South Wales, Australia (Fig. 2). The subcatchments above four hydrometric stations, whose drainage area was extensively burnt by the 2001/2002 wildfires, were selected, while the subcatchments above three unburnt hydrometric stations were used as controls. Burnt subcatchments were Burke River, Nattai River, Glenbrook Creek and Erskine Creek. Control subcatchments were the Grose River, Kedumba River and Kowmung River (Fig. 2). The study area encompasses 245,000 ha, with 73,000 ha burnt by the 2001/2002 wildfires. Four of the seven subcatchments, Burke, Nattai, Kedumba and Kowmung Rivers flow into Lake Burragorang which supplies 80% of the drinking water to the Sydney region. The other three subcatchments, Erskine Creek, Glenbrook Creek and Grose River are located below Lake Burragorang, but contribute large volumes of water to two major adjoining rivers in coastal New South Wales, the Nepean River and Hawkesbury River. These rivers have an important social and economic value, contributing to agriculture, urban, recreational, mining and industrial activities.

The underlying geology consists of Triassic sandstone plateau (Hawkesbury and Narrabeen sandstones) with Narrabeen mudstone embedded throughout. Elevation ranges from 36 m in the Grose River subcatchment to 1370 m in the Kowmung River subcatchment. Mean slope ranges from 5° in Burke to 15° in Kedumba (Table 2).

Tenosols (weakly developed, no obvious horizon), Kandosols (strong texture contrast between the A and B horizons and a massive or weakly structured B horizon) and Kurosols (strong texture contrast and a strongly acid B horizon that may or may not be sodic; Isbell, 2002) are the dominant soils in the south where the Nattai River and Burke River subcatchments are located (ASRIS, 2009). In the north, Glenbrook Creek, Erskine Creek and Grose River subcatchments are dominated by Dermosols (poor texture contrast, well structured B2 horizon) and Kandosols, whilst Tenosols become present as elevation increases. Kedumba River and Kowmung River subcatchments are dominated by Tenosols and Dermosols.

Vegetation is similar across all sites with dry sclerophyll forests and shrubby woodlands being dominant with moist sclerophyll forest and rainforest communities present within the valleys (Keith, 2006). Vegetation communities are dominated by *Eucalyptus* sp. in the canopy and a dense shrubby understory dominated by *Banksia, Acacia, Leptospernum, Hakea* and *Casuarina* sp.

The study area has a warm temperate climate with overall average summer temperatures ranging from approximately 15 °C in December to 30.7 °C in January. Summer is generally more moist than winter, however there is no distinct dry season. Mean annual rainfall across the study area ranges from ~700 to 1400 mm per annum (BOM, 2012). At the time of the 2001/02 wildfire the study region was declared in drought, which was strongly associated with the influence of El Niño-Southern Oscillation (ENSO). In eastern Australia the Southern Oscillation Index (SOI) is used to provide an indication of the intensity of an El Niño or La Nina Event. For example, sustained negative values of SOI indicate El Niño started during 2002/2003 (Fig. 3).

2.1.2. Subcatchment delineation

The drainage area above each hydrometric site was defined in ArcGIS (ESRI, 2009) using a 90-m Digital Elevation Model (DEM; CGIAR-CSI, 2004). The basic steps were to: