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High frequency fire drives forest species change: impacts on ecohydrology and ecosystem functioning

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Fire as a hydrologic agent has been most frequently examined in terms of erosion and water quality, with studies on the ecohydrology expressed as evapotranspiration/streamflow often focussing on short term perturbation that relaxes with vegetation recovery. Far more dramatic ecohydrologic impacts are possible if repeated fire disturbance leads to species change. Such a scenario occurs in some forests in south-eastern Australia, a region that is among the most flammable in global terms due to the confluence of climatic and stand productivity factors. The most vulnerable of these forests are the "ash" type – mainly Eucalyptus regnans and E. delegatensis. The E.regnans ecology has evolved with long fire intervals as medium/hot fire kill the trees, which then regenerate as single aged strands. However there have been several large short interval fire events in mountain forests (eg. 1926-1939, 2003-2006-2009-2019) in the past decades that overlap in area. E.regnans, and the other ash-type species, require 15-20 years to develop seed. If re-burnt, the stands cannot naturally regenerate. Frequently acacia and other understorey species colonise the sites, resulting in a dramatic change in forest structure and biomass.

The implications of this change are significant, with potentially high magnitude changes in ecohydrologic functioning. Further, these areas are the principal water supply catchments the city of Melbourne (> 4 M pop.) and a number of other towns. The impact of high frequency fire that is predicted to increase under climate change therefore has the potential to change ecology, hydrology and essential ecosystem services, in this case, water supply.

An extensive field experimentation and modelling program set out to (a) investigate the climatic conditions under which these wet forests burn and the sensitivity of these drivers to predicted climate change; and (b) evaluate the eco-hydrologic impact of a species change from E.regnans to acacia species over an age sequence of 80 years.

Results revealed there is an envelope of dry surface soil and maximum vapour pressure deficit (VPD) within which there is a 50% chance of uncontrolled fire. The most damaging fires occurred when VPD was within the upper 0.01% of values and available surface soil water below 55%. Modelling suggests this conjunction of drivers will increase significantly in the future.

Stand structure, particularly sapwood area, diverged between the eucalypts and acacias at age 10-20 years, with the difference increasing until acacia death at age 80. This structural parameter scales with ET, with acacias exhibiting a marked decline over time relative to E. regnans. This ET

change is principally driven by sapwood area. These differences increase as the stands age, resulting in A.dealbata using around 30% of an E.regnans stand at age 80. This represents a fundamental change in eco-hydrology, and suggests a system pushed to a state of disequilibrium. The stand structural attributes over the age sequence indicate a large change in carbon stocks, resulting in significant alteration of both carbon and water cycles under this disturbance. The results have significant implications for water supply, forest ecosystem services, and system feedbacks of flammability-fire-ecohydrology.