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Post-fire changes in streamflow explained by forest self-thinning behavior

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Most of the drinking water provided to the Melbourne metropolitan area originates from catchments that are covered by tall-wet eucalyptus forests, which have an estimated mean fire return interval of 80-150 yr. When stand-replacing fires occur in these forests, they result in a significant reduction in streamflow for an extended period of time due to the recovery strategy of the dominant tree species (Eucalyptus regnans and Eucalyptus delegatensis) and the water use of the dense regrowth. Current hydrological models that express this phenomenon are based on empirical data and lack the mechanistic explanation that links changes in streamflow with forest stand dynamics after disturbance. Here, for the first time, we present a simple theoretical framework that shows that this post-fire reduction in streamflow could be explained by the self-thinning behaviour of forest regrowth, which is driven by competition for water and light during recovery after a stand-replacing fire. First, we show that the trend in streamflow following a stand-replacing fire can be replicated simply by using the generic self-thinning line (which represents the maximum carrying capacity of a forest stand for a given mean tree diameter) of the dominant tree species. We then go one step further and show that the magnitude of streamflow reduction and the time it takes for streamflow to recover to pre-fire conditions, are sensitive to both the recovery success and the environmental conditions that control the maximum vegetation carrying capacity across the catchments. By using a simple stand growth and mortality model, we link the competition for water and light and the self-thinning behaviour of the forest to evapotranspiration and streamflow trajectories. This theory provides a simple alternative approach that can be used to improve models that predict streamflow from forested catchments after stand-replacing fires.