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Plant traits determine forest flammability

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Carbon and nutrient cycles in forest ecosystems are influenced by their inherent flammability - a property determined by the traits of the component plant species that form the fuel and influence the micro climate of a fire. In the absence of a model capable of explaining the complexity of such a system however, flammability is frequently represented by simple metrics such as surface fuel load.

The implications of modelling fire - flammability feedbacks using surface fuel load were examined and compared to a biophysical, mechanistic model (Forest Flammability Model) that incorporates the influence of structural plant traits (e.g. crown shape and spacing) and leaf traits (e.g. thickness, dimensions and moisture). Fuels burn with values of combustibility modelled from leaf traits, transferring convective heat along vectors defined by flame angle and with plume temperatures that decrease with distance from the flame. Flames are re-calculated in one-second time-steps, with new leaves within the plant, neighbouring plants or higher strata ignited when the modelled time to ignition is reached, and other leaves extinguishing when their modelled flame duration is exceeded.

The relative influence of surface fuels, vegetation structure and plant leaf traits were examined by comparing flame heights modelled using three treatments that successively added these components within the FFM. Validation was performed across a diverse range of eucalypt forests burnt under widely varying conditions during a forest fire in the Brindabella Ranges west of Canberra (ACT) in 2003. Flame heights ranged from 10 cm to more than 20 m, with an average of 4 m.

When modelled from surface fuels alone, flame heights were on average 1.5m smaller than observed values, and were predicted within the error range 28% of the time. The addition of plant structure produced predicted flame heights that were on average 1.5m larger than observed, but were correct 53% of the time. The over-prediction in this case was the result of a small number of large errors, where higher strata such as forest canopy were modelled to ignite but did not. The addition of leaf traits largely addressed this error, so that the mean flame height over-prediction was reduced to 0.3m and the fully parameterised FFM gave correct predictions 62% of the time. When small (<1m) flames were excluded, the fully parameterised model correctly predicted flame heights 12 times more often than could be predicted using surface fuels alone, and the Mean Absolute Error was 4 times smaller.

The inadequate consideration of plant traits within a mechanistic framework introduces significant error to forest fire behaviour modelling. The FFM provides a solution to this, and an avenue by which plant trait information can be used to better inform Global Vegetation Models and decision-making tools used to mitigate the impacts of fire.