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Predicting spotfire ignition in dry eucalypt litter

Understanding when spotfires are likely to occur is essential for suppression planning and determining the potential impact on fire behaviour and firefighter safety. New research reveals critical fuel bed moisture contents for spotfire ignition success.

Spotting is a natural phenomenon

The process of spotfire ignition and development, or spotting, is an inherent part of bushfire behaviour in Australia. It is a major contributor to the loss of control of fires, the hazard faced by firefighters, and damage to the built environment. Due to its complexity, it is a poorly understood phenomenon. The significance of spotting depends on the type and availability of firebrand material, the ease with which it can be lofted and transported, and the probability that it will ignite a fuel bed when it lands.

Figure 1. Multiple spotfires occurring on the left flank of the Mt Hickey fire, February 8 1982.

Spotting can be characterised by two types of behaviour: high density, short-distance spotting that can lead to multiple simultaneous ignitions, and long-distance spotting that can start new fires up to tens of kilometres from the source fire.

The ease of lofting and transport of a firebrand is determined by its terminal velocity while burning—that is, the maximum speed with which it will both rise and fall in a column of air. Maximum spotting distance is determined by the intensity of the source fire and the flame-out and burn-out time of the firebrand during flight (the length of time that the firebrand will flame and smoulder). The probability that a firebrand will ignite a spotfire is influenced by its state (flaming or glowing) and its mass upon landing. Firebrand travel and ignition potential characteristics can only be determined accurately by burning firebrands at their terminal velocity.

The probability that a firebrand will ignite a fuel bed and then become an established spotfire depends on the firebrand variables listed above as well as fuel bed type and moisture content (MC) and the atmospheric conditions at ground level.

Little research has been carried out on materials notorious for causing spotting (especially the bark of eucalypts, known to potentially make effective firebrands because of its lower density and aerodynamic shape), the ignition probability of firebrands combusting at their terminal velocity, or the ignition probability on fuel beds of Australian forests. Ellis (2011, 2013) studied the firebrand potential of a stringybark (*Eucalyptus obliqua*) and found it to be particularly effective up to distances of several kilometres due to its ease of ignition, low terminal velocity (3 - 5 m/s), long flameout times (up to one minute), and long burnout times (up to five minutes).

This study

The probability of successful spotfire ignition was studied using standardised flaming and glowing firebrands and a representative fuel bed consisting of undisturbed litter of a dry eucalypt forest. The flaming and smouldering firebrand samples were selected to have the combustion and aerodynamic characteristics of small firebrands from the dry forests of southern Australia. Standard flaming firebrands were sections of bamboo stick 50 mm long and 3 mm in diameter that had a terminal velocity of ~4 m/s, an initial mass of 0.6-0.9 g and flamed for 9 s in still air. Standard glowing firebrands were cut sections of shed *E. globulus* bark 50 mm long, 15 mm wide and 2 mm thick. These were burnt at their terminal velocity and when deposited onto the fuel bed had a mean mass of 0.2 g and glowed for 2.5 minutes in wind.

Experiments were conducted in a small wind tunnel that created highly uniform air flow over each fuel bed. Air speeds studied were zero, 1.0 and 2.0 m/s (corresponding to winds of ~11 and ~22 km/h in the open). The fuel bed MCs were between 4 and 21%.

Results

Logistic regression models for ignition probability were developed from analysis of the experimental data. For flaming firebrands, ignition probability is dependent on the presence of wind at the fuel level and fuel bed MC (Figure 2, top). In the absence of wind, a fuel bed MC of ~14% or lower is required for ignition, with a 50% chance of successful ignition occurring once fuel bed MC is below ~9%. In the presence of wind the critical MC is ~21%, with 50% chance of successful ignition occurring once fuel bed MC is below ~13%.

For glowing firebrands, ignition probability is dependent on fuel bed MC and wind speed (Figure 2, bottom). For a fuel level wind speed of 2 m/s, a fuel bed MC of ~10% is needed for successful ignition, with 50% chance of successful ignition occurring once the fuel bed MC is less than ~4%.

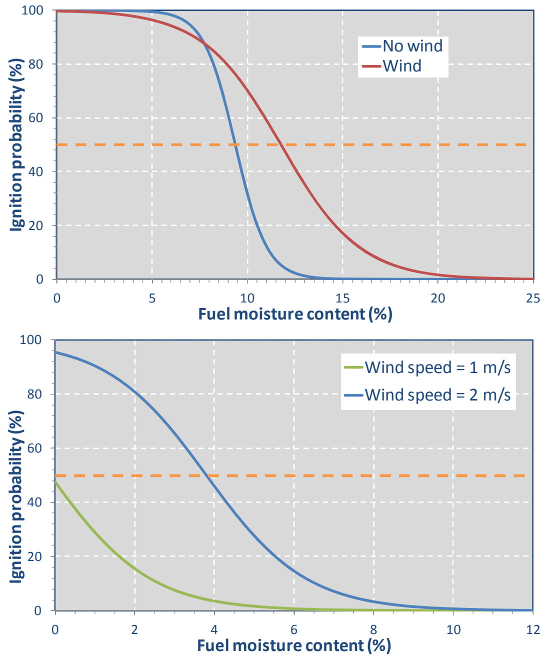

Figure 2. (top) Reduction in ignition probability of flaming firebrands with fuel bed MC in the presence and absence of wind. (bottom) Reduction in ignition probability of glowing firebrands with fuel bed MC for two wind speeds.

At fuel bed MCs less than about 7%, ignition is essentially guaranteed from any flaming firebrand equivalent to the standard sample, regardless of wind conditions. For glowing firebrands, the importance of wind in ignition success suggests that turbulence (i.e. the gust and lull structure) in the air flow at the fuel may play a large role in determining successful ignition from glowing firebrands. In the absence of wind, ignition is unlikely.

Further research is needed to build robust models for the full range of possible firebrand morphologies and environmental conditions (including wind gusts).

Implications

These results identify the existence of key triggers for spotfire potential that will enable fire managers to better determine when spotting will be a hazard and provide a basis for prediction of its occurrence.

The models confirm the dominating influence of fuel bed MC on likelihood of spotfire ignition, consistent with expert observations, and provide a practical tool to calculate the ignition potential of firebrands.

Further reading

Ellis PFM (2015). The likelihood of ignition of dry-eucalypt forest litter by firebrands. *International Journal of Wildland Fire* **24**(2), 225-235.

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