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Laboratory study of initial fire growth in eucalypt litter

Knowing how long it takes a new fire outbreak to develop, grow and reach its steady-state rate of spread for the prevailing conditions is essential to accurate spread predictions and for planning effective suppression. The initial growth of incipient fires in uniform dry eucalypt forest litter fuel was studied in a combustion wind tunnel. Fires were started from points and small lines in a range of burning conditions. A model fitted to the data suggests the shortest time for a point ignition fire to reach steady-state spread is 25 minutes under the lower fuel moisture and higher air speed conditions.

Fire growth modelling

The progressive development of a fire from its ignition to its potential rate of spread for the prevailing conditions, and its associated increase in fire size and intensity, is described as fire growth, development or sometimes acceleration. Models for predicting fire spread operationally in dry eucalypt forests assume fires propagate at their quasi-steady rate of spread and do not consider the time required to reach this spread rate if only just ignited. Despite the fact that knowledge of the rate of growth of an ignition is also important for suppression response planning, empirical and theoretical studies of fire growth from a point in eucalypt forest are few.

Cheney and Bary (1969) proposed an exponential growth function in a time-constant form for fire growth to steady-state rate of spread in a standing eucalypt forest when fuel moisture and weather conditions are stable. Van Wagner (1985) proposed a similar, but in inverted time-rate relationship form, that considered the rate of decrease of the factors inhibiting growth. The constants of both equations incorporate the weather and fuel conditions in which a fire is burning. Both functions (Fig. 1) produce relatively steeply curves attain 50% or more of the steady state spread rate within a short time period, depending on the prevailing burning conditions.

As part of a larger project investigating fire growth in eucalypt forests, a series of experimental fires was conducted in eucalypt litter in the CSIRO Pyrotron to

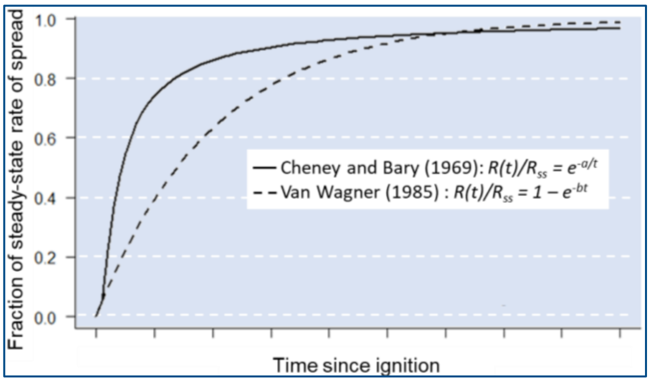

Figure 1. Theoretical fire growth relationships presented as time to fraction of steady-state rate of spread. solid line: Cheney and Bary (1969), dashed line: Van Wagner (1985).

collect data on the growth rate of fires ignited from point and short line sources. These data were then applied to the two theoretical models to create a model of time to steady-state rate of spread.

Laboratory experimentation

Fifty-eight experimental fires were carried out in the CSIRO Pyrotron at two air speeds (1.25 and 2.0 m/s), two fuel moisture content (FMC) groups (≤7.5% and >7.5% oven-dry weight for the low air speed and ≤5% and >5% for the high air speed) and three ignition lengths (point, 400 mm and 800 mm) perpendicular to the air flow. The 1.5 m × 4.8 m heterogenous fuel bed consisted of fine (< 6 mm) dry eucalypt forest litter comprising leaf, twig and bark material collected from a local forest at a dry fuel load of 12 t/ha. Fires were ignited such that head fires could spread 4.0 m with the air flow and backing fire could spread 0.8 m against it.

Interval and cumulative rates of forward spread were computed from flame front arrival times at each 0.5 m interval of head fire spread. Analysis revealed that the initial spread rate of the experimental fires varied with ignition length, with the line ignitions generally spreading faster initially than the point ignitions before decreasing, behaviour that has been observed of line ignitions in the field.

In contrast, the rate of spread of the point ignition fires generally continued to increase with time since ignition, exhibiting a phase of typical initial growth from ignition to a distance of about 2.0-2.5 m before entering a phase in which speed plateaued (i.e., it reached steady state).

Initial rate of growth and final steady-state spread were greatest for fires burning in the higher air speed and lower FMC conditions. Slightly higher acceleration was observed with fires in the higher wind speed and higher FMC than the lower wind speed and lower FMC conditions. Fires in the lowest air speed and higher FMC had the slowest steady state spread and lowest growth rate.

Each of the theoretical relationships were fitted to the data using non-linear regression to solve for the constants. It was found that while each model performed similarly, the Van Wagner model had a slightly lower mean error and no discernible bias. A logarithmic linear model was fitted to the data to estimate the *b* coefficient in the Van Wagner equation as a function of air speed and FMC.

Outcomes and implications

Figure 2 shows the final model based on the form of Van Wagner (1985) for a range of air speed and FMC values. This model suggests that a fire burning in 2 m/s winds at fuel level and low FMC will reach its steady-state rate of spread 25 minutes after ignition, whereas a fire burning in 1.25 m/s winds and higher FMC will take more than 1 hour.

The times to reach the steady-state spread rate observed in these experiments appear to be inconsistent with field observations where fires

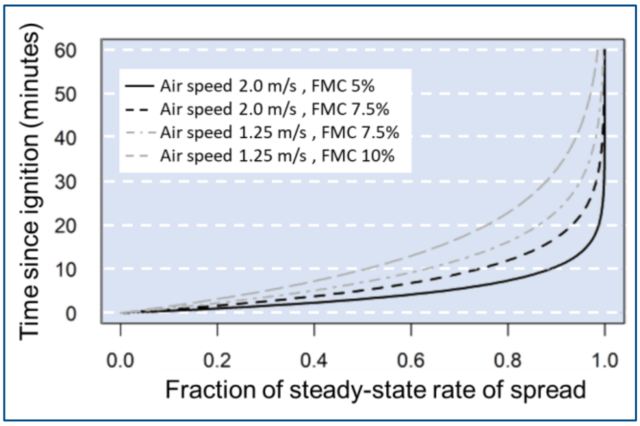

Figure 2. Comparison of time required to reach steady-state rate of spread for different combinations of air speed and FMC using the fitted model based on Van Wagner (1985).

burning under more severe conditions with a faster steady-state rate of spread took longer to reach steady-state than fires burning under milder conditions.

This disparity between field and laboratory observations could arise from the more consistent and less turbulent air flow in the Pyrotron than is found under a forest canopy. Additionally, the absence of multilayered fuel strata in these experiments do not capture the complexities of fuel characteristics of a typical dry eucalypt forest and thus the incremental development of fires through different fuel strata. Further research involving analysis of field-based point ignition experiments is required to investigate this issue.

Further reading

Gould JS, Sullivan AL (2022) Initial growth of fires in eucalypt litter, from ignition to steady-state rate of spread: laboratory studies. *International Journal of Wildland Fire* 31, 163-175. DOI: 10.1071/WF21094

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