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Number 31 | **March 2022**

The Vesta Mk 2 eucalypt forest fire spread model

Reliable and accurate models of the speed of a wildfire front are essential for the timely prediction of its propagation across the landscape, identification of suitable suppression strategies and release of effective public warnings. We used data from field experimental fires and wildfires to derive an empirical model for the rate of forward spread of fires in eucalypt forests applicable to a broad range of wildfire behaviour. The model, named Vesta Mk 2, incorporates the effects of wind speed, fine dead fuel moisture, understorey fuel structure, long term landscape dryness and slope steepness.

The need for a new fire spread model

Fire behaviour analysts conducting manual predictions of wildfires in eucalypt forests rely on a number of different fire spread rate models to cover the full range of potential burning conditions: McArthur's Leaflet 80, McArthur's Forest Fire Danger Meter, the WA Red Book, and the Project Vesta Dry Eucalypt Forest Fire Model (see Cruz *et al.* 2015). However, there is limited guidance as to which model should be used in any particular situation. The models yield quite different outputs for identical inputs, and each have particular under- and over-prediction biases in certain situations. Fire behaviour analysts have to use their experience and expertise to decide which model to use when.

To reduce the uncertainty in the process of predicting wildfire propagation, we aimed to develop a single fire spread model applicable to all eucalypt forest types (from dry to wet) over a broad range of fuel states, burning conditions and fireline intensities.

Model features from user needs

Model construction was informed by a number of desired characteristics identified by fire behaviour analysts, such as incorporating transitions and escalations in fire behaviour, short distance spotting, and utilising readily available inputs. Data analysis was carried out using existing experimental and wildfire datasets and was guided by a solid understanding of the strengths and limitations of the existing models and insights into high intensity fire behaviour gained from consideration of recent wildfire events.

The Vesta Mk 2 fire spread model

At the core of the Vesta Mk 2 model is the concept that as burning conditions change, fire spread is dominated by different fuel layers (Figure 1).

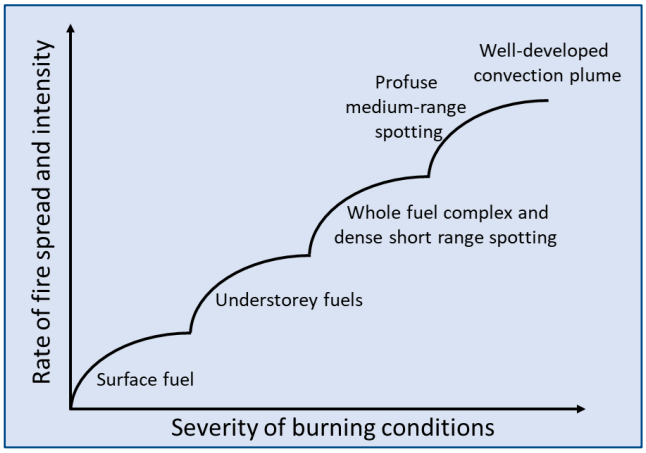

Figure 1. Conceptual stepwise increase in rate of fire spread and intensity as different fuel layers become involved in combustion. Based on illustration from McArthur (1967).

For example, with an increase in fire spread potential due to an increase in wind speed or decrease in fuel moisture, a fire will transition from burning lower understorey fuels (such as surface fuels) to higher fuel strata (such as shrub, bark or overstorey fuels).

These transitions result in stepwise increases in fire spread rate and intensity.

The new model considers three phases of fire propagation in eucalypt forests:

1) low intensity (Phase I)
2) moderate to high intensity (Phase II) and
3) very high and greater intensity (Phase III).

In order to adequately cover the full range of potential rates of fire spread, the Vesta Mk 2 model identifies the expected type of fire under the given set of environmental conditions (i.e., which phase dominates), and then determines the resulting rate of forward spread of the fire.

The Vesta Mk 2 model is also linked to the flame height and maximum spotting distance sub-models developed for the original Vesta model.

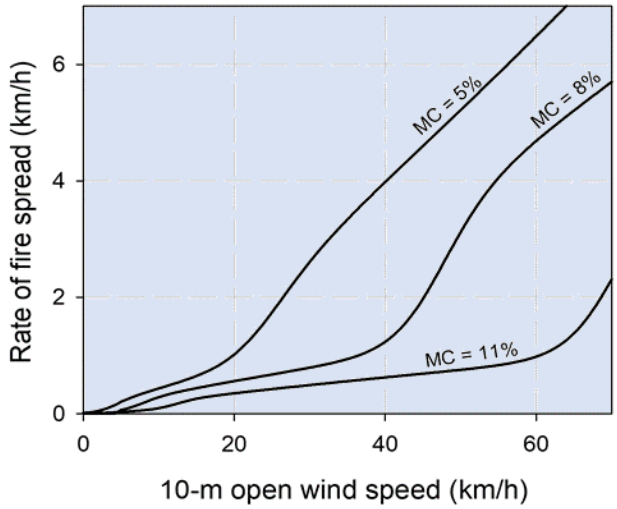

Figure 2. Example of predicted rate of fire spread by the Vesta Mk 2 model for three fuel moisture content (MC) values across a range of 10-m open wind speeds. Steeper sections in a curve indicate rapid escalation in fire spread due to the transition between fire spread phases.

Model inputs

The Vesta Mk 2 model has seven inputs (Table 1), directly incorporating the effects of wind speed, fine dead fuel moisture content, surface and near-surface fuel loads, understorey fuel structure, and slope steepness (in the direction of fire spread). Long-term landscape dryness as estimated by the McArthur (1967) Drought Factor (DF) is used to estimate fuel availability. A wind adjustment factor associated with forest type is also required for estimating understorey wind speed.

Table 1. Vesta Mk 2 rate of fire spread model inputs

VARIABLE
10-m open wind speed (km/h)
Wind adjustment factor (dimensionless)
Fine dead fuel moisture content (%)
Drought Factor (0-10, dimensionless)
Surface and near-surface fuel load (t/ha)
Understorey fuel height (m)
Slope steepness (degrees or percent)

Details on model characteristics, assumptions and limitations, and guidance on model usage are given in the comprehensive user's guide.

The Vesta Mk 2 model has also been implemented in version 0.7 of Amicus, the computerised bushfire knowledge base and decision support system.

Further reading

Cruz MG, Cheney NP, Gould JS, McCaw WL, Kilinc M, Sullivan AL (2022) An empirical-based model for predicting the forward spread rate of wildfires in eucalypt forests. *International Journal of Wildland Fire* 31, 81-95. (Free open-source access)

Cruz, MG. The Vesta Mk 2 rate of fire spread model: a user's guide. CSIRO, Canberra, ACT. 76 pp.

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Cruz, MG, Gould, JS, Alexander, MA, Sullivan, AL, McCaw, WL, Matthews, S, 2015. A guide to Rate of Fire Spread Models for Australian Vegetation. CSIRO and AFAC, Melbourne, Vic. 125.

McArthur AG (1967) Fire Behaviour in Eucalypt Forests. Forestry and Timber Bureau Leaflet 107. Forest Research Institute, Canberra, ACT. 36 pp.

CONTACT US
t 1300 363 400
+61 3 9545 2176
e enquiries@csiro.au
w www.csiro.au

FOR FURTHER INFORMATION
Land and Water
Dr Andrew Sullivan
t +61 2 6246 4051
e Andrew.Sullivan@csiro.au
w www.csiro.au/en/Research/LWF

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