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The effect of fuel load on the spread rate and flame characteristics of grassfires

The effect of grass fuel load on fire behaviour and fire danger has been a contentious issue for some time in Australia. Existing operational models have placed different emphases on the effect of fuel load on model predictions, creating uncertainty in the operational assessment of fire potential and distrust in model results. Analysis of a series of field experiments across a broad range of grasslands found an inverse relationship between fuel load and fire spread rate. A fuel load effect function has been developed that can be applied to grassfire spread models used in Australia.

The question of fuel load

Fuel load, the dry weight of biomass available for combustion by fire, is commonly used in many fire management applications such as fire danger estimation, fire behaviour prediction and assessment of fuel management needs. Early grassfire behaviour prediction tools used in Australia assumed that rate of spread was directly proportional to fuel load. Later models removed this effect due to a lack of direct evidence and the dependence of the biomass quantity in a grass sward on the structural properties of the grass species (pastures with higher fuel loads typically contain coarser grasses). In the 1980s a large experimental programme was carried out to "*resolve the conflicting information about the importance of fuel load*". This research found no evidence that fuel load significantly and directly influenced grassfire spread rate (Cheney *et al.* 1993).

Contrary to these findings, and despite the lack of supporting evidence, the effect of fuel load on rate of fire spread and fire potential has continued to be applied in operational decision support tools in Australia, leading to uncertainty and mistrust in fire behaviour model outputs.

New research to quantify the effect

This research aimed to quantify the effect of grass fuel bed structure and biomass on the rate of forward spread and flame characteristics of free-burning grassfires in Australia. It was conducted over a broad range of naturally-occurring fuel loads in undisturbed natural pastures. A large number of experimental fires (Fig. 1) were carried out in Victoria, New South Wales and Queensland. Total fuel load varied from 1.7 t/ha to 10.5 t/ha. Fires were conducted with the Grassland Fire Danger Index (GFDI) varying between 3.4 and 76 (ratings of Low to Severe), with 44 fires conducted at High or greater Fire Danger Rating.

Figure 1. Typical high intensity experimental grassfire propagation in a 33 × 33 m plot in which the fire reaches steady-state rate of spread for the prevailing conditions.

What did we find?

Observed rate of fire spread varied between 12.5 and 150 m/min. Regression analysis showed rate of spread was significantly but *inversely* correlated with fuel load (i.e. rate of spread decreased with increasing fuel load). The analysis revealed that for practical purposes the effect is negligible for fuel loads between 2 and 5.5 t/ha, as found by Cheney et al. (1993). However, above 5.5 t/ha there is an observable reduction in fire spread rate with increasing fuel load. The CSIRO Grassland Fire Spread model (Cheney *et al.* 1998) predicted the new fire spread observations without a noticeable bias up to a fuel load of 5 t/ha. Above this value the model over-predicted the measured rates of spread.

To address this issue, a fuel load effect function was developed that can be applied directly to the CSIRO Grassland Fire Spread model for undisturbed grasses (Fig. 2). With this function applied, the CSIRO Grassland Fire Spread model produced more accurate results for fires in grasslands with higher fuel loads, specifically by significantly reducing the mean prediction error and bias.

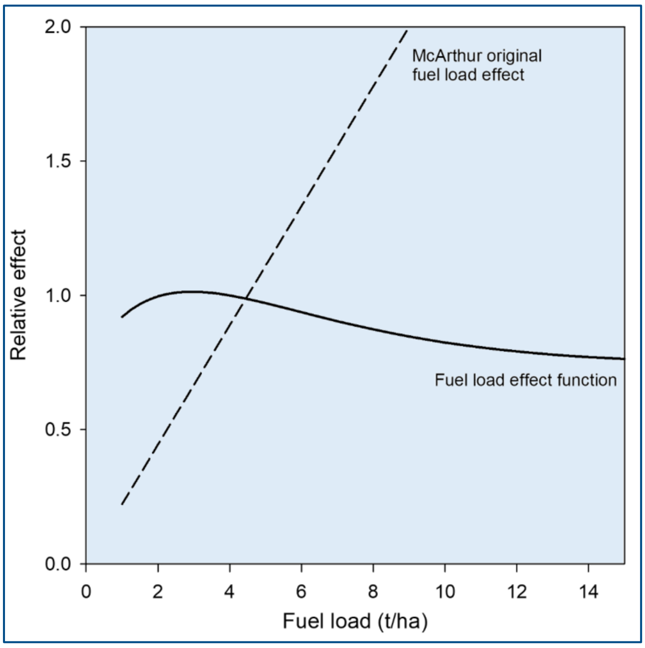

Figure 2. Relative effect of the new fuel load function on the rate of spread of grassfires compared to the current practice of McArthur's fuel load effect. The magnitude of the new effect is negligible for loads between 2 and 5.5 t/ha.

Management implications

The experimental results contradict current operational practice, which assumes that fuel load has a strong positive effect on rate of spread.

The distribution of fuel loads for undisturbed grasslands found in our experimental sites and in other fuel assessment studies suggest average fuel loads of 3.5 t/ha with an interquartile range of between 2.7 and 3.6 t/ha for southern and eastern Australia grasslands. Within this range there is no effect of fuel load on rate of fire spread, and the application of the fuel load effect function is not necessary.

The results presented here are applicable to environments where fuel load is not a limiting factor. In sparse-cover grasslands, such as those found in arid and semi-arid regions of Australia, fuel load (as a surrogate of cover) is a limiting factor. Here, decreases in fuel load might constrain the forward propagating flux to unburned fuels, limiting flank propagation and overall fire growth.

The findings from the study only apply to natural and undisturbed grasslands where grasses have not been modified in anyway. They are not applicable to grazed or eaten-out paddocks where there has been a drastic change in fuel structure (shorter, more compacted, or less continuous fuels). Further research is required to determine if the findings apply to these modified pasture conditions and harvested crops.

The outcomes of the research illustrate the drawbacks of using fuel load as a surrogate for specific fire model inputs such as pasture condition.

Further reading

Cruz MG, Sullivan AL, Gould JS, Hurley RJ, Plucinski MP (2018) Got to burn to learn: the effect of fuel load on grassland fire behaviour and its management implications. *International Journal of Wildland Fire* 27, 727-726.

References

Cheney NP, Gould JS, Catchpole WR (1993) The Influence of Fuel, Weather and Fire Shape Variables on Fire-Spread in Grasslands. *International Journal of Wildland Fire* 3, 31-44.

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