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Improving the prediction of rate of fire spread in partially cured grasslands

The state of curing of a grass sward has long been known to have a direct effect on the speed of a fire, with fires spreading faster in more fully cured swards than those that are less cured. A research partnership between CSIRO and the Victorian Country Fire Authority has shown that current systems for incorporating the effect of grass curing on fire behaviour under predict fire potential when grasses are not fully cured. A new mathematical function to described this effect has been developed for incorporation into grassfire rate of spread predictions.

Grass fuel dynamics

The lifecycle of annual grasses (i.e. germination, growth, flowering, setting seed, drying out (curing) and death) controls the flammability of grassland fuels. The onset of senescence following flowering and setting of seed initiates an irreversible process that increases the proportion of dead material in the sward (a reflection of the degree of curing) and decreases its overall moisture content. This results in an increase in the amount of fuel available for combustion and significantly impacts the ease of ignition and ensuing behaviour of a fire.

Annual grasses and their lifecycles vary considerably across Australia, influenced by species, soil structure and moisture, and climate. After the growth stage, grasslands are at their lowest curing level, i.e. uniformly green and with the highest fuel moisture content levels. Flaming combustion cannot be sustained in such fuels and fires will not spread.

Once senescence commences in individual plants, the overall condition of a sward becomes quite complex with a mix of living, dying, drying out and dried out fuels. Fire spread also becomes similarly complicated. Understanding just how a fire behaves in such fuel conditions is critical to predicting its behaviour, particularly under more potent burning conditions.

Figure 1. Aerial view of simultaneous paired experiments to examine the effect of different curing states on fire behaviour. The fire at top right is in fully cured grass whereas the fire in the foreground is in 60% cured grass.

Estimating grass curing

Operationally, the degree of curing is usually obtained from visual estimates based on expert assessment supported by photographic field guides or through analysis of remote-sensing satellite imagery. Despite the effort that has gone into developing these methods, it is important to recognise that none of these yield the true curing level, which requires time-consuming destructive sampling of grasses and partitioning into live and dead components.

Our sampling protocol in the current research project expanded the fuel component groups from two (live and dead), to four: green (i.e. live), senescing, recently dead and old dead fuel (previous year's growth).

We found that visual curing assessments resulted in an over-prediction bias of curing level and failed to capture the effect of senescence on fuel availability due to misclassification of fuel components. For example, discoloured senescing fuels were classified as dead even though they were still partially alive and had relatively high fuel moisture content.

This result highlights the need for comprehensive visual curing assessment training that enables accurate and unbiased determination of the degree of curing in grasslands.

A new curing relationship

The findings of the field-based experimental burning program to quantify the effect of the degree of grass curing on fire propagation (Fig 1) were surprising.

Firstly, it was found that sustained fire spread occurred at quite low curing levels--down to 20-30%, where previously it has been assumed that sustained spread required curing values greater than 50%.

Secondly, it was found that the current systems used in Australia to incorporate the effect of grass curing on fire behaviour resulted in significant under-predictions of rate of forward fire spread in partially cured grasslands. Fires in fuels at curing levels between 50 and 80% were observed to spread up to ten times faster than predicted.

A new relationship between degree of curing and fully cured rate of fire spread that better captures the effect of partial curing has been developed:

$$\Phi C = \frac{1.036}{1+103.989\exp[-0.0996(C-20)]} \qquad (1)$$

where ΦC is the curing rate of spread coefficient, C is the degree of curing and 20 is the curing value below which fires will not spread.

This relationship has a significant effect on predicted rate of spread when compared to previous models for grass curing coefficient. It results in sustained fire spread at lower curing values and faster fire spread at values less than fully cured (Fig. 2).

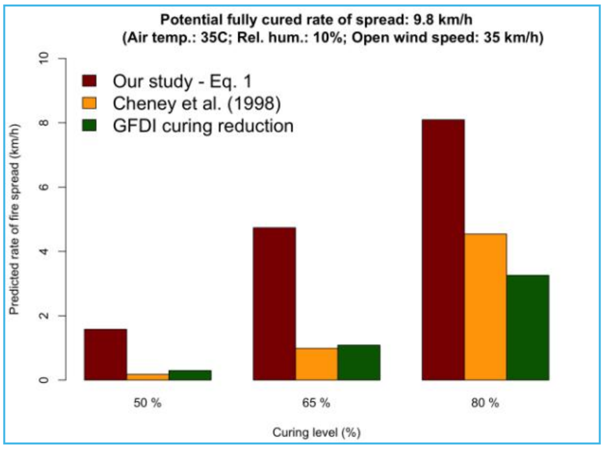

Figure 2. Comparison of predicted rates of fire spread for different curing levels using Eq 1, the currently used function of Cheney et al. (1998) and the Grassland Fire Danger Index (McArthur 1966).

Next steps

In collaboration with other partner agencies (the New South Wales Rural Fire Service and the Queensland Fire and Emergency Services), the study has been extended to explore the effects of grass curing in different grassland fuel complexes and burning conditions. The soundness of the new curing function (Eq. 1) is being evaluated against this comprehensive dataset. Rigorous testing is required to determine the impact of the new function on the operational prediction of fire behaviour and danger.

Further reading

Cruz MG, Gould JS, Kidnie S, Bessell R, Nichols D, Slijepcevic A (2015) Effects of curing on grassfires: II. Effect of grass senescence on the rate of fire spread. *International Journal of Wildland Fire* 24, 838-848.

Kidnie S, Cruz MG, Gould J, Nichols D, Anderson W, Bessell R (2015). Effects of curing on grassfires: I. Fuel dynamics in a senescing grassland. *International Journal of Wildland Fire* 24, 828-837.

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Cheney NP, Gould JS, Catchpole WR (1998) Prediction of fire spread in grasslands. *International Journal of Wildland Fire* 8, 1-13.

CFA (2014) Grassland Curing Guide. Country Fire Authority of Victoria, Burwood East. 37 pp.

McArthur AG (1966) Weather and Grassland Fire Behaviour. Forestry and Timber Bureau Leaflet 100. Commonwealth Department of National Development, 23 pp.

FOR FURTHER INFORMATION

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