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Evaluation of grass dead fuel moisture content models

Accurate estimates of the moisture content of dead grass fuels is critical for accurate predictions of grassland fire behaviour. Six dead fuel moisture prediction models were assessed using measurements of dead grass moisture content collected across eastern Australia. The best-performing model was that derived from Alan McArthur's 1960 tables, which is built into the Mk 2 CSIRO Grassland Fire Spread Meter.

Dead fuel moisture

The moisture content of a fuel determines the energy requirements for its ignition, hence exerting a strong effect on fuel availability and fire behaviour characteristics such as fire sustainability, spread rate and intensity. Dead fuel moisture content is one of the two (along with wind speed) most important variables affecting grassland fire behaviour.

Being able to correctly estimate dead fuel moisture, particularly as it varies spatially and temporally, is key to the accurate prediction of landscape-scale fire spread. Grass fuels are finer than other common bushfire fuels, resulting in faster response in moisture content to changes in conditions. Grasses are also more open to the full drying effects of solar radiation and wind. Furthermore, most grass fuel is vertically oriented, limiting the effect of rainfall and soil moisture on dead fuel moisture content. The combination of these features means grass fuels are typically drier than other fine fuels, such as forest litter, during peak afternoon burning conditions.

Dead fuel moisture models

In Australia, several models and tools exist to estimate dead grass fuel moisture content operationally. There are also a number of other models that have been developed and used overseas that could be applied to Australian grasslands.

In our study, six models appropriate for grass fuels were identified and evaluated for their capacity to predict dead fuel moisture content of grassland fuels under the dry conditions typical of Eastern Australia during summer. The models evaluated were:

Figure 1. Understanding grass moisture content is important for predicting likely behaviour and spread of grass fires.

1) AM60, the fuel moisture table of McArthur (1960) expressed as an equation by Cheney *et al*. (1989),
2) MK 5, the fuel moisture equation describing the function in the McArthur Mk 5 Grassland Fire Danger Meter (McArthur 1977),
3) NFDRS, the 1-h fine dead fuel moisture model of the US National Fire Danger Rating System,
4) hFFMC, the hourly version of the Fine Fuel Moisture Code (FFMC) of the Canadian Fire Danger Rating System,
5) Koba, a parameterised version of the process-based model of Matthews (2006), and
6) GFMC, a reformulated version of the hFFMC for matted grass fuels.

All of these models are described as vapour exchange models in which the transfer of moisture into and out of the fuel is dominated by atmospheric conditions. AM60 and MK 5 are purely empirical and require only air temperature and relative humidity as inputs if the fuel is fully cured. NDFRS, hFFMC and GFMC are semi-physical and require additional information (e.g. the fuel's equilibrium moisture content, solar radiation or precipitation). Koba is a fully physical model that accounts for radiative and moisture fluxes between the fuel and surrounds.

Model assessment

Data on dead fuel moisture content in standing grass swards were collected at five sites in Eastern Australia: Wangaratta South and Wendouree in Victoria; Tamworth and Braidwood in New South Wales; and Toowoomba in Queensland. Goodness-of-fit metrics (e.g. mean absolute error (MAE), mean bias error and mean absolute percentage error) were used to assess model performance along with paired t-tests to test the equivalency of mean observed and predicted moisture content values.

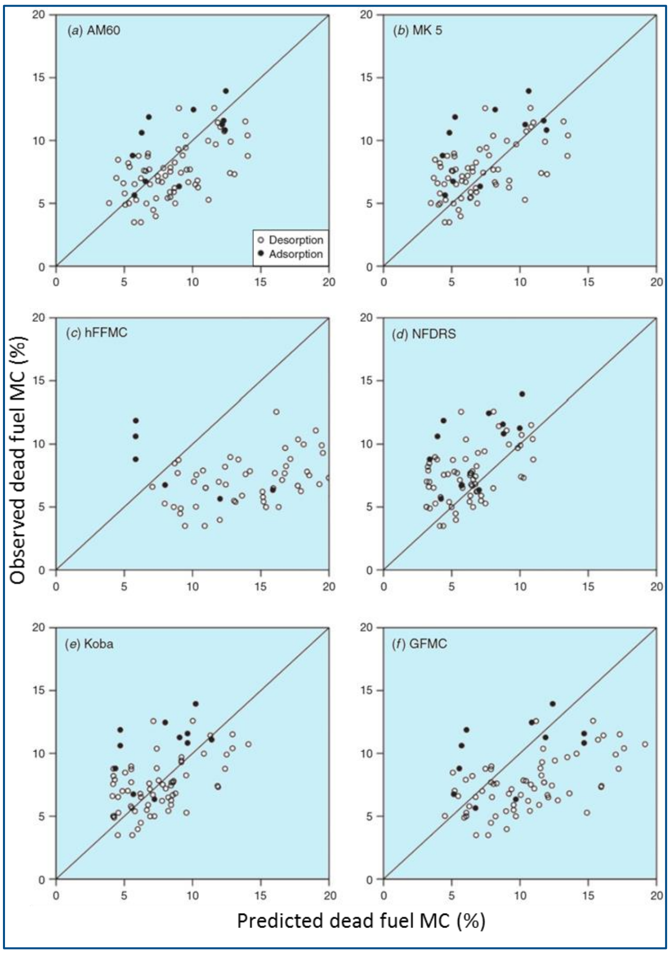

Figure 2. Observed moisture contents versus model predicted values segregated by desorption and adsorption phase.

Figure 2 shows the observed versus model predicted values. AM60, MK 5 and Koba were found to perform the best with the lowest MAE (2% moisture). hFFMC and GFMC gave the poorest predictions. Koba and MK5 had the lowest MAE in the desorption (drying) phase but with higher errors in the adsorption (wetting) phase. AM60 performed consistently well under both drying and wetting phases. Koba's high computational requirements preclude it from operational use at this time.

Implications

Our results suggest the AM60 should be the fuel moisture model of choice for general fire spread prediction purposes. This is due to its consistency across the range of burning conditions and the fact it was used to parameterise the current operational grass fire spread model.

AM60 is given by the equation:

$$MC = 9.58 - 0.205\ T + 0.138\ RH$$

where *MC* is grass moisture content (% oven-dry weight), *T* (°C) is air temperature and *RH* (%) is relative humidity, both measured at 1.2 m.

Further reading

Cruz MG, Kidnie S, Matthews S, Hurley RJ, Slijepcevic A, Nichols D, Gould JS (2016) Evaluation of the predictive capacity of dead fuel moisture models for Eastern Australia grasslands. *International Journal of Wildland Fire* 25, 995–1001.

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