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Are models of bushfire spread prediction improving?

The ability to accurately predict the behaviour and spread of a bushfire enables fire managers to develop and implement safe and effective suppression strategies and to release timely and effective public warnings. We compared the predictive capability of five older rate of fire spread models with newer versions and found a reduction in prediction bias and prediction error, highlighting the value of new, improved models.

Is bushfire behaviour science advancing?

Analytical models built to predict the likely behaviour of bushfires, namely the forward or head fire rate of spread (arguably the most important fire behaviour characteristic), have been under development for the past 80 years. A question one might ask when examining the accumulated body of research is: “Has the capability of fire spread models to accurately predict fire propagation improved?” Or alternatively, “Are the current fire spread models substantially better than the previous models?”

These questions are pertinent everywhere but especially in Australia where wildfires often threaten life and property, and fire spread models, developed for specific fuel types, are widely used operationally to support wildfire control and fuel management.

How good are fire spread models?

We analysed the predictive performance of a number of rate of spread models used operationally in Australia to quantify the improvements (or lack thereof) in model accuracy resulting from ongoing model developments over the past 30 or so years.

We compiled all known fire spread model evaluation studies where there was a direct comparison between model predictions and field observations, or where information was provided from which simulations for models not considered could be undertaken. The data mostly came from wildfires but also included some prescribed fires. An initial analysis of the data available revealed five pairs (older versus newer) of Australian fuel-type specific fire spread models suitable for analysis: grasslands, temperate shrublands, semi-arid shrublands and dry eucalypt forests, in addition to a pair of models for crown fire spread in exotic pine plantations.

Are models improving?

Figure 1 presents an example of the observed rates of spread in forest fires from the independently collected dataset plotted against corresponding values predicted by the McArthur (1967) Mk 5 Forest Fire Danger Meter and the Cheney *et al.* (2012) Dry Eucalypt Forest Fire Model intended to replace it.

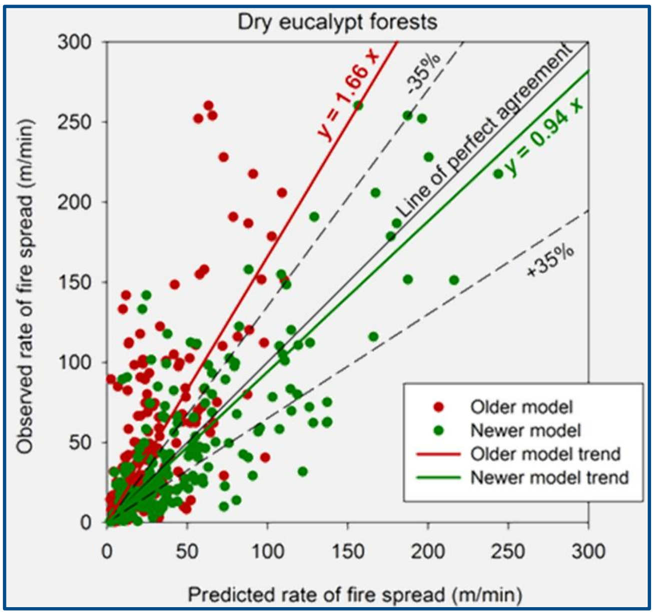

Figure 1. Example scatterplot for dry eucalypt forests of observed fire spread rates vs. predictions from the older McArthur (1967) model (red dots) and the newer Cheney et al. (2012) model (green dots) and the linear trends. The dashed lines around the line of perfect agreement indicate the ±35% error interval.

This figure shows a substantial under-prediction bias in the older model and a significant improvement in the newer model, particularly the absence of prediction bias with the green trend line lying much closer to the line of perfect agreement, albeit with some scatter. The level of scatter is characteristic of wildfire data due to uncertainties in input conditions.

As a trend across all fuel types, the newer models showed a marked improvement over their previous counterparts with a large reduction in overall error (Fig. 2a), and most significantly, a reversal of under-prediction bias (Fig. 2b). Only the semi-arid shrubland did not show a reduction in overall error, but the prediction bias was reversed and reduced.

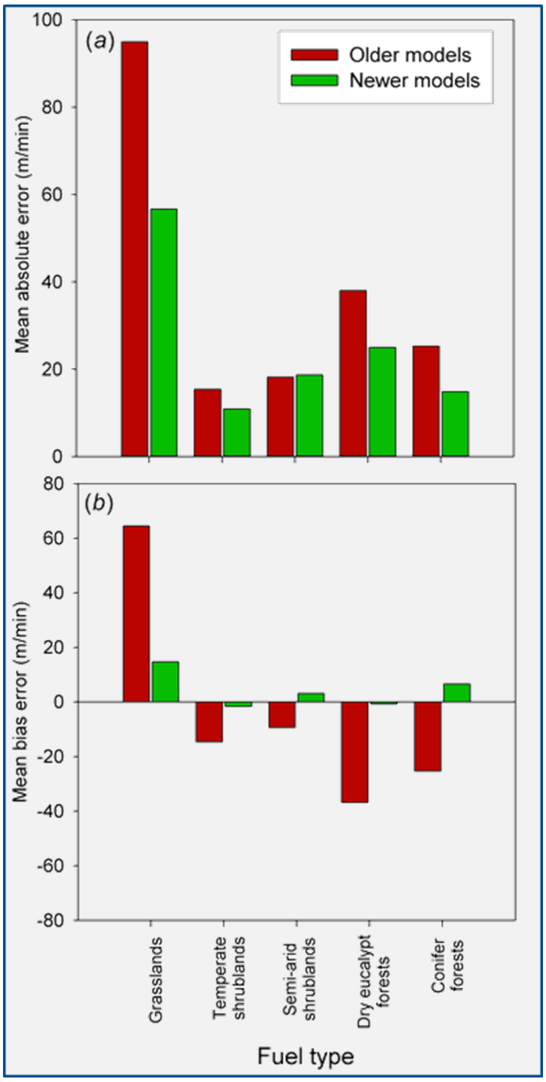

Figure 2. Change in (a) mean absolute error and (b) mean bias error between older (red) and newer (green) rate of fire spread models. There is an almost uniform trend of improvement with newer models across all vegetation types.

Implications

The improvements in the predictive accuracy of the newer models have not been fortuitous but the result of improvements in bushfire behaviour science. These improvements include more robust experimental designs, datasets for model development covering a wider range of conditions and fire behaviour, and improved data analysis techniques using meaningful functional forms rather than driven solely by statistical fitting.

An important observation of these model evaluation results is the fact that the error statistics for the grassland, temperate shrubland and dry eucalypt forest are based on ranges of fire behaviour and certain environmental conditions (e.g. fine dead fuel moisture content and wind speed) well beyond the range of the data used in model development.

Of critical importance to these findings is the approach taken in Australia to not assume that existing models are necessarily satisfactory or sufficient, despite their level of use. An ongoing endeavour to overcome perceived and identified model limitations and to develop improved tools has resulted in substantial improvements in model accuracy and thus operational reliability. In contrast, no such improvement in operational rate of fire spread models has been observed elsewhere in the world over the last 30 years.

Further reading

Cruz MG, Alexander ME, Sullivan AL, Gould JS, Kilinc M (2018) Assessing improvements in models used to operationally predict wildland fire rate of spread. *Environmental Modelling & Software* 105, 54–63.

References

Cheney NP, Gould JS, McCaw WL, Anderson WR (2012) Predicting fire behaviour in dry eucalypt forest in southern Australia. *Forest Ecology and Management* 280, 120–131.

McArthur AG (1967) Fire Behaviour in Eucalypt Forests. Forestry and Timber Bureau Leaflet 107, Commonwealth Department of National Development (Canberra).

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