CSIRO PyroPage
Putting science into practice
www.csiro.au
Number 1 | **April 2015**

Kataburn – Predicting downslope rate of fire spread

A new model for determining the correction factor for downslope rate of fire spread has been developed. All Australian operational fire spread models need a correction factor to incorporate the effect of topography on rate of spread.

Predicting downslope rate of fire spread

In Australia, we have been using Alan McArthur's rule of thumb for modifying the flat ground rate of spread (as predicted by his meters) to account for the multiplying effects of slope for more than 50 years. While this rule of thumb, which essentially says that the flat ground rate of spread (predicted using wind and fuel moisture conditions) doubles for every 10° of positive slope, has not been completely validated, the results of a number of studies have not discredited it.

McArthur's rule of thumb goes on to say that there is a corresponding decrease on downslopes. However, the exact nature of this 'corresponding decrease' was never fully explained. Initially, McArthur indicated that the nature of this decrease was not as strong as the upslope but in the book *Bushfires in Australia* by RH Luke and McArthur (1978) they presented a graph that suggested the downslope correction was the inverse of the upslope correction; that is, rate of spread halves for every 10° of negative slope. This was formalised as a mathematical function by Noble *et al.* (1980) and is what is currently employed in all fire spread prediction tools:

$$R_s = R_f \times e^{(-0.069\times\theta)} \equiv R_f \times 2^{(\theta/10)}$$

where R_s is the slope- affected rate of spread, R_f is the flat ground rate of spread and θ is the angle of the slope in degrees.

Hobart 1967: Prediction of fire spread in complex topography is not a simple matter.

At the same time there has been an implicit understanding in the fire management community (and supported by anecdotal observations from the likes of McArthur in Australia and G. Byram and R. Rothermel in the United States) that when fires are large and travelling over undulating terrain, the effect of the upslope and downslope runs effectively cancel each other out, leading to a simple approximation to flat ground rate of spread across the topography. At first glance, McArthur's rule of thumb for both upslopes and downslopes seems to support this but, in fact, it doesn't. Applying McArthur's rule of thumb as given by Noble *et al.*, results in an overall rate of spread that can be very much slower (as much as 4-8 times) over undulating terrain than that of flat ground rate of spread.

Kataburn

To solve this dilemma, a new model for predicting rate of spread on negative slopes called kataburn (from the Greek *kata* meaning 'down') was developed. This model is predicated on two assumptions: 1) that fires burning across undulating topography will approximate flat ground rate of spread, and 2) that the upslope function currently employed is correct (while the example given here is that of McArthur's, i.e. doubling flat ground rate of spread for every 10°, any upslope function can be used). This results in a slightly more complex equation:

$$R_s = R_f \times \frac{2^{(-\theta/10)}}{2(2^{(-\theta/10)}) - 1}$$

where θ is less than zero (i.e. negative). As values of -θ decrease to larger negative values, the downslope rate of spread will begin to level out at about half the flat ground rate of spread, which better approximates McArthur's original version of his slope correction model (Fig. 1).

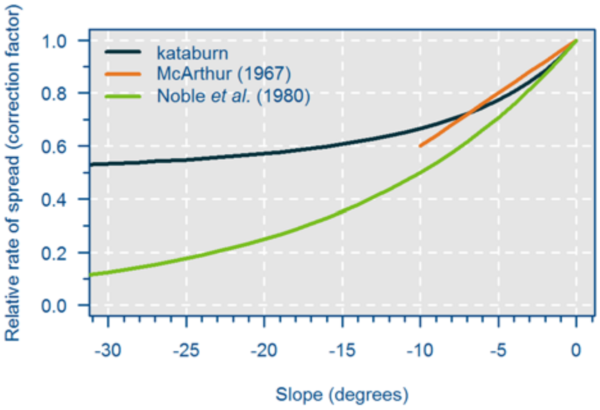

Figure 1. Graph showing the relative difference between the new kataburn downslope correction factor (black line), McArthur's original function (orange line) and the Noble *et al.* (1980) function (green line).

Now, this version of kataburn may also result in overall rates of spread that are slightly different to the flatground rate of spread (particularly when the upslope angle is greatly different from the downslope angle) but the error is much reduced compared to the Noble *et al.* model and is a much more practical version for operational implementation than the complete solution which requires information about the upslope component of the terrain.

Application

The nature of fire behaviour in complex terrain is itself very complex. The interaction of topography with the wind, fuel and the fire means that fires may spread in unexpected directions at speeds that are also unexpected. Understanding the potential behaviour of such fires is critical for accurate prediction of fire spread and the safe execution of fire suppression operations. In forest fuels, spotting (the transport of burning material ahead of the main fire to start new fires) further complicates fire spread predictions and may enable a fire front to skip over downslope regions.

When carrying out manual fire spread predictions in complex topography and attempting to incorporate the influence of terrain on fire spread using slope correction (Fig. 2), care must be taken to consider only that slope in the direction of the wind. Australian fire behaviour models take into account wind to determine the flat ground rate of spread. Only slope in the direction of wind must be used to apply the slope correction factor as given in Figure 2.

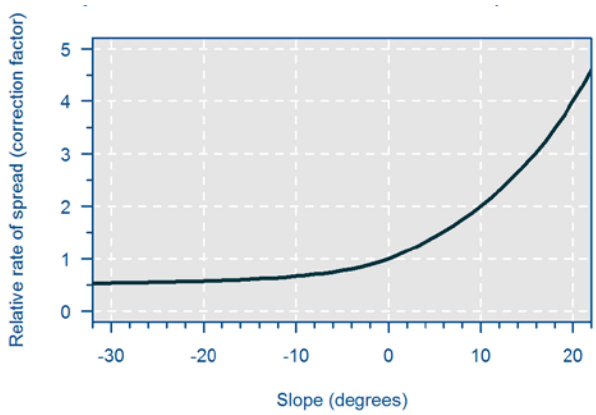

Figure 2. Graph of recommended slope correction factor values for Australian fire spread models for -30° to +20° slopes.

Further reading

Sullivan, A. L., Sharples, J. J., Matthews, S. & Plucinski, M. P. 2014. A downslope fire spread correction factor based on landscape-scale fire behaviour. *Environmental Modelling & Software 62*, 153-163

References

Luke, R.H. and McArthur, A.G. 1978. *Bushfires in Australia*. AGPS, Canberra. 378 pp.

McArthur, A.G. 1967. Fire Behaviour in Eucalypt Forests. Forestry and Timber Bureau Leaflet *107. Commonwealth Department of National Development*, 36 pp

Noble, I. R., Bary, G. A. V. & Gill, A. M. 1980. McArthur's fire-danger meters expressed as equations. *Australian Journal of Ecology 5*, 201-203

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

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