Explaining feedbacks between fire and flammability in the Snowgums and beyond

PHILIP ZYLSTRA

Centre for Environmental Risk Management of Bushfires, University of Wollongong. Email: pzylstra@uow.edu.au

Changing fire regimes are gaining recognition as one of the chief impacts of a changing climate on terrestrial biota, partially due to growing awareness that the feedbacks between fire and the flammability of a forest have the potential to amplify any other changes. If we are to effectively respond to this, it is essential that we learn to understand and quantify those feedbacks as they apply in each situation.

The *fuel–age paradigm* is the assumption that recently burnt forests are less flammable than long-unburnt forests. If this is the case, then the feedback between fire and flammability is negative: more frequent fire will create a less flammable landscape and the escalation in fire will be self-limiting. Management fires can be lit under safer conditions and reduce the risk.

The efficacy of such prescribed burning can be measured from fire histories using a statistic called *leverage* (Loehle 2004), meaning the area protected from fire per area burnt. The concept began as a theoretical exercise with the assumption that recently burnt areas do not re-burn in subsequent fires. When this was modelled, burnt patches cast a shadow of protection to provide leverage as high as 11 (i.e., 11ha protected for every hectare burnt), underpinning the popular belief that prescribed burning was the practice of lighting a small fire to stop a large one.

Measured leverage values however are much lower, and to date no published study has found a value greater than one (Boer *et al.* 2016). In every forest community examined, prescribed burning is more accurately described as the practice of lighting a large fire to stop a small one. In south east Australia, leverage has in fact more often been negative than positive (Price *et al.* 2015), and this evidence of widespread positive fire-flammability feedbacks should cause serious concern.

Explaining the mechanisms

Forest flammability has frequently been related to the fuel load, or weight of dead fine fuels on the ground. These are burnt away by fire and take time to re-accumulate and reach equilibrium, so accordingly flammability should increase with time since fire and all feedbacks should be negative. This view however ignores the many other drivers of flammability (Gill and Zylstra 2005). In the Australian Alps, there has been tension between it and the observation that burning plants produce larger flames than burning leaf litter, and that fire can promote the growth of plants (Zylstra 2006). This was raised as a major criticism of broad-scale burning in montane and subalpine areas by Roger Good (1986), who noted that leguminous genera such as *Daviesia, Oxylobium* and *Bossiaea* were germinated by the very fires lit to reduce flammability (Figs. 1 & 2).

Following the 2003 bushfires, work was commenced through the NSW National Parks and Wildlife Service with the Bushfire Cooperative Research Centre to build a fire behaviour model capable of determining exactly what role plants had in the flammability of forest stands. Traditionally, fire behaviour models in Australia have been constructed from empirical data, making them reliable only for the range of fuels and conditions that had been studied. In contrast, the Forest Flammability Model (FFM)

Figure 1. Subalpine woodland six years after fire (Source: Zylstra 2013)

Figure 2. Long-unburnt subalpine woodland (Source: Zylstra 2013)

(Zylstra 2011) is a biophysical, mechanistic model that combines laboratory studies of leaf flammability with the physics of heat transfer, in-forest wind dynamics and the geometry of the plant community to calculate the propagation of flame from one leaf, branch, plant or plant stratum across the gaps that separate them to the next potential fuel. In this way, the FFM does not use broad assumptions to make predictions, but examines the effect of plants on flammability from an objective platform.

Testing Good's Hypothesis

To assess the utility of the model for answering questions around feedbacks, Good's Hypothesis of a positive feedback in subalpine forest was chosen as a 'risky prediction' as it countered the prevailing fuel-age paradigm. FFM modelling predicted that until Snowgum forests had regenerated a tree canopy, fires would burn faster and more frequently have large flames than in old forests. This prediction was empirically tested by comparing fire records for subalpine forest across the Australian Alps National Parks in mainland Australia. This revealed that forests which had been burnt within the previous 14 years were burnt by subsequent fires 2.3 times more often than were older forests ($p = 0.05$, Zylstra 2013). Good's hypothesis was supported by both mechanistic argument and empirical evidence: burning Snowgum forest makes it more flammable.

Wider implications

By establishing the link between plant species and the flammability of a forest, the FFM represents a milestone in the study of plants and fire. Historical work has shown that fire regimes affect plant traits and their distributions, but the FFM can now be used to study how plant traits and distributions affect fire regimes, regardless of the community (Fig. 3).

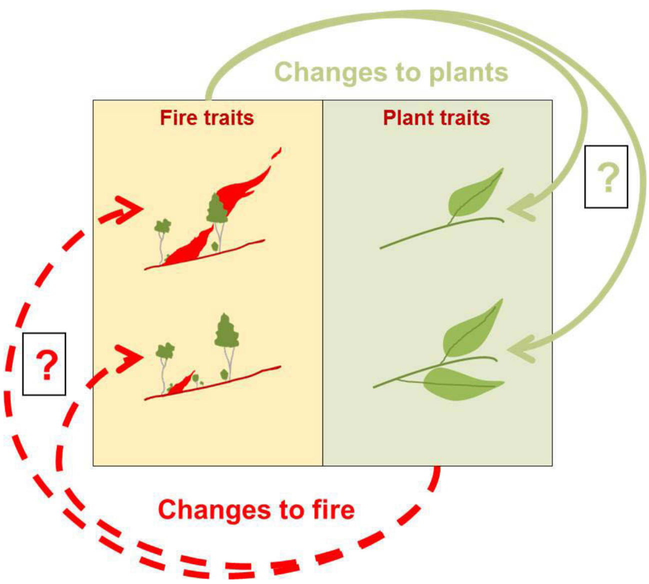

Figure 3. Fire-flammability feedbacks, completing the links between fire behaviour and fire ecology.

Conclusions and future direction

Assuming negative fire-flammability feedbacks across diverse plant communities results in under-estimation of fire-related risks, and in ineffective or counter-productive management responses where the feedback is in fact positive. The FFM is capable of quantifying these feedbacks, enabling informed, evidence-based responses.

Current work on the FFM continues in validating the model, producing software and integrating with remote-sensing technologies.

Acknowledgement

Development of the FFM has been funded by the NSW Office of Environment and Heritage, with the initial model developed as a PhD project while on staff, and subsequent work carried out as part of the Centre for Environmental Risk Management of Bushfires at the University of Wollongong. Ross Bradstock's assistance has been central to this.

Roger Good's work provided much of the initial inspiration for the development of the FFM, and during the project he provided advocacy, funds, insight and equipment. This work continues his battle for the mountains and the wild places at risk from the things we understand too poorly.

References

Boer, M.M., Price, O.F. and Bradstock, R.A. (2015). Wildfires: Weigh policy effectiveness. *Science.* 350, 920. doi:10.1126/science.350.6263.920-a

Gill, A.M and Zylstra, P. (2005). Flammability of Australian forests. *Australian Forestry* 68, 87–93.

Good, R.B. (1986). A basis for fire management in alpine National parks, In: *Proceedings of the National Parks Association Conference on Management of Alpine National Parks*. Canberra, ACT, pp. 82–104.

Loehle, C. (2004). Applying landscape principles to fire hazard reduction. *Forest . Ecology and Management*. 198, 261–267. doi:10.1016/j.foreco.2004.04.010

Price, O.F., Penman, T., Bradstock, R.A., Boer, M.M. and Clarke, H. (2015). Biogeographical variation in the potential effectiveness of prescribed fire in south-east Australia. *Journal of Biogeography*. 42, 2234–2245. doi:10.1111/jbi.12579

Zylstra, P. (2006). *Fire History of the Australian Alps*. Australian Alps Liaison Committee, Jindabyne. http://www.australianalps.environment.gov.au/publications/research-reports/fire-history.html

Zylstra, P. (2011). *Forest Flammability: Modelling and Managing a Complex System*. PhD Thesis, University of NSW, Australian Defence Force Academy. http://handle.unsw.edu.au/1959.4/51656

Zylstra, P. (2013). The historical influence of fire on the flammability of subalpine Snowgum forest and woodland. *The Victorian Naturalist.* 130, 232–239.