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Modelling leaf, plant and stand flammability for ecological and operational decision making

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Numerous factors have been found to affect the flammability of individual leaves and plant parts; however the way in which these factors relate to whole plant flammability, fire behaviour and the overall risk imposed by fire is not straightforward. Similarly, although the structure of plant communities is known to affect the flammability of the stand, a quantified, broadly applicable link has proven difficult to establish and validate. These knowledge gaps have presented major obstacles to the integration into fire behaviour science of research into factors affecting plant flammability, physiology, species succession and structural change, so that the management of ecosystems for fire risk is largely uninformed by these fields.

The Forest Flammability Model (Zylstra, 2011) is a process-driven, complex systems model developed specifically to address this disconnect. Flame dimensions and position are calculated as properties emerging from the capacity for convective heat to propagate flame between horizontally and vertically separated leaves, branches, plants and plant strata, and this capacity is determined dynamically from the ignitability, combustibility and sustainability of those objects, their spatial arrangement and a vector-based model of the plume temperature from each burning fuel.

All flammability properties as well as the physics of flame dimensions, angle and temperature distributions and the vertical structure of wind within the plant array use published sub-models which can be replaced as further work is developed. This modular structure provides a platform for the immediate application of new work on any aspect of leaf flammability or fire physics.

Initial validation of the model examined its qualitative predictions for trends in forest flammability as a function of time since fire. The positive feedback predicted for the subalpine forest examined constituted a ‘risky prediction’ by running counter to the expectations of the existing approach, however examination of historical fire sizes confirmed the positive feedback (Zylstra, 2013). The capacity to model even counter-intuitive trends in flammability represents a fundamental advance in the management of fire risk, underpinning the importance of work on those fields that compose the sub-models.

Ongoing validation work has focused on accuracy in flame height and fire severity prediction, with excellent results to date. Further studies will examine quantitative estimates of fire risk parameters and the reliability of rate of spread predictions.

By accurately modelling the relationship between seemingly disparate studies of leaf flammability, moisture, physiology and forest structure, the Forest Flammability Model has the potential to resolve some long-standing questions (Yebra et al., 2013) as well as to provide insight into the effect of climate or management-induced ecosystem changes on fire behaviour and risk.

References

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