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Foreword

Forest fires and climate change: causes, consequences and management options

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Fire is, in many cases, an essential ecosystem component that ensures the sustainability of its processes and communities. Since its emergence, fire has played a key role as an environmental filter, selecting for species and their traits, and shaping ecosystems' communities. However, not all fires are the same and ecosystems exposed to fire regimes out of their historical range of variability might become vulnerable and suffer irreversible changes.

During the International Union of Forest Research Organizations (IUFRO) World Congress held in Salt Lake City, Utah, United States (5–11 October 2014), two technical sessions – 'Forests, fire and climate change dynamics' and 'Managing forests for fire in a changing climate' – addressed the interactions between climate change and forest fire regimes, their ecological impacts and consequences, and the role of landscape management to mitigate those impacts. This special section brings together papers presented during those technical sessions and assembles studies by scholars from North America, Europe, Asia and Oceania. It is a reflection of the relevance of the fire and climate change interactions worldwide.

The papers in this section focus on three main themes that emerged during the sessions. First, fire regimes are changing as a result of changes in climate conditions. Second, changes in fire regimes may have significant ecological consequences because the newly emerged regimes could affect the ecosystem's ability to recover and provide services. Third, there is an opportunity for land management to mitigate these impacts, either by limiting changes in fire regime or by maintaining and enhancing landscape resilience.

Fire regimes are determined by climate–weather, vegetation and direct human influence (Flannigan *et al.* 2009), with climate being recognised as a major determinant of fire patterns on a global scale (Marlon *et al.* 2008). Fire frequency and intensity, two attributes commonly used to describe fire regimes, are predicted to increase, at least in the medium-term, in areas where climate change will increase aridity, leading to new fire regimes (Flannigan *et al.* 2009). Several mechanisms underpin this link between climate change and the emergence of new fire regimes, including increases in fuel availability. Krasovskii *et al.* (2016) evaluate the effect of including a function reflecting fuel moisture in a mechanistic fire modelling algorithm employed to reproduce burned areas at a country scale for historical climate. Accounting for fuel moisture resulted in a dramatic improvement in accuracy of modelled burned areas for a range of European countries. The results point to the potential consequences that changes in fuel moisture, as a result of changing climate and weather conditions, may have on fire patterns (Tian *et al.* 2014).

Another important interaction between climate and fire regimes comes from anticipated changes in fuel loads. Ruthrof *et al.* (2016) address the idea that changes in forest structure resulting from a climate induced die-off could lead to subsequent changes in fire behaviour. In their paper, the authors quantify changes in fuel loads and understorey microclimate following a forest die-off in south-western Australia. Their results indicate that the measured increases in dead wood mass and increased near-ground solar radiation associated with the die-off could lead to increases in fire spread of up to 30%. This is a striking finding given the greater number of die-off events from increasing drought in many regions of the world (Allen *et al.* 2015)

Impacts on ecosystems' species composition and functioning are expected as new fire regimes approximate to the extremes of the historical range of variability that current ecosystems have evolved within. In their review, Fairman *et al.* (2016) analyse the impacts of increasing wildfire frequency on temperate forests, using the fire tolerant (resprouter) and fire sensitive (obligate seeder) eucalypt forests of south-eastern Australia as a case study. The authors review historical and recent evidence that suggests that recurrent wildfires could lead to a shift from fire sensitive (obligate seeder) forest to non-forest state if fire intervals are shorter than the species' juvenile period. Thought-provoking is their analysis on the impacts of increased fire frequency on fire tolerant resprouter forests, which points to potential changes in forest structure resulting from increased tree mortality and reduced recruitment. Nevertheless, some ecosystems may show higher resilience to fire frequency in terms of species composition. For example, Chick *et al.* (2016)

analyse the diversity and functional composition of the soil seedbank of a heathland in south-eastern Australia. Their findings suggest that the richness and functional diversity of the propagules in the soil seedbank did not change with time since fire. Therefore, it is possible that in these fire-prone and fire-dependent systems, recurrent fires will not have a negative impact on the belowground diversity reservoir.

As an ecosystem's species composition and structure change in response to new fire regimes, so does its ability to provide services and values. Cai and Yang (2016) explore the link between high-severity fires, which are predicted to increase under climate change, and forest aboveground productivity via shifts in stand structure in a boreal forest in north-eastern China. Their results show that, a decade after a stand-replacing fire, forest stands that had been burned with high severity had significantly lower forest regeneration net primary productivity than those burned with low severity. This difference was a result of both a lower tree sapling density and understorey vegetation abundance in the high-severity areas. The authors suggest that a change in fire regime towards high-severity fires could result in a shift in forest structure, which may influence future forests' capacity to sequester carbon.

Land management can contribute to mitigating the impacts of emergent fire regimes on ecosystems (Shive *et al.* 2014). In a modelling exercise comparing wildfire scenarios with and without fuel treatments, Elliot *et al.* (2016) found a significant reduction in post-fire erosion and runoff, and therefore an increase in the forest's ability to provide clean water, when fuel reduction treatments were applied in a forested watershed in California, USA. This mitigation effect was related to a reduction in the fire probability and intensity that resulted from reducing the amount and type of fuel available for a wildfire.

The contributions in this special section offer a contrast in approaches and concepts, and illustrate the importance of addressing the uncertainties around the emergence of new fire regimes from multiple perspectives: the causes, the consequences and the management alternatives. We hope that these studies will prompt further work and evaluation of the problem of forest fires in a changing climate.

References

Allen CD, Breshears DD, McDowell NG (2015) On underestimation of global vulnerability to tree mortality and forest die-off from hotter drought in the Anthropocene. *Ecosphere* **6**, 129. doi:10.1890/ES15-00203.1

Cai W, Yang J (2016) High severity fire reduces early successional boreal larch forest aboveground productivity by shifting stand density in northeastern China. *International Journal of Wildland Fire* **27**, 861–875. doi:10.1071/WF15026

Chick MP, Cohn JS, Nitschke CR, York A (2016) Lack of soil seedbank change with time since fire: relevance to seed supply after prescribed burns. *International Journal of Wildland Fire* **27**, 849–860. doi:10.1071/WF15013

Elliot W, Miller M, Enstice N (2016) Targeting forest management through fire and erosion modelling. *International Journal of Wildland Fire* **27**, 876–887. doi:10.1071/WF15007

Fairman TA, Nitschke CR, Bennett LT (2016) Too much, too soon? A review of the effects of increasing wildfire frequency on tree mortality and regeneration in temperate eucalypt forests. *International Journal of Wildland Fire* **27**, 831–848. doi:10.1071/WF15010

Flannigan MD, Krawchuk MA, de Groot WJ, Wotton BM, Gowman LM (2009) Implications of changing climate for global wildland fire. *International Journal of Wildland Fire* **18**, 483–507. doi:10.1071/WF08187

Krasovskii A, Khabarov N, Migliavacca M, Kraxner F, Obersteiner M (2016) Regional aspects of modelling burned areas in Europe. *International Journal of Wildland Fire* **27**, 811–818. doi:10.1071/WF15012

Marlon JR, Bartlein PJ, Carcaillet C, Gavin DG, Harrison SP, Higuera PE, Joos F, Power M, Prentice I (2008) Climate and human influences on global biomass burning over the past two millennia. *Nature Geoscience* **1**, 697–702. doi:10.1038/NGEO313

Ruthrof KX, Fontaine JB, Matusick G, Breshears DD, Law DJ, Powell S, Hardy G (2016) How drought-induced forest die-off alters microclimate and increases fuel loadings and fire potentials. *International Journal of Wildland Fire* **27**, 819–830. doi:10.1071/WF15028

Shive KL, Fulé PZ, Sieg CH, Strom BA, Hunter ME (2014) Managing burned landscapes: evaluating future management strategies for resilient forests under a warming climate. *International Journal of Wildland Fire* **23**, 915–928. doi:10.1071/WF13184

Tian X-r, Zhao F-j, Shu L-f, Wang M-y (2014) Changes in forest fire danger for south-western China in the 21st century. *International Journal of Wildland Fire* **23**, 185–195. doi:10.1071/WF13014