Pyrogeography: integrating and evaluating existing models of Australian fire regimes to predict climate change impacts

doi: 10.5281/zenodo.7996994

Principal Investigator: Brett Murphy[9]

Group Members: Matthias Boer[1], David Bowman[2], Ross Bradstock[3], John Carter[4], Geoff Cary[5], Mark Cochrane[6], Rod Fensham[7], Meg Krawchuk[8], Owen Price[9], Jeremy Russell-Smith[10], Dick Williams[11], and Grant Williamson[2]

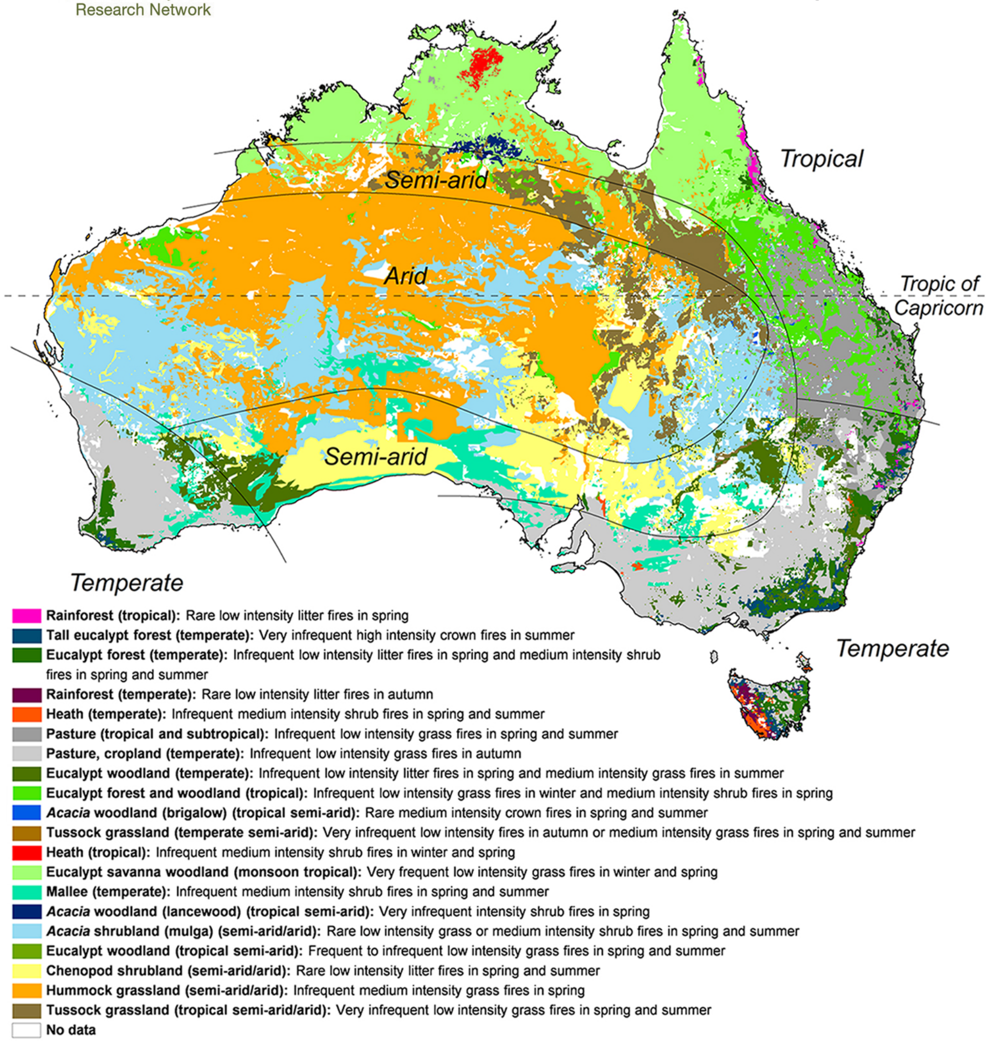

Figure 1: The distribution of major fire regimes niches throughout Australia, ordered according to decreasing annual net primary productivity. To view this map interactively go to http://www.aceas.org.au/portal/

Project Objectives

Fire is a critical process in Australian landscapes, affecting biodiversity and ecosystem function, atmospheric greenhouse gas concentrations, and human health, safety and property. Yet our understanding of the drivers of fire regimes remains limited. Only recently has there been impetus to form unifying theories of the biogeography of fire at regional and continental scales, and existing theories have yet to be rigorously evaluated using extensive, continental-scale datasets. The need to understand how fire regimes are related to environmental conditions is made urgent by rising atmospheric CO2 concentration and the associated prospects of rapid climate change. Given the strong effect of CO2 on vegetation productivity and biomass, and of climate on fire weather and fuel availability, future dramatic shifts in fire regimes have been predicted, although the magnitude and even direction of the predicted changes tend to be highly uncertain.

The working group aimed to address important knowledge gaps in the biogeography of fire in Australia by:

(1) Developing an approach to classifying and mapping broad fire regimes at a continental scale. A continental description of the diversity of fire regimes is a key step in understanding the global drivers and constraints of landscape fire, as well as illuminating possible climate change effects by providing potential analogues for future fire activity

(2) Reviewing drivers of variation in fire regimes and their relative importance

(3) Developing a framework for assessing the vulnerability of fire regimes to change.

Methods

To broadly characterise Australia's fire regimes, we reclassified a continental-scale vegetation map, defining classes based on typical fuel (e.g. litter, grass, shrubs) and fire types (e.g. surface, crown, and ground). Classes were intersected with a broad climate classification to derive a map of twenty broad fire regimes (Figure 1). Using expert elicitation and a literature search, we validated each fire regime and characterised typical and extreme fire intensities and return intervals. Satellite-derived active fire detections were used to determine seasonal patterns of fire activity within fire regimes.

We considered that two of the most likely impacts of climate change on fire regimes would be via changes in: (1) biomass to burn; and (2) short- to medium-term fire weather, affecting the availability of fuel to burn and rates of fire spread. Hence, we described a climate space with axes representing annual means of (1) rainfall (a surrogate for biomass availability); and (2) potential evapotranspiration (a surrogate for fire weather). Plotting a surface representing AVHRR satellite-derived fire frequency (1997-2010) within this space (Figure 2) allowed us to infer the likely driver of change in each of Australia's 20 broad fire regimes. The location of fire regimes relative to this surface indicates whether changes in biomass or fire weather are likely to be the main drivers of change.

Major Findings

Australia's fire regimes are closely correlated with the latitudinal gradient in summer monsoon activity. Frequent, low intensity fires occur in the monsoonal north, and infrequent, high intensity fires in the temperate south, demonstrating a trade-off between frequency and intensity. That is, very high intensity fires are only associated with very low frequency fire regimes in the high biomass eucalypt forests of southern Australia. While these forests occasionally experience extremely intense fires, these regimes are exceptional, with most of the continent dominated by grass fuels, typically burning with relatively low intensities. Fire is rare in dense-canopied vegetation, such as arid Acacia shrublands, due to sparse fine fuels, and rainforests, due to the combination of sparse fine fuels and infrequent microclimatic conditions suitable for fire.

The approach we have developed to define continental-scale fire regimes, using a combination of remote sensing and thematic data, expert elicitation and literature review, will provide insights into the spatiotemporal patterns of fire, informing models that predict effects of climate change on fire regimes. Our approach can be applied globally, providing opportunities to undertake comparative pyrogeographic analyses.

The climatic correlates of recent fire activity provide insights into the vulnerabilities of Australian fire regimes to global environmental change. Maximum fire activity occurs at high levels of mean annual rainfall and potential evapotranspiration, where fuel loads are typically high and fire weather seasonally severe (Figure 2), consistent with the predictions of recent conceptual models (Meyn et al., 2007; Bradstock, 2010). Annual fire activity is severely constrained at low values of either mean annual rainfall (biomass limited) or potential evapotranspiration (fire weather limited). We expect that fire regimes in high rainfall areas, such as southern Australia, will be most strongly affected by changes in the frequency of severe fire weather, while fire regimes in low rainfall areas, such as central Australia, will be most affected by changes in productivity and fuel abundance, possibly as a result of changes in rainfall or atmospheric CO2 concentration.

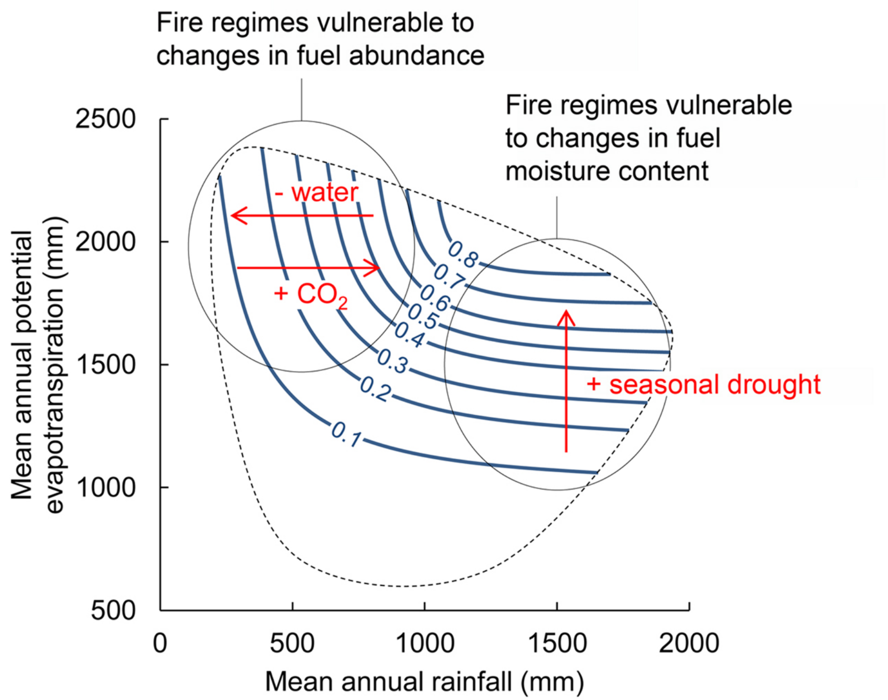

Figure 2. Climatic control of maximum fire frequencies throughout Australia, and climatic zones with fire regimes vulnerable to changes in either fuel abundance or fire weather. The contour lines describe a surface representing the upper bound (99% quantile) of AVHRR satellite-derived fire frequency (1997-2010) (expressed as fires year-1); highest fire frequencies occur at high levels of mean annual rainfall and potential evapotranspiration, where fuel loads are typically high and fire weather seasonally severe. The dashed line represents the climatic envelope occupied by the vast majority of the Australian continent.

How will this affect Australian ecosystem science & management?

The generation of a broad fire regimes map for Australia will help to contextualise regional approaches to fire management. A concept that arose from the working group is that of 'fire countries' - broad biogeographic areas with similar patterns of fire regimes and fire management issues. Such a concept will help scientists convey to policymakers that fire management practices appropriate for one 'fire country' may be entirely inappropriate for another (e.g. grazing as a fire management tool in central Queensland vs. the Australian Alps). The approach we have developed to quantify the vulnerability of fire regimes to changes in fuel abundance and fire weather will allow land managers to better predict the impacts of global environmental change on ecosystems.

References

Bradstock, R. A. (2010) A biogeographic model of fire regimes in Australia: current and future implications. *Global Ecology and Biogeography*. 19, 145-158.

Meyn, A., White, P. S., Buhk, C. & Jentsh, A. (2007) Environmental drivers of large, infrequent wildfires: the emerging conceptual model. *Progress in Physical Geography*. 31, 287-312.

Outputs and Products

Murphy B.P., Williamson G.J. & Bowman D.M.J.S. (2011) Fire regimes: moving from a fuzzy concept to geographic entity. New Phytologist 192, 316-318.
Bowman D.M.J.S., Murphy B.P., Boer M.M., Bradstock R.A., Cary G.J., Cochrane M.A., Fensham R.J., Krawchuk M.A., Price O.F. & Williams R.J. (2013) Forest fire management, climate change and the risk of catastrophic carbon losses. Frontiers in Ecology and the Environment 11 (2), 66-68.
Murphy B.P., Bradstock R.A., Boer M.M., Carter J., Cary G.J., Cochrane M.A., Fensham R.J., Russell-Smith J, Williamson G.J. & Bowman D.M.J.S. (2013) Fire regimes of Australia, a pyrogeographic model system. Journal of Biogeography doi: 10.1111/jbi.12065
Boer M.M., Bowman D.M.J.S., Bradstock R.A., Cary G.J., Cochrane M.A., Fensham R.J., Krawchuk M.A., Murphy B.P., Price O.F. & Williams R.J. (in prep.) Tree-grass ratios determine transformational shifts of fire regimes in response to climate change.

Participant's institutions: [1]University of Western Sydney, [2]University of Tasmania, [3]University of Wollongong, [4]Queensland Department of Environment and Heritage Protection,[5]Australian National University, [6]South Dakota State University, [7]University of Queensland, [8]University of California, Berkeley, [9]University of Melbourne, [10]Bushfires NT, [11]CSIRO Ecosystem Sciences.

2013