THEME 1.5- HISTORICAL AND SEASONAL CONTEXT ANALYSIS

Theme Leader: Rachael Nolan

Subproject: Estimated risk mitigation from prescribed burning prior to the 2019/20 fire season

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1. Theme

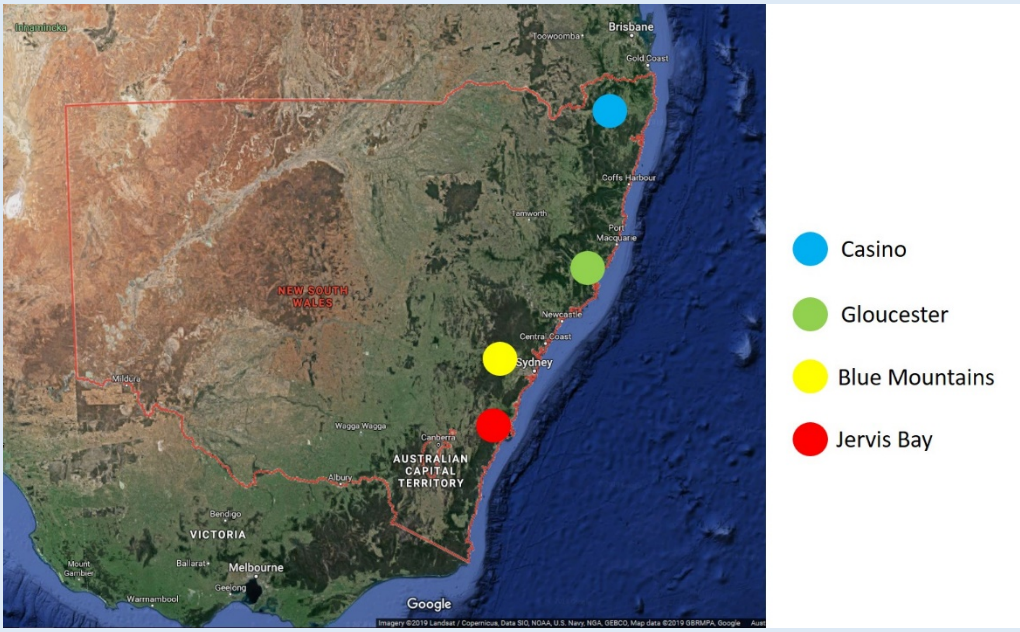
Historical and seasonal context of the 2019/20 NSW bushfires.

2. Project question or problem statement

How was risk to life, property and environmental values affected by prescribed burning prior to the 2019/20 season? How did the extreme weather conditions of the 2019/20 season influence risk mitigation from prescribed burning compared to results which integrate the probabilities of the full range of weather conditions, based on long-term records?

3. Geographic extent

Figure 1. Location of case study landscapes.



4. Key findings

- Levels of prescribed burning leading up to the 2019/20 fire season were estimated to leave considerable residual risk for most values (e.g. > 50% of a zero treatment scenario) though results varied across landscapes (see solid black bars in Figures 2-7).
- We estimated that a 5% p.a. treatment scenario would have reduced risk but still resulted in high residual risk (> 50% residual risk except in the Blue Mountains) (see dotted black bars in Figures 2-7).
- There was substantial variation between case study landscapes in the predicted level of relative risk reduction resulting from prescribed burning, with the Blue Mountains landscape much more sensitive to treatment than in the Casino, Gloucester and Jervis Bay landscapes. Such variations in prescribed burning effectiveness (i.e. level of risk reduced) may be due partly to the spatial configuration of assets and natural vegetation in each landscape.
- Weather conditions based on the severe weather conditions experienced during the 2019-20 fire season were estimated to result in higher risk than the long-term scenarios based on the full range of

weather conditions for the historical record at each case study landscape (compare circles and triangles in Figures 2-7).

- In general, increasing rates of prescribed burning treatment were predicted to decrease risks to assets: i.e. overall area burnt by wildfire, life loss, house loss, damage to roads and damage to powerlines. At the same time, increasing rates of prescribed burning treatment were predicted to increase the area burnt below minimum tolerable fire interval and associated risk to some elements of biodiversity, in most cases.

5. Significance of findings in context of previous studies

These findings are consistent with previous studies which have found that

- prescribed burning may offer partial risk mitigation, not risk elimination (e.g. Cirulis et al. 2019, Penman et al. 2020)
- the risk mitigation potentially resulting from prescribed burning varies considerably between regions and management values (e.g. Cirulis et al. 2019). That is, there is not a 'one size fits all' solution to prescribed burning treatment.
- Prescribed burning is likely to be less effective at mitigating risk to lives, property and infrastructure under severe fire weather conditions (e.g. Price and Bradstock 2012).

6. Limitations and remaining knowledge gaps

This analysis was based on large scale fire behaviour simulations under a range of ignition locations, prescribed burning treatment rates and locations, and fire weather conditions.

This approach assumes that fire spread is a function of fire weather, fuel load and factors such as topography. Fire behaviour simulators built on these assumptions have recently been evaluated (Faggian et al. 2017). The approach also assumes that planned and unplanned fires consume most fuel and that fuel begins to accumulate after fire as a function of time since fire, eventually stabilising at an equilibrium amount. In reality fuel consumption rates vary considerably within any given fire and are typically lower in prescribed fires than wildfires (see Project Report on fire severity).

These results represent simulated properties of a wildfire originating from a single ignition. These simulations do not take into account the specific fire history leading up to the 2019-20 fire season.

Further information about methods can be found in the Appendix, including details of how house loss, life loss, road and powerline damage and area burnt below minimum tolerable fire interval were estimated.

7. Implications for fire management

- Prescribed burning can partially mitigate risk to people, property and infrastructure, but can increase the risk of vegetation being burnt below its tolerable ecological threshold.
- The effectiveness of prescribed burning depends on the specific risk being mitigated (e.g. house loss, life loss, infrastructure damage, environmental condition) as well as properties of the specific landscape being treated (e.g. vegetation type, climate, population density and arrangement of assets in the landscape).
- Fire seasons characterised by increased frequency of extreme weather conditions have substantially increased risks from wildfire regardless of treatment strategy. Further, the increase in risk due to extreme weather typically strongly outweighs the decrease in risk associated with even the highest rates of prescribed burning. Conversely, the relative reductions in risk from prescribed burning are greater during such extreme seasons.

8. Figures

Figure 2. Risk trajectory for area burnt under different treatment strategies and weather conditions. Risk is relative to a control scenario (no prescribed burning and long-term weather = 1, grey dotted line indicates 50% risk reduction). Marker size represents rate of edge treatment, marker colour represents rate of landscape treatment and marker shape represents weather conditions (circles on left represent long-term weather, triangles on right indicate weather from 2019/20 fire season). The current treatment rate in each landscape is indicated by the solid black bar, an alternative 5% treatment strategy is indicated by the dotted black bar.

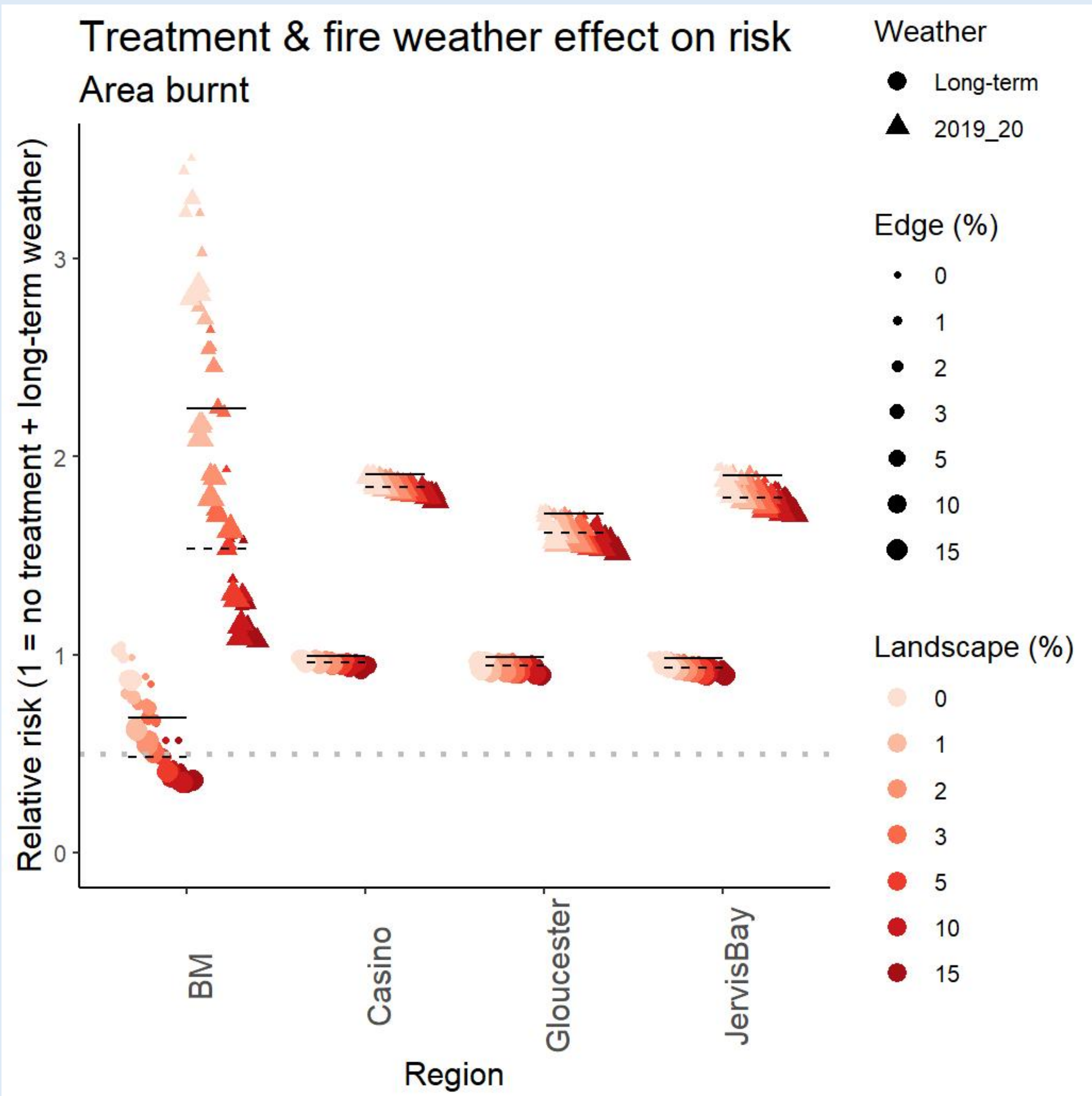


Figure 3. Risk trajectory for life loss under different treatment strategies and weather conditions. Risk is relative to a control scenario (no prescribed burning and long-term weather = 1, grey dotted line indicates 50% risk reduction). Marker size represents rate of edge treatment, marker colour represents rate of landscape treatment and marker shape represents weather conditions (circles on left represent long-term weather, triangles on right indicate weather from 2019/20 fire season). The current treatment rate in each landscape is indicated by the solid black bar, an alternative 5% treatment strategy is indicated by the dotted black bar.

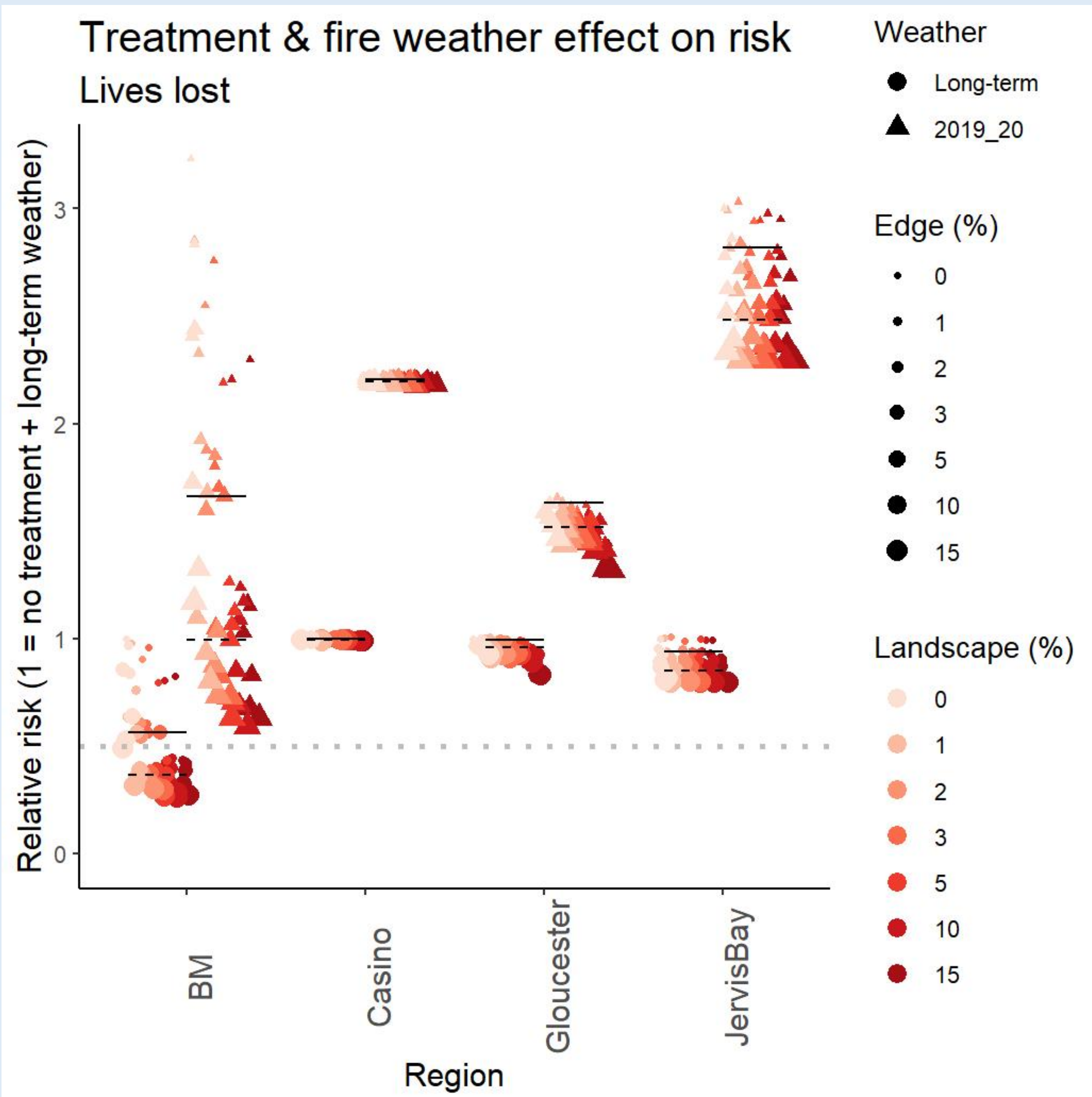


Figure 4. Risk trajectory for house loss under different treatment strategies and weather conditions. Risk is relative to a control scenario (no prescribed burning and long-term weather = 1, grey dotted line indicates 50% risk reduction). Marker size represents rate of edge treatment, marker colour represents rate of landscape treatment and marker shape represents weather conditions (circles on left represent long-term weather, triangles on right indicate weather from 2019/20 fire season). The current treatment rate in each landscape is indicated by the solid black bar, an alternative 5% treatment strategy is indicated by the dotted black bar.

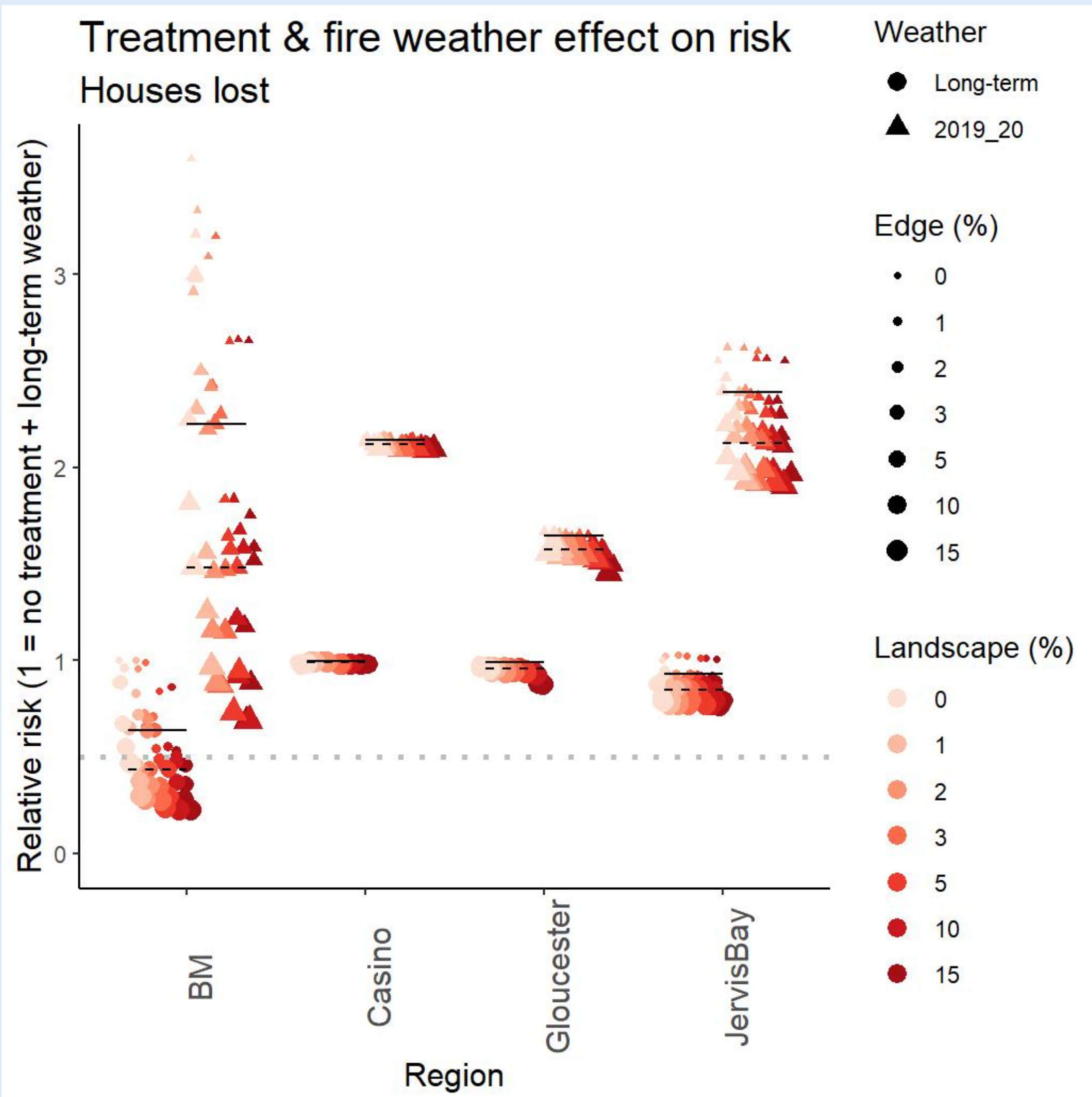


Figure 5. Risk trajectory for length of road damaged under different treatment strategies and weather conditions. Risk is relative to a control scenario (no prescribed burning and long-term weather = 1, grey dotted line indicates 50% risk reduction). Marker size represents rate of edge treatment, marker colour represents rate of landscape treatment and marker shape represents weather conditions (circles on left represent long-term weather, triangles on right indicate weather from 2019/20 fire season). The current treatment rate in each landscape is indicated by the solid black bar, an alternative 5% treatment strategy is indicated by the dotted black bar.

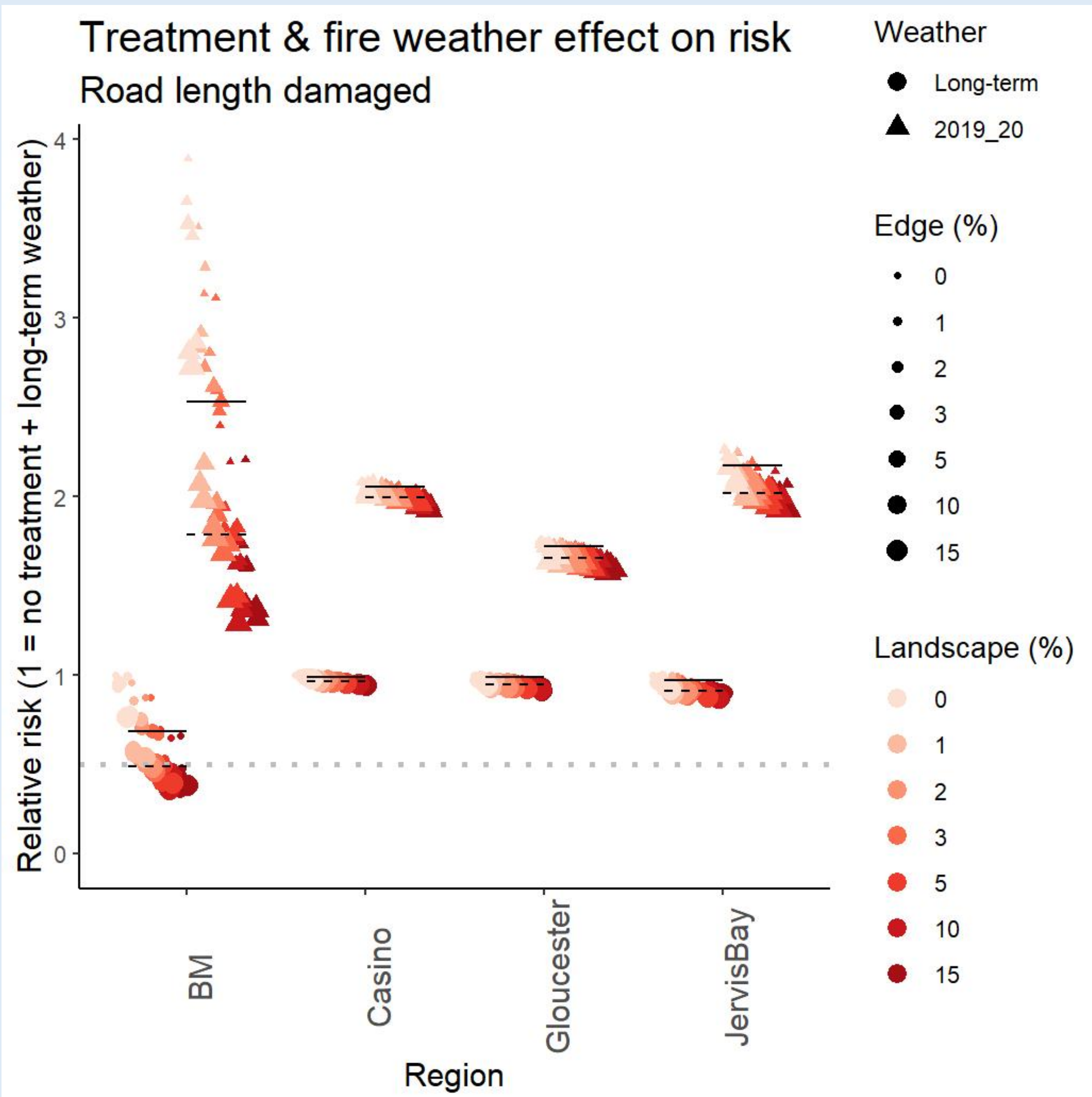


Figure 6. Risk trajectory for length of powerline damaged under different treatment strategies and weather conditions. Risk is relative to a control scenario (no prescribed burning and long-term weather = 1, grey dotted line indicates 50% risk reduction). Marker size represents rate of edge treatment, marker colour represents rate of landscape treatment and marker shape represents weather conditions (circles on left represent long-term weather, triangles on right indicate weather from 2019/20 fire season). The current treatment rate in each landscape is indicated by the solid black bar, an alternative 5% treatment strategy is indicated by the dotted black bar.

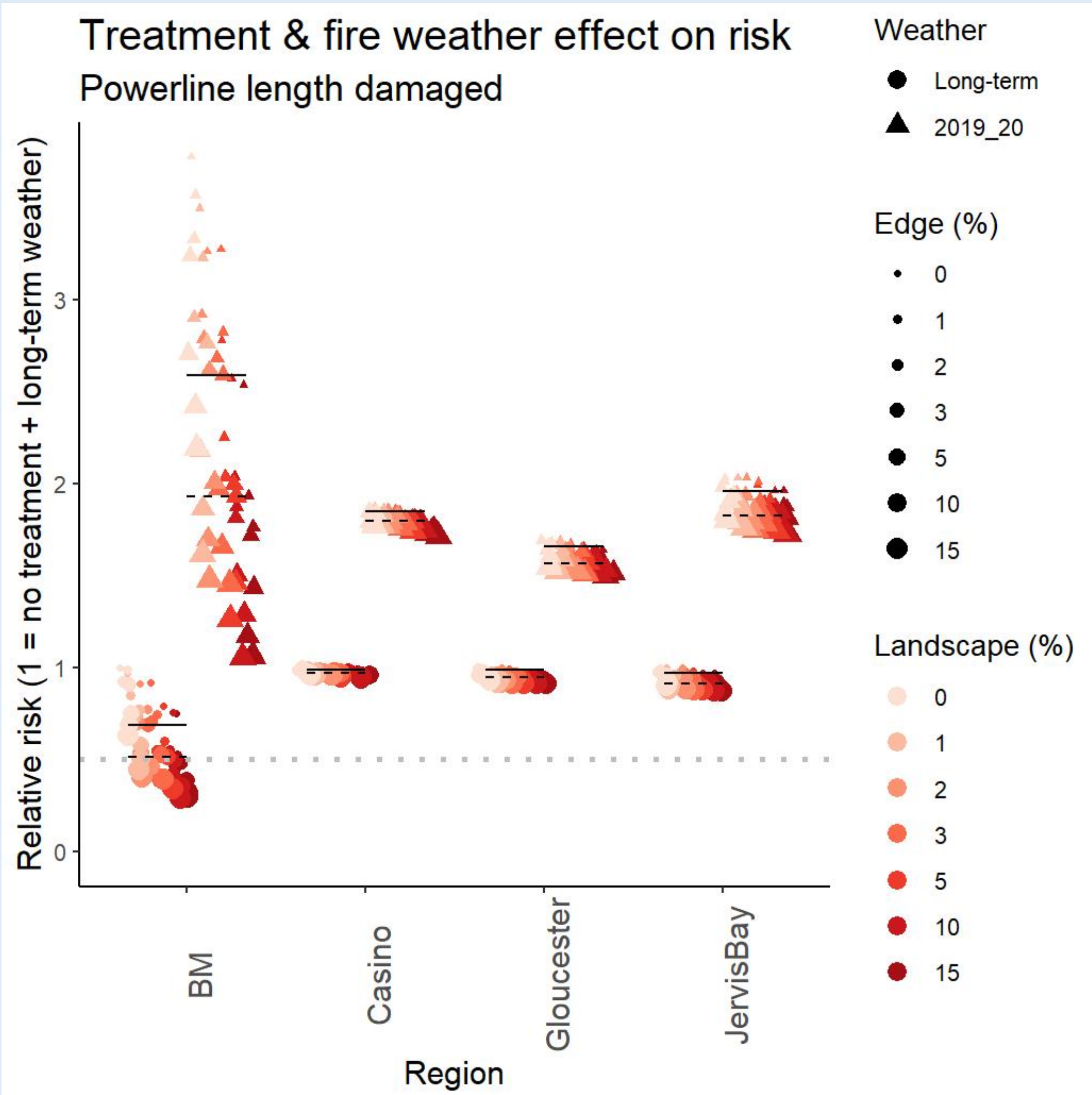


Figure 7. Risk trajectory for area burnt below minimum tolerable fire interval (TFI) under different treatment strategies and weather conditions. Risk is relative to a control scenario (no prescribed burning and long-term weather = 1, grey dotted line indicates 50% risk reduction). Marker size represents rate of edge treatment, marker colour represents rate of landscape treatment and marker shape represents weather conditions (circles on left represent long-term weather, triangles on right indicate weather from 2019/20 fire season). The current treatment rate in each landscape is indicated by the solid black bar, an alternative 5% treatment strategy is indicated by the dotted black bar.

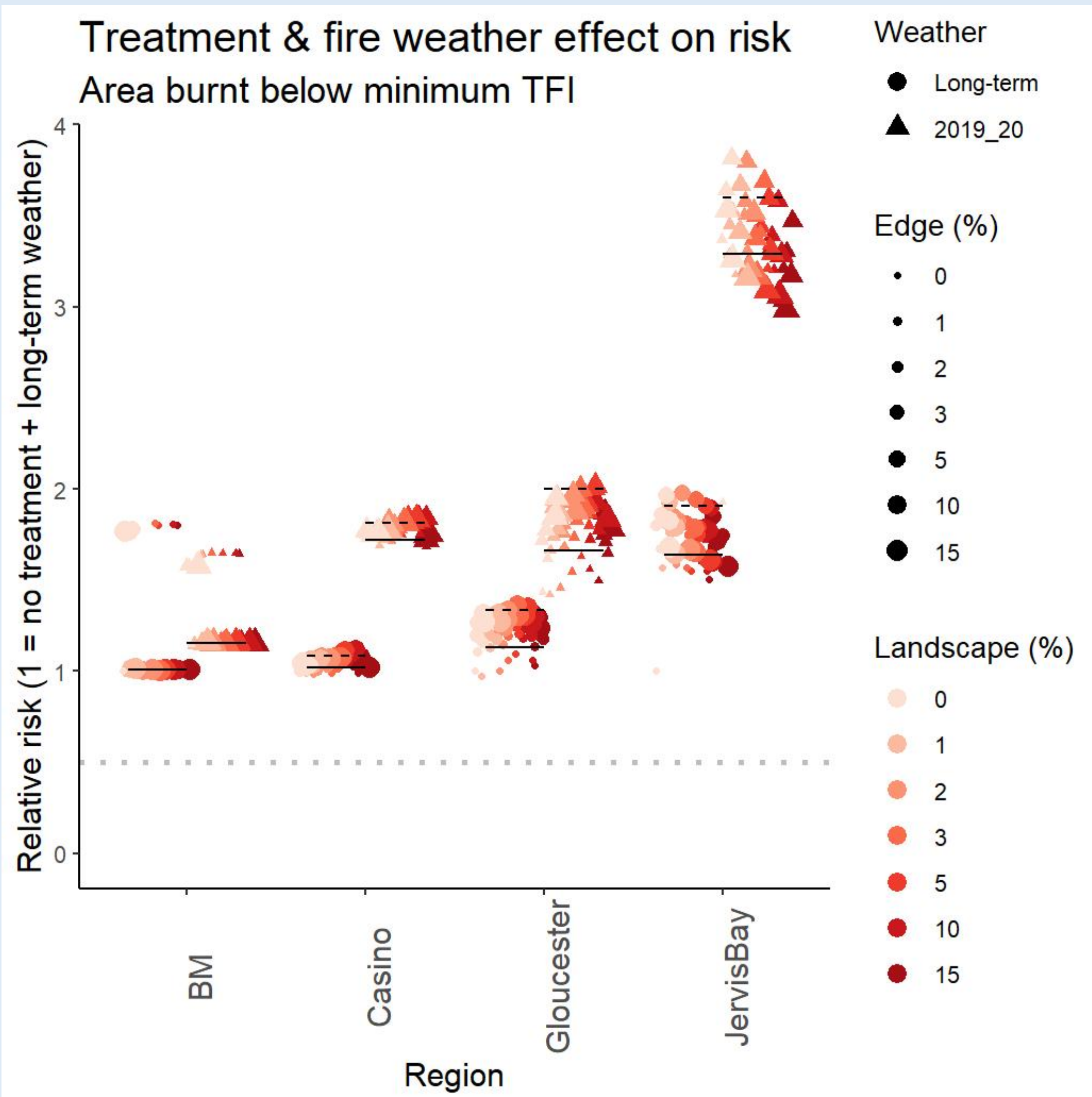
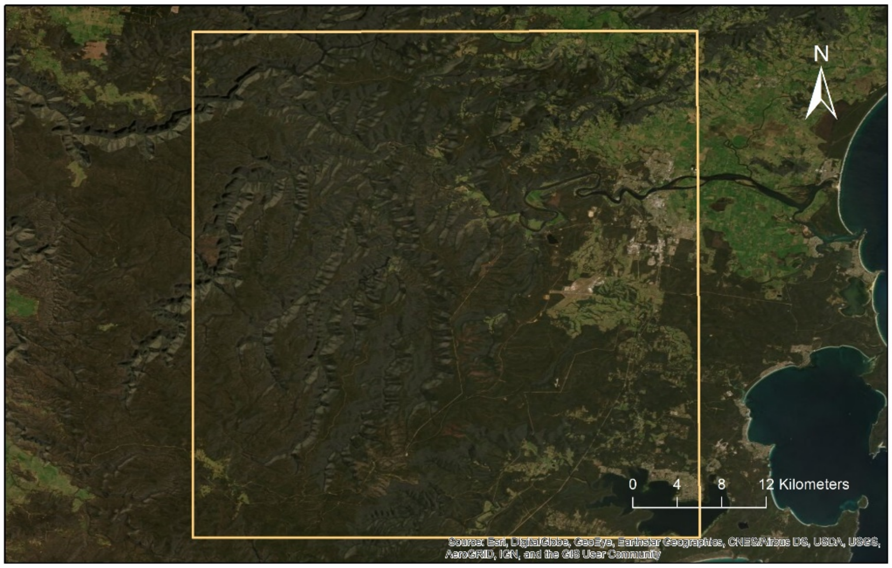


Figure 8. Location of Casino case study landscape

Figure 9. Location of Gloucester case study landscape

Figure 10. Location of Blue Mountains case study landscape

Figure 11. Location of Jervis Bay case study landscape



9. Key reference list

Ager AA, Houtman RM, Day MA, Ringo C & Palaiologou P (2019), Tradeoffs between US national forest harvest targets and fuel management to reduce wildfire transmission to the wildland urban interface, Forest Ecology and Management, 434, 99-109

Alcasena FJ, Ager AA, Bailey JD, Pineda N & Vega-García C (2019), Towards a comprehensive wildfire management strategy for Mediterranean areas: Framework development and implementation in Catalonia, Spain. The Science of the Total Environment 621, 872–885. doi:10.1016/J.SCITOTENV.2017.11.297

Bentley PD, Penman TD (2017) Is there an inherent conflict in managing fire for people and conservation? International Journal of Wildland Fire 26, 455–468. doi:10.1071/WF16150

Cirulis B, Clarke H, Boer M, Penman T, Price O and Bradstock R (2019) Quantification of inter-regional differences in risk mitigation from prescribed burning across multiple management values. International Journal of Wildland Fire. https://doi.org/10.1071/WF18135

Faggian N., Bridge C., Fox-Hughes P., Jolly C., Jacobs H., Ebert B., Bally J. (2017), Final Report: An evaluation of fire spread simulators used in Australia, Bureau of Meteorology, Melbourne: Australia.

Finney MA, McHugh CW, Grenfell IC, Riley KL & Short KC (2011), A simulation of probabilistic wildfire risk components for the continental United States, Stochastical Environmental Research and Risk Assessment, 25, 973-1000

Penman T, Clarke H, Cirulis B, Boer MM, Price O & Bradstock R (2020) Cost-effective prescribed burning solutions vary between landscapes in eastern Australia. Frontiers in Forests and Global Change. doi: 10.3389/ffgc.2020.00079

Price OF, Bradstock RA (2012). The efficacy of fuel treatment in mitigating property loss during wildfires: insights from analysis of the severity of the catastrophic fires in 2009 in Victoria, Australia. Journal of Environmental Management 113, 146-157.

10. Appendix

Summary of methods

Fires were simulated at 1,000 different ignition locations in each case study landscape. This was repeated for up to 49 permutations of edge and landscape treatment (0, 1, 2, 3, 5, 10 and 15% for both locations). This was also repeated for each FFDI category that had been observed at the nearest Bureau of Meteorology automatic weather station to each landscape. The pooled results from the resultant fires were measured to estimate the impact on five management values. Further details can be found in Cirulis et al. (2019). The key difference is that two sets of simulations were run: 1) with weather based on the full historical record of fire season observations (the control scenario), 2) with weather only from the 2019-20 fire season. Key features are paraphrased below.

Fire behaviour simulations

We used PHOENIX RapidFire v4.0.0.7 (Tolhurst et al. 2008), applied operationally in NSW and other south-eastern Australian states. Fire growth and rate of spread follow Huygens' propagation principle of fire edge (Knight and Coleman 1993), a modified McArthur Mk5 forest fire behaviour model (McArthur 1967; Noble et al. 1980) and a generalisation of the CSIRO southern grassland fire spread model (Cheney et al. 1998). A 30-m resolution digital elevation model was included to allow PHOENIX to account for the influence of topography on fire behaviour. Fuel accumulation models for major vegetation types of the case study landscape were provided by the NSW Rural Fire Service. Output included ember density, convection, intensity and flame length.

Model input data

Weather was supplied from the nearest Bureau of Meteorology automatic weather station for each case study landscape. Weather streams were grouped by the five fire danger categories that have been recorded in each case study landscape (Low–moderate, High, Very high, Severe, Extreme). Road and powerline location data was supplied by the NSW Department of Planning, Industry and Environment. PHOENIX estimates fuel loads using separate fuel accumulation curves for combined surface and/near-surface, elevated and bark fuels (Hines et al. 2010). These curves use a negative exponential growth function and vary between vegetation types (Watson 2011). The treatable portion of each case study landscape was separated into management-sized 'burn blocks'. Where available data were provided by the NSW Department of Planning, Industry and Environment. For burn blocks classified as edge, a minimum burn interval of 5 years was used as it reflects what is feasible to achieve by the agencies while still allowing fuels to recover sufficiently. For landscape blocks, the minimum burn interval is the minimum tolerable fire interval for the majority of the vegetation type within each block. Ignition locations were selected based on an empirical model developed for similar forest types (Clarke et al. 2019). Individual fires were ignited at 1100 hours and propagated for 12 h, unless self-extinguished within this period.

Impact estimation

Area burnt was a direct output from the fire behaviour simulations. Effectiveness of prescribed burning at mitigating wildfire impacts was assessed on five values: house loss, loss of human life, length of powerline damaged, length of road damaged and area burnt below minimum tolerable fire interval (TFI). Area burnt below TFI was calculated from area burnt and existing TFI mapping supplied by management agencies. The probability of house loss was calculated as a function of ember density, flame length and convection as presented in Tolhurst and Chong (2011). House loss was calculated per 180-m cell and then multiplied by the number of houses in that cell to estimate the number of houses lost per fire. Statistical loss of human life was based on house loss (using the house loss function), the number of houses exposed (using simulation output) and the number of people exposed to fire (Harris et al. 2012). We used a simple threshold of 10 000 kW/m to determine if roads or powerlines within each 180-m cell were considered damaged by fire.

References

Cheney N, Gould J, Catchpole WR (1998) Prediction of fire spread in grasslands. International Journal of Wildland Fire 8, 1–13. doi:10.1071/WF9980001

Clarke, H., Gibson, R., Cirulis, B., Bradstock, R. A., and Penman, T. D. (2019). Developing and testing models of the drivers of anthropogenic and lightning-caused ignition in southeastern Australia. J. Environ. Manage. 235, 34–41. doi:10.1016/j.jenvman.2019.01.055

Hines F, Tolhurst KG, Wilson AAG, McCarthy GJ (2010) 'Overall fuel hazard assessment guide. 4th edn.' (Department of Sustainability and Environment: Melbourne, Victoria, Australia). Available at https://www.ffm.vic.gov.au/__data/assets/pdf_file/0005/21110/Report-82-overall-fuel-assess-guide-4th-ed.pdf

Harris S, Anderson W, Kilinc M, Fogarty L (2012) The relationship between fire behaviour measures and community loss: an exploratory analysis for developing a bushfire severity scale. Natural Hazards 63, 391–415. doi:10.1007/S11069-012-0156-Y

Knight I, Coleman J (1993) A fire perimeter expansion algorithm-based on Huygens wavelet propagation. International Journal of Wildland Fire 3, 73–84. doi:10.1071/WF9930073

McArthur AG (1967) Fire behaviour in eucalypt forests. Leaflet 107. (Commonwealth of Australia, Forestry and Timber Bureau: Canberra, ACT, Australia)

Noble I, Gill A, Bary G (1980) McArthur's fire-danger meters expressed as equations. Australian Journal of Ecology 5, 201–203. doi:10.1111/J.1442-9993.1980.TB01243.X

Tolhurst K, Shields B, Chong D (2008) PHOENIX: development and application of a bushfire risk-management tool. Australian Journal of Emergency Management 23, 47–54.

Tolhurst KG, Chong DM (2011) Assessing potential house losses using PHOENIX RapidFire. In 'Proceedings of Bushfire CRC & Australasian Fire and Emergency Service Authorities Council (AFAC) 2011 conference science day', 1 September 2011, Sydney, NSW. (Ed. RP Thornton) pp. 74–76. (Bushfire CRC: Sydney, NSW, Australia) Available at http://www.bushfirecrc.com/sites/default/files/managed/resource/74-86_assessing_potential_house_losses.pdf

Watson PJ (2011) Fuel load dynamics in NSW vegetation. Part 1: forests and grassy woodlands. Report to the NSW Rural Fire Service. (Centre for Environmental Risk Management of Bushfires, University of Wollongong: Wollongong, NSW, Australia).