

Higher fuel loads and more fire follow removal of Indigenous cultural burning across southeast Australia

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The current wildfire crisis in southeast Australia is unprecedented. The transition from Indigenous to colonial land management since 1788 has resulted in a build-up of woody fuels, which, in combination with climate change, has resulted in more extreme bushfires.

The present: unprecedented wildfires

The Australian "Black Summer" bushfires in 2019/2020 have been part of a series of recent wildfires that have attracted global media coverage and scientific interest. This event had significant immediate and ongoing financial costs, and a series of disastrous environmental consequences. With ca. 18 million hectares burned, the 2019/2020 event represents the worst fire season in the recorded history of southeast Australia thus far. Nine times more forest and woodlands burned in this single fire season than in the previous 17 years combined (Bowman et al. 2020). This event is an example of how the compounded effects of climate change and urban expansion are increasing fire impacts to levels unmatched in recorded history (Bowman et al. 2017).

The catastrophic bushfires in Australia exhibit a similar pattern of increasingly severe wildfires recorded in British Columbia (2017), California (2018, 2020), and the Amazon (2019). These regions were long managed by Indigenous peoples through cultural burning and were then subsequently invaded and colonized by Europeans who implemented different land management practices, including fire suppression. Following this transition, cultural burning was often banned or suppressed in the subsequent centuries, which has had important consequences for fire regimes and the ecosystems in which they operated.

In the wake of these events, researchers and policymakers have been urged to address questions about future land and fire management by including the legacy of historical burning on present landscapes. For example, much attention has been directed towards traditional landscape management's implications for bushfire mitigation, and how past landscapes were managed throughout the millennia before British invasion and colonization of Australia (Steffensen 2020). It is imperative that we understand how landscapes have changed under different management techniques (Indigenous vs. post-colonial). Such knowledge can be provided by paleoecological studies, which can offer a unique and unbiased view of this critical issue.

The past: changes in land cover and fire since colonization in southeast Australia Indigenous people have inhabited the Australian continent for at least 65,000 years

(Clarkson et al. 2017). Before British colonization in 1788 CE, Indigenous people managed Australia's flammable vegetation using long-standing firing practices called "cultural burning" (Gott 2005). This management shaped the balance between herbaceous and woody biomass, limited shrub density in understorey vegetation, and maintained patchy, open woodlands and savanna-like vegetation (Gott 2005; Gammage 2011). This management occurred across a broad altitudinal gradient. Due to limited ground-to-crown connectivity and fuel abundance, this managed landscape was less prone to destructive fires than current forests (Gott 2005). In contrast, British colonists managed land through deforestation and intense firing to clear areas deemed suitable for farming (e.g. low-elevation plains). However, forests in unsuitable areas (high-elevation or rugged terrain) were left unmanaged or exploited through selective logging for firewood or timber (Griffiths 2001).

Currently, there is a vast array of evidence for sophisticated, Indigenous cultural burning practices, as provided by oral tradition, historical, and ethnographic sources (Gott 2005; Gammage 2011; Pascoe 2014). The latter depict much of the southeast Australian pre-colonial landscape as open and grassy, with scattered trees and shrubs (Gammage 2011 and references therein). However, empirical evidence is scant, and a consensus

in the scientific community is lacking. We carried out the first regional-scale scientific assessment of the land-cover and fire activity change before and after British colonial settlement of SE Australia (Mariani et al. 2022). This new work presents an integration of novel pollen-based land-cover reconstructions (REVEALS modeling; Sugita 2007) and fire histories.

Our land-cover reconstruction of SE Australian vegetation shows that pre-colonial landscapes were predominantly grassy, with low tree cover (14% on average), consistent with a savanna-like environment at the regional scale. Our findings agree with the long-neglected, cultural knowledge of Indigenous people and corroborate historical records, including early settlers' diaries and artworks. These findings contrast with previous interpretations based on unmodeled pollen results, which grossly overestimated past tree cover across the region (Mariani et al. 2022). Since colonization, shrub cover increased across much of the SE Australian region, thickening the understorey of forests and woodlands (Fig. 1a; Mariani et al. 2022).

Long-term fire history reconstructions demonstrate that fire has long been present in the Australian landscape, deeply intertwined with climatic change and Indigenous cultural practices (Kershaw et al. 2002; Mooney

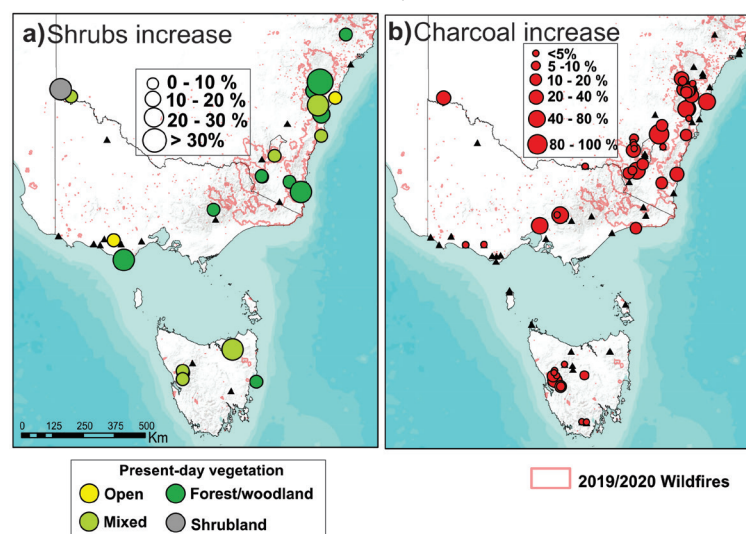


Figure 1: Map of Southeast Australia showing sites with a positive percent increase in (A) shrub cover and (B) charcoal influx following British colonial settlement post-1788 CE (modified from Mariani et al. 2022). Shrub cover and charcoal increases are evident in forest/woodland areas along the coast of SE Australia, where the 2019/2020 fires had the most extreme impacts (pink outline). Sites showing no increase in (A) shrubs or (B) charcoal are shown as black triangles.

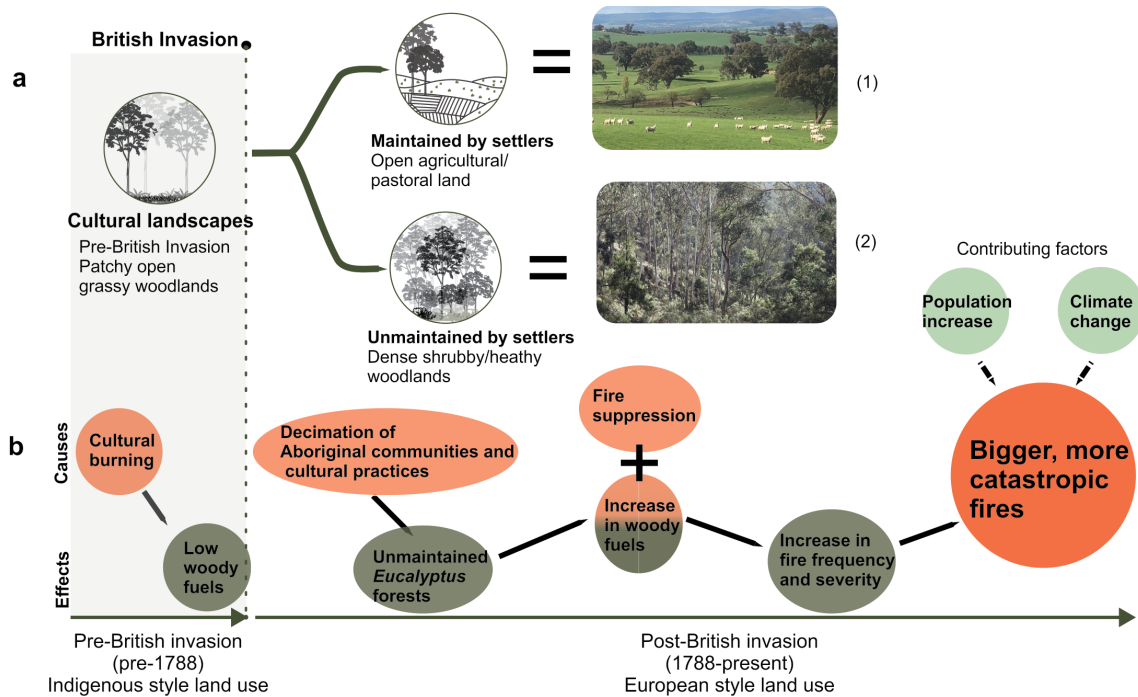


Figure 2: Summary diagram showing (A) the diverging trajectories of Southeast Australian landscapes following colonial settlement; (1) areas maintained by settlers for farming purposes; (2) areas not maintained by settlers undergoing an increase in shrub cover (Mariani et al. 2022); (B) trajectory of change in forests/woodlands since British invasion (reproduced from Fletcher et al. 2021a).

et al. 2011). The consistent occurrence of charcoal in sediments prior to 1788 (Mooney et al. 2011) indicates that fire was an almost universal feature of the southeast Australian landscape. After British colonization, we detected a substantial increase in biomass burned across most areas, especially within woodland/forest (Fig. 1b). This recent increase led to biomass burning levels exceeding levels in the Holocene record (Mariani et al. 2022; Mooney et al. 2011).

Fire's increase after colonial settlement has multiple non-exclusive causes: (1) disruption of Indigenous burning, which would have promoted the accumulation of woody biomass conducive to more intense bushfires; (2) post-colonial firing practices targeted at the removal of woody biomass for land clearance in areas deemed suitable for agriculture according to European standards; and/or (3) recent climate change favoring dryness of fuels and biomass accumulation through CO₂ fertilization.

Paleodata help refine this list of possible causes. Our land-cover and fire activity reconstructions indicate divergent trends in different land-use areas (open vegetation areas vs. forests/woodlands), with open vegetation areas displaying a decrease in woody cover following colonial settlement, while an increase in woody fuels occurred in forests/woodlands. This suggests that management practices, rather than the spatially consistent influences of regional climate, are likely to blame for the increase in fire. Indeed, the greatest post-colonial shrub increase occurred in the forest/woodland zones most affected by the 2019/2020 wildfires (Fig. 1a). While extreme fire-weather driven by climate change was responsible for fuel dryness during this event (Nolan et al. 2020), we suggest that the increased volume and connectivity of woody fuels, due to shrub encroachment following the cessation of cultural burning,

has raised wildfire risks to unprecedented levels (Fig. 2).

The future: restoring Indigenous fire management

Following the unprecedented 2019/2020 wildfire event, some researchers and policymakers have advocated for the return and expansion of Indigenous cultural burning practices to mitigate climate-driven catastrophic wildfires. However, there are various barriers to the effective reinstatement of Indigenous fire management in SE Australian forests. For example, there is some uncertainty about the degree to which Indigenous people managed high biomass and extremely flammable *Eucalyptus* forests (77% of Australian total forest area) prior to 1788. Researchers at the University of Melbourne and the Australian National University, under the guidance and inspiration of local Indigenous communities, are currently collecting high-resolution data from targeted forest areas within SE Australia through the Discovery Indigenous Australian Research Council (ARC)-funded project, PF-FIRE (Past Fire Frequency and Intensity Reconstructions; pf-fire.science.unimelb.edu.au).

A related issue is the myth of "wilderness" areas, which are depicted as uninhabited, free from past human agency, that attract visitors globally. This affects public perceptions, and influences land-management decisions in colonized lands, neglecting Indigenous people's agency on the landscape (Fletcher et al. 2021b). SE Australian forests and woodlands cannot be defined as "wilderness", as they have been the homelands of Indigenous Australians and, as such, cannot be conceptualized in dualistic "nature vs. culture" terms. This dualistic thinking has underpinned land management and created legal barriers that prevent Indigenous people from efficiently and effectively managing

their lands. For more effective land and fire management, Indigenous people must be engaged in all stages of scientific research and the development of policies and practices aimed at mitigating extreme bushfires in southeast Australia.

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