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Reply to: Logging elevated the probability of high-severity fire in the 2019–20 Australian forest fires

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REPLYING TO D. B. Lindenmayer et al. *Nature Ecology & Evolution* https://doi.org/10.1038/s41559-022-01716-z (2022)

The 2019–20 Australian bushfires are of enormous global significance, illuminating how climate change and landscape fire interact[1–4]. There is now broad scientific consensus that these fires were the direct result of anomalous climatic conditions, including intense drought and hot dry conditions with recurrent episodes of dangerous fire weather all driven by anthropogenic climate change[1,4]. Neither published empirical research nor state and federal government inquiries made a link between the 2019–20 fires and forestry practices[5]. For instance, a broadscale analysis of fire-severity mapping of forests across land tenures in the state of New South Wales (NSW), Australia burned in 2019–20 (~4.1 Mha) found no clear differences in the proportion of high or extreme fire severities between native forests in National Parks (54.5% of the area burned) and those in public forests available for timber production and privately owned forests (43.2% of the area burned)[6]. Lindenmayer et al.[7], nonetheless, argued that "logged areas were more severely impacted and caused the fires to be more difficult to control" and hence "to safeguard Australia from future catastrophic fires" native forest logging should be minimized.

The claims of Lindenmayer et al.[7] were not based on empirical analyses of the 2019–20 fires, rather they were obtained through extrapolation of research in a geographically restricted forest type (tall *Eucalyptus regnans* forests) in the state of Victoria, Australia, outside the area burnt in these fires.

Bowman et al.[8] empirically investigated these claims[7] using available geographic data and geospatial statistics. Specifically they[8] tested two propositions of Lindenmayer et al.[7]: (1) native forest harvesting substantially exacerbated the severity of the 2019–20 fires and (2) the most prudent response to providing wood supply needs is to substitute native forest logging with plantations. A feature of the analysis[8] was the very large area sampled (~2.35 Mha) that included forests of a wide range of *Eucalyptus* species, most of which were dominated by post-fire resprouters[9]. Native forest logging had a small and variable effect relative to the overwhelmingly strong effect of fire weather and fire spread variables[8]. Additionally, it was found that non-native conifer plantations were more prone, and *Eucalyptus* plantations as prone, to canopy damaging fire as were native forests[8]. In response to this research, Lindenmayer et al.[10] reiterate their original hypothesis that logging exacerbated the 2019–20 fires, while again providing no empirical evidence relating these fires to forestry practices. To advance this debate, we re-analysed our original data and briefly discuss other issues raised by these authors.

Negligible effect of forestry on 2019–20 fire severity

Our initial analysis showed a relatively small positive effect of recent harvesting on fire severity; however, the overall effect size is negligible on an area basis because such a small proportion of the area burned (<5%) was affected by recent harvesting (Fig. 1). This sharply contrasts with Fig. 1 in the response from Lindenmayer et al.[10]. That figure doesn't consider area weighting and is taken out of the statistical context of Bowman et al.[8].

Dangerous fire weather overwrites forest disturbance history

Lindenmayer et al.[10] further suggested that past logging exacerbated extreme fire behaviour, such as pyrocumulonimbus (PyroCb or 'fire thunderstorms') events that were a dominant, and historically anomalous, feature of the 2019–20 fires[11]. Rapid spread of fire under extreme weather conditions between 28 December 2019 and 4 January 2020 ('fire runs') has been independently mapped for area burned by the 2019–20 fires south of latitude 34.5° S and with associated PyroCb events[11]. In this mapped area we find that there are no strong differences in the sample points used in the Bowman et al.[8] analysis in terms of disturbance histories (undisturbed >25 yr; burnt <25 yr; harvested <25 yr; and harvested + burnt <25 yr) among fire run (+/– PyroCbs) and non-fire run areas (Fig. 2). Additionally Fig. 2 shows that extreme fire weather associated with PyroCb events causes fires that damage or destroy forest canopies regardless of disturbance history. This simple re-analysis shows that there is no relationship between past logging, fire severity and extreme fire behaviour.

General discussion

The response variables used in our landscape analyses are remotely sensed severity categories. These categories are derived from comparison of remote sensing imagery taken before and after a fire event[12]. The pre- and post-fire spectral differences are expressed as a

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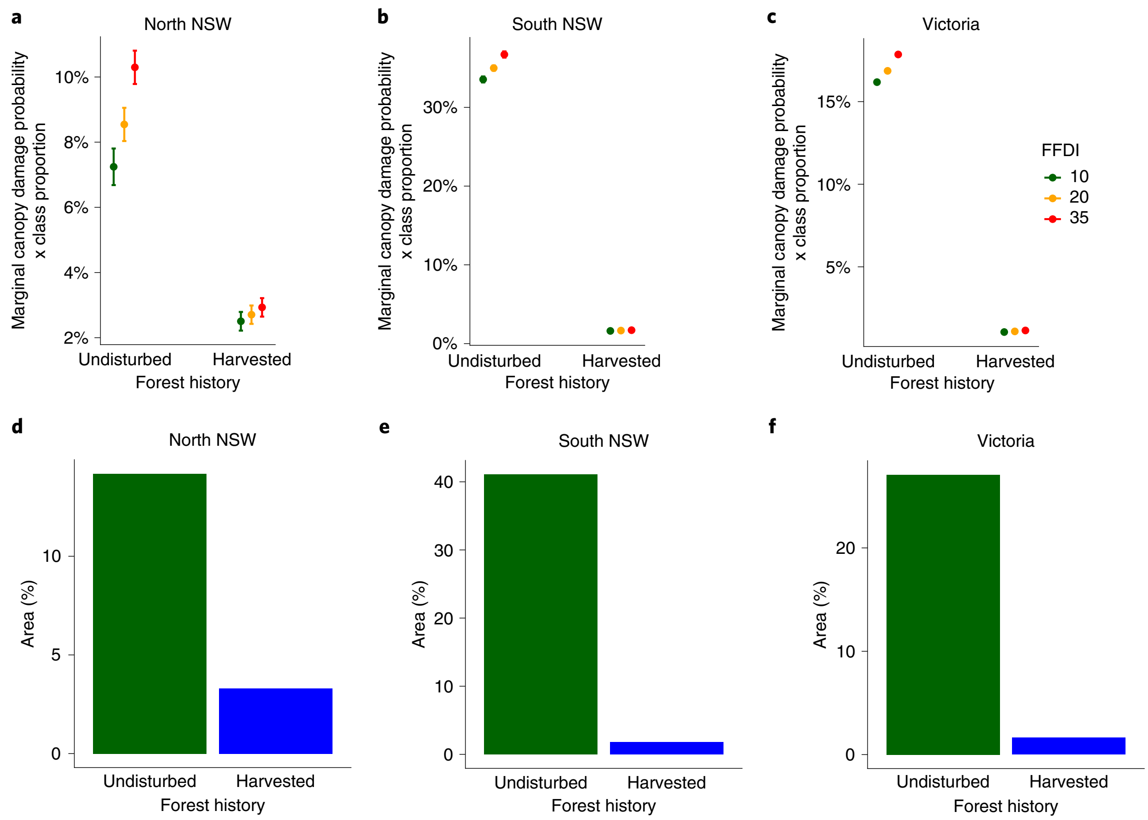

Fig. 1 | Relative canopy damage probability for undisturbed and harvested forests under different fire weather conditions in eastern Australia. **a**–**c**, Shown are three study regions where fires burnt in 2019–20 in eastern Australia: northern NSW (**a**), southern NSW (**b**) and eastern Victoria (**c**). To derive these, the marginal probabilities of crown damage for three Forest Fire Danger Index classes derived in the Bowman et al.[8] analysis were multiplied by the percentage of sample points classified as 'undisturbed' in the last 25 yr and 'harvested' in the last 25 yr to relativize to area. **d**–**f**, Here, the percentages within the study areas in **a** to **c**, respectively, are shown of undisturbed *Eucalyptus* forest (defined as unlogged or unburned in the last 25 yr) compared to that harvested (defined as logged but unburned in the last 25 yr) affected by the 2019–20 fires. To provide a valid comparison with Fig. 1 in the response from Lindenmayer et al.[10], we excluded all sample points burned in the last 25 yr.

continuous variable that is subsequently segmented into pragmatically defined categories that scale to the degree of canopy damage. For instance, a previous study[12] used four categories to characterize fire severity in forests: extreme—full canopy consumption; high—full canopy scorch +/− partial consumption; moderate—partial canopy scorch; and low—intact canopies with burnt understory. Lindenmayer et al.[10] incorrectly assert that the high fire-severity category only equates to full canopy scorch, whereas this category by definition also includes partial canopy consumption caused by fire in the forest canopy[12].

Bowman et al.[8] contrasted the two highest fire-severity categories (extreme and high) with the low severity category. The exclusion of the partial canopy scorch category was based on the need to sharpen the contrast between fire-severity categories: the moderate severity class has mosaics of burned and unburnt crowns and so blunts contrasts between fires that do or do not cause canopy damage. Such grouping of severity categories is routinely used in landscape fire-severity analyses, including those by Lindenmayer's group[13–17]. Regardless, our re-analysis demonstrated that using the most extreme severity category alone has no effect on the conclusion that the impacts of forestry disturbance were overwhelmed by extreme fire weather conditions (Fig. 2).

Bowman et al.[8] also reported that ~25% of the plantation estate in NSW was burned by the 2019–20 fires, much of it at high severity, which has exacerbated current Australian timber supply shortages. Such losses of plantations undermine claims[7,18] that this type of timber production is more appropriate than native forestry for reducing fire risks while meeting wood supply needs. This claim was simply reiterated by Lindenmayer et al.[10], along with the new suggestion that the standard practice of thinning in conifer plantations may exacerbate the risk of severe fires. This claim is contrary to some published evidence[19] and at odds with the extremely precautionary approach foresters have to managing fire risk in these high-value timber production estates. Bowman et al.[8] also found that *Eucalyptus* plantations were as prone to high-severity fire as some post-harvest regenerating native forests. To be clear, we do not suggest that native forestry is universally more appropriate than plantations. Plantations provide the dominant source of timber for the Australian community and have many advantages for wood production; however, the fire risks in both production systems need to be carefully considered.

The focus of Bowman et al.[8] was whether the globally significant 2019–20 fires were exacerbated by forestry using a top-down analytical perspective. By contrast, Lindenmayer et al.[7] used a bottom-up analogic perspective to posit that possible local-scale effects of forestry increase the risk of severe fire (a 'landscape trap'[20]) and amplify these fires through spatial contagion. The findings of Bowman et al.[8] and the re-analyses presented here do not support their hypothesis that forestry practices were associated with spatial contagion of high/extreme severity fires. Our findings have critically important, unresolved implications for forest and fire management given the vulnerability of recently clear-felled native forests, plantations and the very large area of native forests regenerating following the recent fires. There is urgency to address these issues given the trajectory

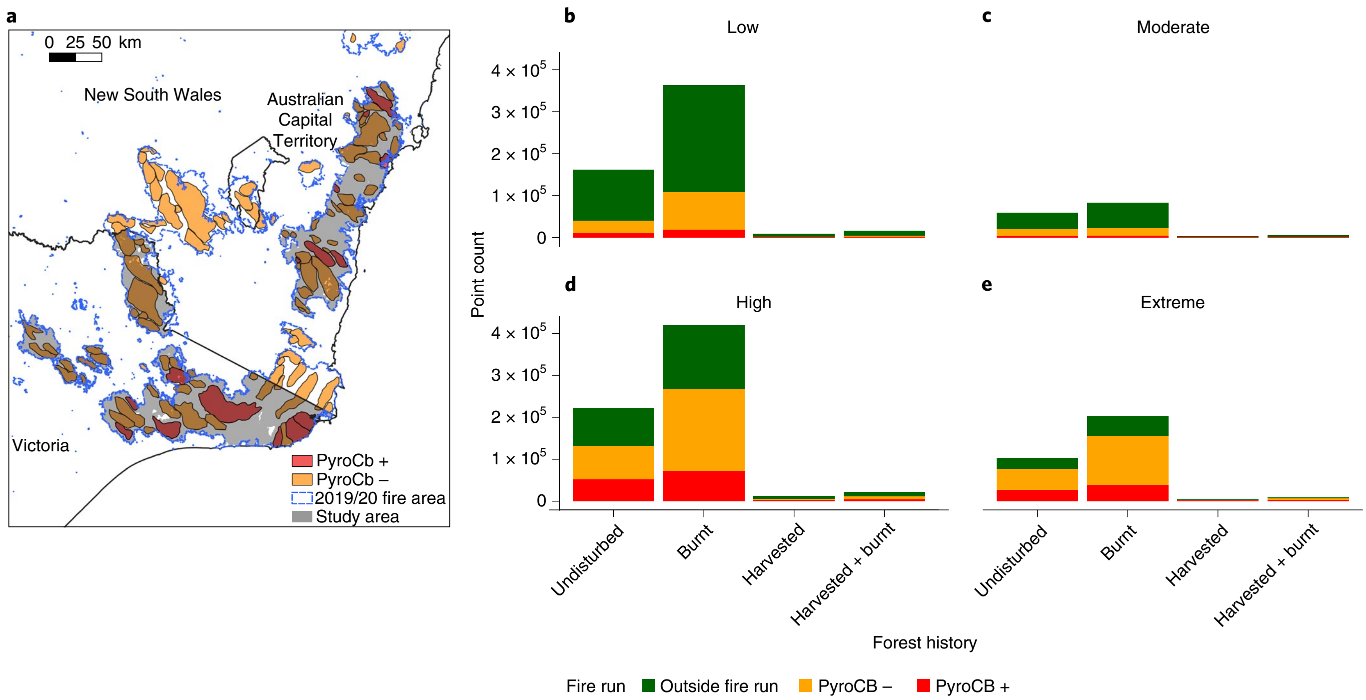

Fig. 2 | Relationship between forest management, fire runs and the development of PyroCb events and during the 2019–20 Australian bushfires. a, Map showing the extent of the 2019–20 fires and the area sampled by Bowman et al.[8]. Overlaid on these areas are contiguous areas of high/extreme severity fires ('fire runs') that were, or were not, associated with PyroCb events according to the mapping of ref. [11]. **b**–**e**, Stacked bar charts of absolute number of sample points for four fire-severity categories (low (**b**), moderate (**c**), high (**d**) and extreme (**e**)) used by Bowman et al.[8], broken down by four disturbance history categories (undisturbed for >25 yr; burnt in <25 yr; harvested in <25 yr; and harvested + burnt in <25 yr). Within each bar the number of sample points outside a fire run or within a fire run associated with, or not associated with, a PyroCb according to ref. [11] are shown. PyroCb spatial data are available from: http://www.highfirerisk.com.au.

for a hotter, drier climate in temperate Australia and other fire-prone forested landscapes elsewhere in the world. Solely focusing scientific and media attention on the small, and highly variable, relationship between past logging and fire severity distracts from evidence-based policy regarding options for managing future fire risks.

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Author contributions

D.M.J.S.B. conceptualized the analysis and led the writing. G.J.W. analysed the data, produced the visualization and contributed to the writing. R.K.G., R.A.B. and R.J.K. contributed to the writing and analysis.

Competing interests

R.J.K. serves as a member of Vicforests Science Committee. The remaining authors have no competing interests.

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