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| **Title** | Professort |
| **First name** | Philip |
| **Last name** | Zylstra |
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| **I am making this submission as** | Academic |
| **Submission type** | Personal |
| **Organisation making the submission (if applicable)** | |
| **Your position in the organisation (if applicable)** | |
| **Consent to make submission public** | Public |
| **Your story** | I am a fire behaviour scientist and developer of the only peer-reviewed fire behaviour model for NSW forests. Before working in research, I worked in fire management for the NSW Government, including work as a specialist remote area firefighter. |
| **1.1 Causes and contributing factors** | Two causal factors stand out with regard to this past fire season in NSW – the extremity of the climatic drivers, and the fact that it occurred at the peak of historic prescribed burning in NSW National Parks. As a fire behaviour scientist, I will focus on the second of these.<br><br>According to NPWS mapped records, more prescribed burning has occurred in this past decade than in any before – more than twice the rate of the preceding decade. While it is correct that these totals were less than those recommended by some, it is apparent that the most extreme fire season coincided with the |

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| | greatest amount of prescribed burning. The area of ‘young’ fuels (burnt within the past 6 years) approximately doubled over the past decade. If landscape flammability is indeed related to the area of ‘young’ or recently burnt forests, then there should have been a decline in flammability over the past decade, rather than such an increase.<br><br>I've examined this issue in detail in the attached submission. |
| **1.2 Preparation and planning** | |
| **1.3 Response to bushfires** | |
| **1.4 Any other matters** | |
| **Upload files** | NSW-Independent-Bushfire-Inquiry.pdf - Download File |

SUBMISSION

# NSW Independent Bushfire Inquiry

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# Contents

## Biography

I am a fire behaviour scientist working in adjunct roles with Curtin University and the University of Wollongong. I have developed the only peer-reviewed modelling of fire behaviour for the majority of Australian ecosystems, and have globally pioneered techniques to mechanistically link fire behaviour to characteristics of the ecosystems burning. My work links plant traits and forest growth and health to fire behaviour, but also predicts the impacts that such behaviour will have on individual flora and fauna, and on soils. I have also pioneered methods for empirically measuring historical fire regimes that most effectively minimise landscape flammability. My work has been influenced by a background in fire management and remote-area firefighting, together with mentoring by Ngarragu and Wolgalu teachers in SE Australia.

# Fuel management and the 2019/20 season

In this submission, I address the first of the terms of reference, relating to the causes and drivers of the fires, namely:

THE CAUSES OF, AND FACTORS CONTRIBUTING TO, THE FREQUENCY, INTENSITY, TIMING AND LOCATION OF, BUSHFIRES IN NSW IN THE 2019-20 BUSHFIRE SEASON, INCLUDING CONSIDERATION OF ANY ROLE OF WEATHER, DROUGHT, CLIMATE CHANGE, FUEL LOADS AND HUMAN ACTIVITY.

Two causal factors stand out with regard to this past fire season in NSW – the extremity of the climatic drivers, and the fact that it occurred at the peak of historic prescribed burning in NSW National Parks. As a fire behaviour scientist, I will focus on the second of these.

According to NPWS mapped records [1], more prescribed burning has occurred in this past decade than in any before – more than twice the rate of the preceding decade (Fig. 1)[2]. While it is correct that these totals were less than those recommended by some, it is apparent that the most extreme fire season coincided with the greatest amount of prescribed burning. The area of 'young' fuels (burnt within the past 6 years) approximately doubled over the past decade (Fig. 2). If landscape flammability is indeed related to the area of 'young' or recently burnt forests, then there should have been a decline in flammability over the past decade, rather than such an increase.

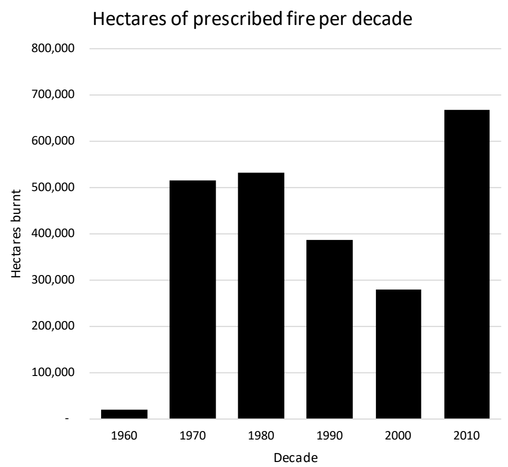


**Figure 1** | Area of NSW National Park burnt by prescribed fire per decade.

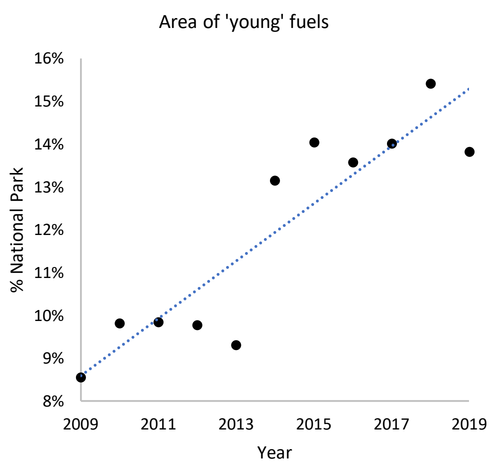


**Figure 2** | Area of land burnt within the previous 6 years in NSW National Parks, 2009 - 2019

One response to this is the claim that there is a threshold percentage of land that must be treated before a prescribed burning program is effective, but observations from the current season call this into question.

Numerous firefighters have reported this season that prescribed burns have been ineffective; some describing the claim that more burning would have stopped the fires as "a running joke" [3]. This was also true for areas recently burnt by wildfire. The Gospers Mtn fire north of Sydney, for example, ignited and grew to a very large fire in country that had been burnt six-years earlier. The main run of the Werri Berri fire near Bemboka passed unhindered through the area burnt in the winter of 2018 by the Yankees Gap wildfire (*Fig.* 3) – itself an escaped prescribed burn that destroyed houses in the area. An analysis of fire severity for NSW found that wildfires burned through almost all recent prescribed burns in the state, indicating that for the vast majority of cases, these provided no material assistance in containing fires [4] (*Fig. 4*).

The claim that more prescribed burning would have had a different effect must be considered in this context. If most individual burns were ineffective, then it is unlikely more ineffective treatments would constitute an effective treatment program.

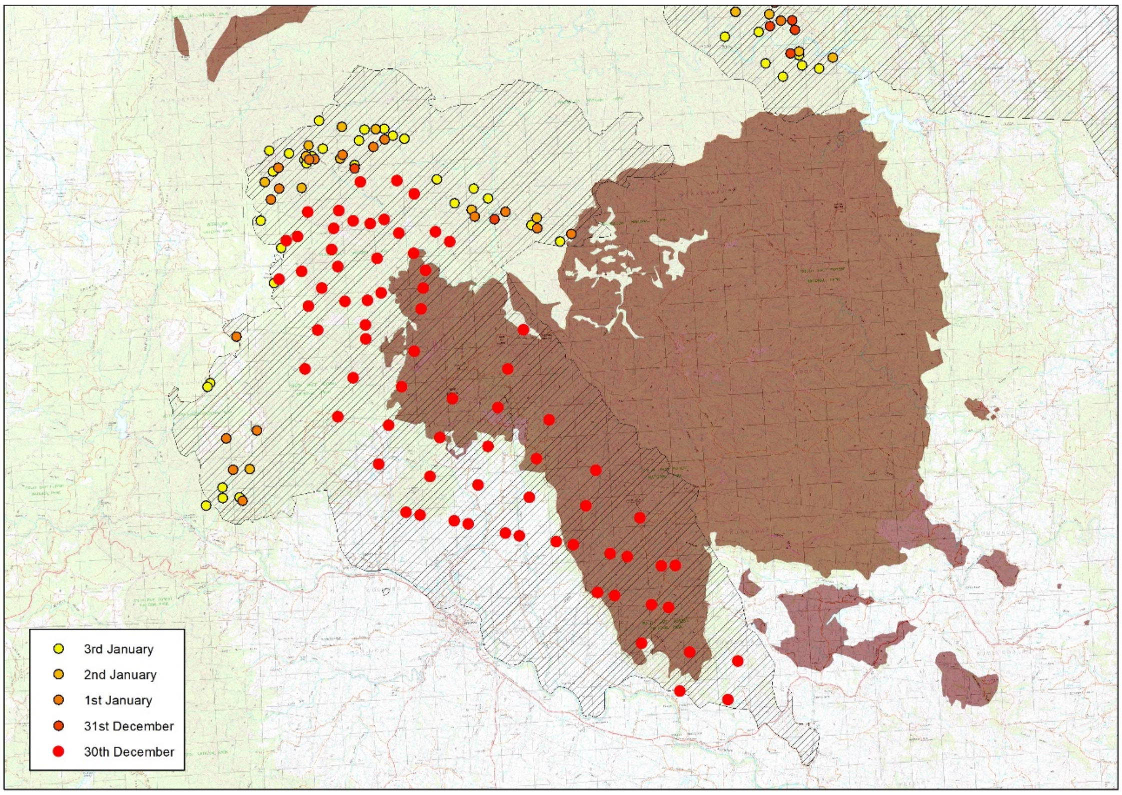


**Figure 3 |** RFS mapping of the Werri Berri fire (hatched area) and the 2018 Yankees Gap fire, overlaid with satellite-detected hotspots indicating the date of fire spread. The main fire run took place on the 30th December 2019 and spread to the south-east unhindered through the Yankees Gap burn scar. Fire spread on the northern edge occurred on subsequent days under mild weather, and largely halted at a fire trail. It is not possible to determine from this map whether that was due purely to fire suppression at the trail, a backburn lit from the trail, or whether the recently burnt forest provided assistance.

In some cases, prescribed burns can prove a hindrance to fire control operations. The western flank of the Green Wattle fire for example was at one stage bound by a three-year-old prescribed burn. However, the edge burnt through this downhill and against the prevailing wind (*Fig.* 5). Another one-year-old burn lay directly in its path and along a fire trail, yet fire crews were not prepared to trust in the efficacy of this burn, and chose instead to defend the trail using a backburn. This backburn again spread consistently down-slope through the one-year-old fuels, with no observable reduction in the depth of the leading edge relative to the surrounding 22yo fuels. In this instance, the burn merely proved ineffective. Had the burn proved more effective, it may have hampered the backburn.

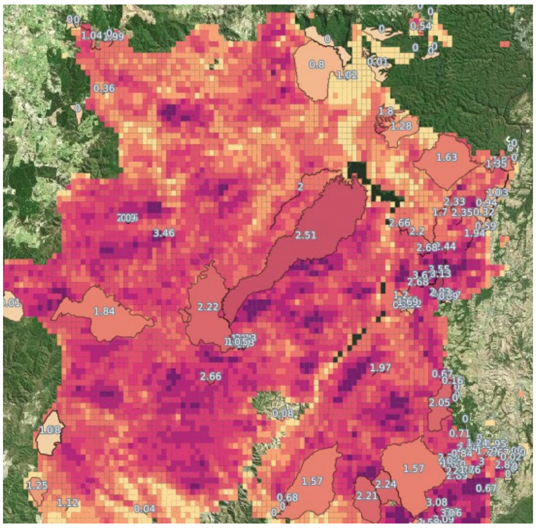

**Figure 4 |** Mapped fire severity for the Green Wattle fire, overlaid with areas of recent (up to 5 years) prescribed burns coloured and numbered by mean severity for the burn.


**Figure 5 |** Western edge of the Green Wattle fire spreading down-slope through a 4-year-old prescribed burn. A 1-year-old prescribed burn lies in its path, but no confidence has been placed in this, and a backburn has been lit from the trail at its centre. The backburn is spreading down-slope through the 1-year-old fuels, with no difference in depth of the flaming edge compared to the 22-year-old fuels at the top of the image.

## Underpinning theory

The foundation of fire management in Australia is the assertion that rates of fire spread are directly proportional to 'fuel load' or the weight of fine dead materials on or close to the ground, so that fire risk can be minimised by burning forests to reduce those fuels [5]. This theory is derived from a leaflet [6], presenting nine data points. Despite their critical importance to decisions affecting the survival of people, other species, and entire ecosystems; these data were never subjected to peer-review but have been accepted as presented in the leaflet. At the time, the author took pains to make clear that:

*"many of my observations and comments are tentative and may be proved wrong or subject to drastic change as more data becomes available"* [7].

Since McArthur's time, the relationship between fuel load and rate of spread has been formally tested in properly conducted scientific experiments. It has been demonstrated conclusively that this relationship *does not exist*, that altering the fuel load does not alter the rate of fire spread [8]. Subsequent work showed that the drivers of fire spread and severity are the living plants. This was shown empirically for lower plant strata in *E. marginata* forests of SW Australia [9,10], then demonstrated mechanistically as a general process of fire spread validated for a range of forests and conditions in SE Australia [11,12]. Plants affect flammability either by acting as fuels, or, if not burning, by creating a microclimate that reduces light and wind speed beneath their canopies. Whether plants accelerate fire by burning, or slow it by creating overstorey shelter, depends on the size of the gaps between the plants, the flammability of the donor (burning) plants, and the ignitability of the receiver plants, or those that may potentially ignite. To date, there is no peer-reviewed scientific work supporting the assumed relationship between fuel load and rate of spread, yet it continues to underpin Australian fire management at the expense of the actual science.

The two views have opposite implications for the ways in which fire should be managed. Under the traditional view, fuels accumulate, so that flammability is highest in long-unburnt forests. This imposes a single rule for fire management: frequent disturbance through burning or manual fuel removal. Under the scientific view, however, plants drive the flammability of a forest, so flammability varies according to plant dynamics. There are two outcomes from this that are central to the discussion. Firstly, if flammability varies according to floristics and structure, then every plant community has differences that cannot be captured by a single rule. Secondly, flammability will change in a forest according to the growth and dynamics of the component species.

One of the central tenets of ecology is the law of self-thinning [13,14]. Conditions at a site can support a finite quantity of biomass. As plants grow in individual biomass, less individuals can be supported at a site, and self-thinning occurs. The phenomenon of 'woody thickening' is a corollary of this. Woody thickening or the proliferation of dense shrub and sapling growth is specifically a response to disturbance [15]. Disturbance by fire or clearing allows increased light access to the soil surface, and may add nutrient additions through ash. This increases the energy balance and, consequently the biomass that may be supported. Many plant species have propagation mechanisms that can take advantage of disturbances through seed germination for example, so such disturbances result in dense propagation of small individuals competing to survive the inevitable self-thinning.

The result is a common vegetation dynamic: following disturbance that removes higher foliage (e.g. scorching or consumption by flames, or mechanical removal for timber), vegetation growth is stimulated close to the ground. This new vegetation grows taller, but also self-thins until eventually a more open understorey returns. The implications of this for flammability dynamics can be illustrated using an example from alpine ash (*Eucalyptus delegatensis* subsp. *delegatensis*) forests in the SE Australian highlands.

Alpine ash is a fire sensitive, obligate-seeding species. As a result, fires that scorch the tree canopy kill the trees outright [16], so that the forest must regrow from seed. The change in structure from this is pronounced: overstorey shelter is entirely removed and returns as dense, low vegetation close to the ground, where it is readily ignited and can burn without protection from the wind. The increase in flammability is marked.

It is not only high severity fire that affects ash flammability, however. Low severity fire that does not kill the canopy still causes heating of the soil, germination of leguminous undergrowth, and loss of taller midstorey plants that would have provided some degree of overstorey shelter.

I measured this effect in an alpine ash forest in northern Kosciuszko National Park, while working in the Fire Management Team for the Southern Ranges Branch of the NSW National Parks and Wildlife Service [17]. A fire trail in the Bogong wilderness area separated an area of mature ash from an area that had been burnt by low-intensity prescribed fire 12 years earlier. The effect of the prescribed burn had been to remove the midstorey of ash saplings and small trees, and germinate a dense understorey of the leguminous shrub *Daviesia latifolia* (Figs. 6 & 7). Although the effect on flammability may not have been as stark as that from a high-severity fire, the same processes were apparent, still increasing fire risk. Overstorey shelter had been reduced and vegetation now grew closer to the ground where it could be readily ignited.

I modelled the effect that this would have on fire behaviour using the Forest Flammability Model [11,12] now in the package FRaME (Fire Research and Modelling Environment) [18]. It should be noted that FRaME is currently *the only peer-reviewed fire behaviour model for NSW forests*, and the only extant model to derive fire behaviour predictions using research on plant flammability traits. It's also been proven to correctly predict trends in flammability from the patterns I've described [19].

**Figure 6 |** Mature ash forest, showing an open understorey of scattered shrubs with occasional small trees

**Figure 7 |** Adjacent ash forest burnt 12 years earlier by a low-intensity prescribed burn, with a dense understorey of fire-germinated *Daviesia latifolia* and no small tree midstorey.

I modelled fire behaviour for the weather conditions of autumn 2018. The taller, denser shrub layer in the area resulting from the low intensity prescribed burn produced flames that were on average nearly four times taller than in the original forest. Aggressive firefighting techniques (direct or parallel attack) would have been possible for nearly that entire season in the older forest, but these were now possible less than half as often in the area prescribe burnt. The likelihood that any wildfire that season would come through and kill the canopy of the forest through scorch was now also 11 times greater (Table 1).

**Table 1 |** Modelled fire behaviour for alpine ash forest, in its original untreated state, and in recovery from a prescribed burn.

| | Shrub cover | Shrub height (m) | Flame height (m) | | Rate of Spread (km/h) | | Parallel attack success | Likelihood of crown death |
|---|---|---|---|---|---|---|---|---|
| | | | *Average* | *Max* | *Average* | *Max* | | |
| Original forest | 20% | 1.5 | 0.7 | 4.7 | 0.05 | 0.51 | 92% | 6% |
| Prescribed burn | 80% | 2.1 | 2.6 | 6.9 | 0.04 | 0.95 | 42% | 68% |

This is the direct opposite of that expected from the traditional belief. The traditional approach predicts that fuel accumulation renders these forests highly flammable and thereby encourages the introduction of fire. The scientific approach predicts that long-unburnt forests may in-fact be fire advantages due to their low flammability. These expectations need to be compared to empirical observations.

## Empirical evidence

By definition, a flammable age class will over time burn more often than a less flammable class. Flammability Ratio [19] is a technique that measures every mapped wildfire in an area to find how much they favoured each age class. It is best understood as a mass analysis of case studies, where these are conducted for every part of every fire, examining every age. As a result, it is very powerful, and has so far reported clear trends at the highest level of significance. In all cases to date, these are consistent with those predicted from mechanistic modelling: a short *young* period of bare ground and very small seedlings, followed by a period of highly flammable *regrowth* that may last for decades, then an indefinite period of low flammability, *mature* forest. These three periods have been measured in woody communities ranging from low, dry open woodland through to tall wet forests and subalpine communities. The empirical evidence is consistent with the mechanistic expectations: enhanced flammability is a product of forest disturbance. Forests become less flammable if they are allowed to recover beyond the regrowth period.

These findings confirm the mechanistic expectations for alpine ash described in the last section, where forests have been on average more than eight times as likely to re-burn if they had experienced either a planned or unplanned fire in the previous 21 years, compared to older forests [20] (Fig.8). Other work examining low, dry sclerophyll forest illustrates the mechanism from surveyed data: as lower vegetation grows in height but self-thins after fire (Fig. 9), the mechanistically modelled trend in flammability matches the empirically measured trend (Fig. 10) [21].

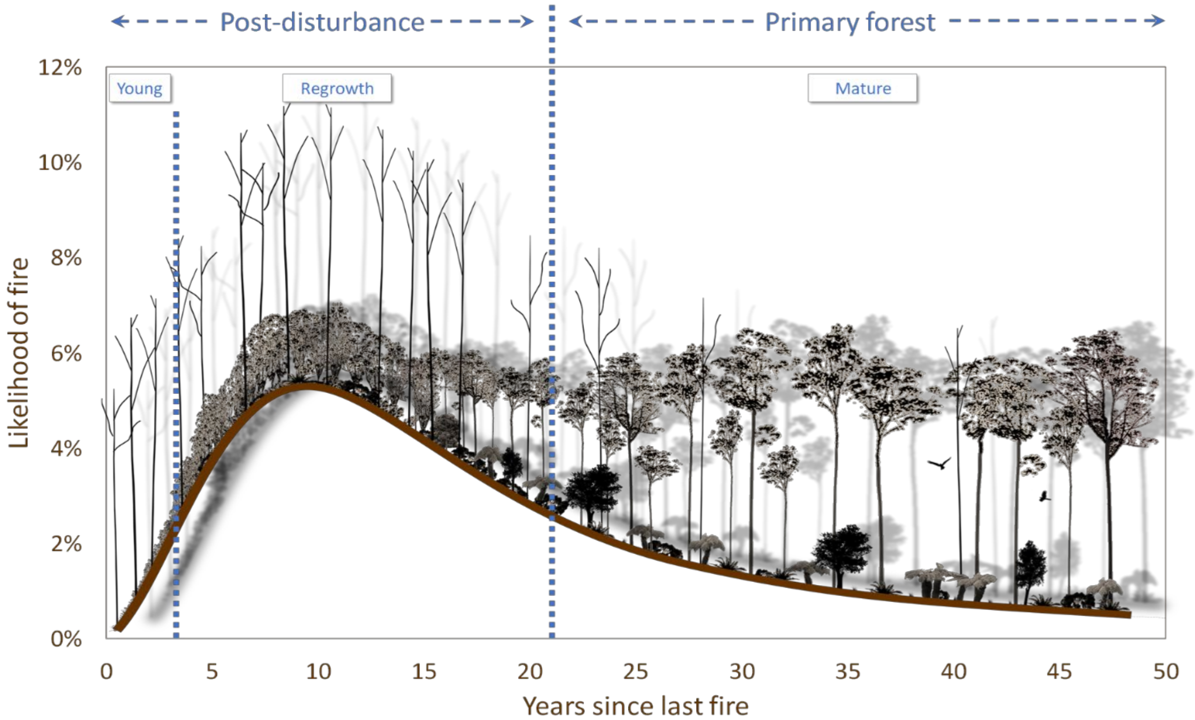


**Figure 8** | Flammability dynamics in alpine ash, illustrating the *young* and *regrowth* stages of post-disturbance regrowth, compared to mature forest. The brown curve shows the empirically measured trend in the likelihood of fire at a point.

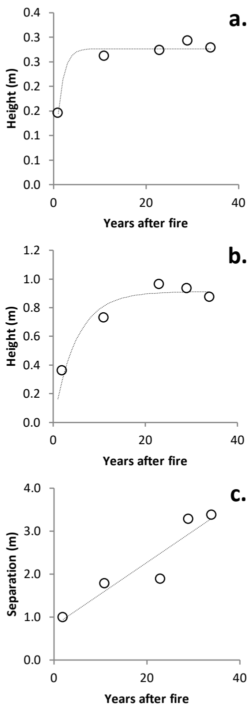


**Figure 9** | Measured vegetation dynamics for Southern Tablelands Dry Sclerophyll forests. a) height of grasses, b) height of shrubs, and c) separation between shrubs, increasing over time as expected from the self-thinning rule.

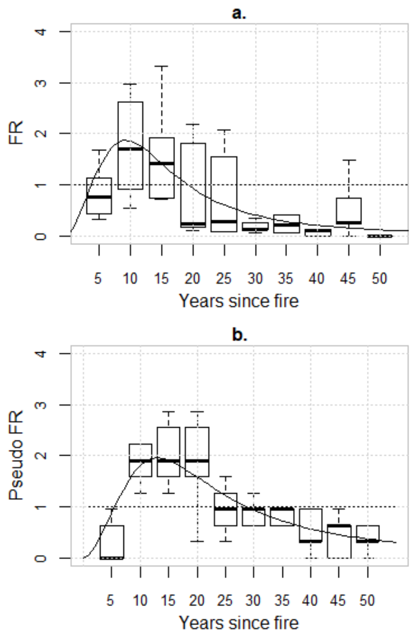


**Figure 10** | **a.** Empirically measured FR for Southern Tablelands Dry Sclerophyll forests (from Zylstra 2018), **b.** modelled FR for Southern Tablelands Dry Sclerophyll forests. Box plots show standard interquartile ranges; whiskers extend to 1.5 standard deviations.

In contrast to this evidence, it is still widely assumed that long-unburnt forests are in their most flammable state due to fuel accumulation. This has introduced circular logic to the way that analyses are conducted. This follows the following pattern:

a) Assume that fuel accumulation drives flammability
b) Treat regrowth forest as if it is long-unburnt because the weight of fuels has reached a quasi-equilibrium state, when the regrowth forest is still actually in recovery from the past fire
c) Compare the flammability of young and regrowth forests, thereby confirming a).

In three reviews of prescribed burning effectiveness, there are almost no instances where the long-unburnt category was older than the range of regrowth forests that have been measured in eastern Australia [5,22,23]. It should be noted that these periods are short in comparison to slower-growing ecosystems such as the Great Western Woodlands, where the regrowth period lasts centuries [24]. These case studies therefore provide no insights into the value of burning forests instead of maintaining them in a mature state. Rather, they externalise the cost of treatments, measuring the decades of flammable regrowth as if they are untreated areas, when in fact they were made flammable by the treatments.

A more recent form of analysis is the measurement of 'leverage', which is the area of wildfire reduction per area of young forest [25]. Leverage is inherently more objective than case studies because it is a landscape measure and not subject to cherry picking. However, it maintains a structural bias. Leverage divides the area of *young* landscape from the rest, combining *regrowth* and *mature* forest into a single long-unburnt category. This again externalises costs, artificially inflating the flammability of older forests by measuring flammable regrowth along with mature forest instead of accounting for it as a cost of the treatment.

Despite this inbuilt exaggeration of the effectiveness of prescribed burning, leverage studies rarely report a statistically significant effect of prescribed burning. A global analysis found that leverage was statistically significant in only one Australian location: spinifex communities burnt with indigenous cultural burns in the Great Sandy Desert [26]. A larger study of leverage across SE Australia reported that of the 30 bioregions measured, leverage was positive (recent fire reduced subsequent wildfire) in only four, and that it was more often negative (recent fire made subsequent fire more likely). Importantly though, no test was made to determine whether these relationships were statistically significant or not.

## Historical evidence

Prior to the mid-20th century, graziers and some other private landholders burned forested areas widely and regularly. It is popularly claimed in more recent years that this was a continuation of Aboriginal cultural burning practices, but that is highly unlikely. Far from seeking out guidance and learning from the First Nations, graziers were the front line of the widely documented colonisation of Aboriginal lands. Widespread burning of forests conducted by many graziers bears no resemblance to what is known of Aboriginal cultural burning, but in fact represents a continuation of traditional British practices. It is well-documented that English and Scottish graziers burned forests for the purpose of land clearing to create grazing lands, and that this is the origin of the English moors [27–30]. This history is reflected in the language used, where removal or replacement of native species with European species is termed "improvement", native shrubs are referred to by the names of English species that were burned regularly [31], and burning is referred to using the widespread European notion of "cleaning up" the forest.

What is known of the history of fires prior to the 1950s reveals that very large fires were in fact common, but – critically – they were predominantly escaped burns lit by graziers [32]. Reconstruction of some of these such as the 1939 Black Friday fires (Fig. 11) enabled some analysis of this period for the Australian Alps, revealing that very large burnt areas in the range of one million ha or more occurred only as a confluence of many fires, invariably lit by graziers and other landholders, or escaped from timber mills [33]. When strict controls on fire were introduced to the area during the 1950s, these very large fires immediately ceased to occur. The largest fires after that period were an order of magnitude smaller, until the onset of the 21st century. Very large fires returned in 2003, again in 2006, and now again in 2019/20. As before, such large burnt areas have only occurred through the confluence of multiple fires lit under extreme conditions, but the critical difference has been that the source of ignition has been lightning rather than human, reflecting the increase in dry lightning across the southern hemisphere as the climate changes [34].

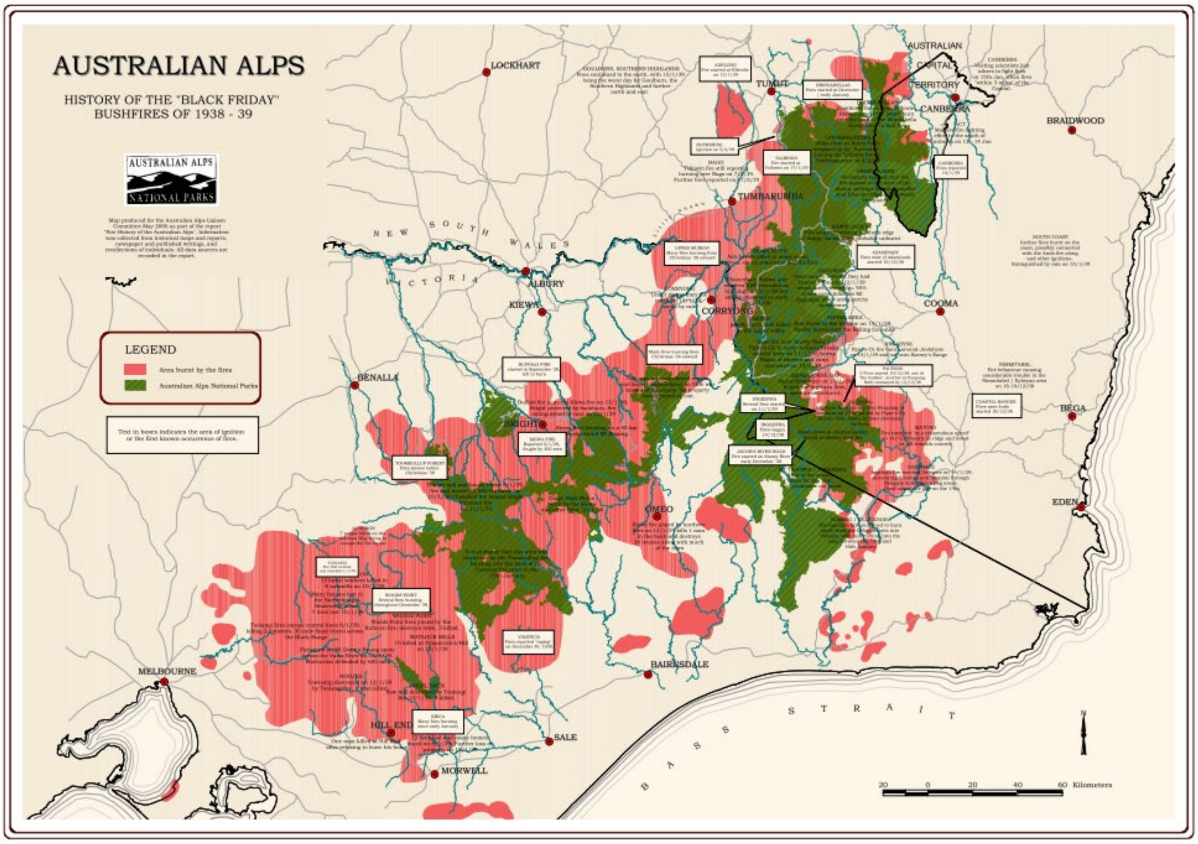


**Figure 11 |** The 1939 Black Friday fires, overlaid with the 2006 extent of the Australian Alps National Parks. The Victorian component was mapped as part of the Royal Commission, and the NSW component mapped from historical analysis by P. Zylstra. Text boxes detail what is known of ignition sources.

All available evidence at this point then indicates that the widespread burning by landholders prior to the mid-20th century was responsible for greatly increased fire impact. Regulating those burning practices reduced fire impact by an order of magnitude, but this reduction is now being reversed as the climate warms and increasing fire frequency creates a more flammable landscape.

## Influences of previous forestry operations

Given that elevated forest flammability appears to be a product of disturbance, previous forestry operations have likely had an influence on landscape flammability leading up to this season. Numerous studies have examined the relationship between logging and landscape flammability, whether through selective logging or thinning, or through clearfell approaches. Earlier studies tended to be departmental reports which saw operations to be purely for the purpose of acquiring timber or growing better quality timber. The link to fire was based around concerns that such operations *increased* fire risk [35–37]. This literature experienced a sharp change in focus in recent years, with forest industry bodies funding research [38] that now made the counter-claim: that thinning forests *reduced* fire risk. This work is based on modelled outcomes rather than empirical measurements [39,40], using models that do not address the mechanistic drivers of flammability.

Empirical measurements consistently demonstrate that forestry operations cause large increases in fire risk [41–43], although these do not differentiate between different forms of forestry. The single apparent exception to this was a 2013 paper led by Peter Attiwill [44], which argued that

*"…there was an apparent increase in the severity of crown fire with time since logging or bushfire up to about age 30 years (Figure 4), rather than a decrease as shown by Price and Bradstock".*

While this statement is correct, it ignores the majority of the data presented in Figure 4 of their paper, which does not support their central finding that "timber harvesting does not increase fire risk". This figure is presented and annotated here (Fig. 12) to contrast the claim with the data on which it is purportedly based. The data clearly show that the likelihood of crown fire increases up to about 30 years, but critically, it then shows a consistent *decrease* in likelihood as forests age beyond this point. This non-linear trend of low flammability immediately after disturbance followed by decades of increased flammability declining to indefinite low flammability is exactly consistent with the trends reported for logging effects in mountain ash [41,43], post-fire effects in ash forests [20,45], and, indeed consistent with the three-stage dynamics described earlier.

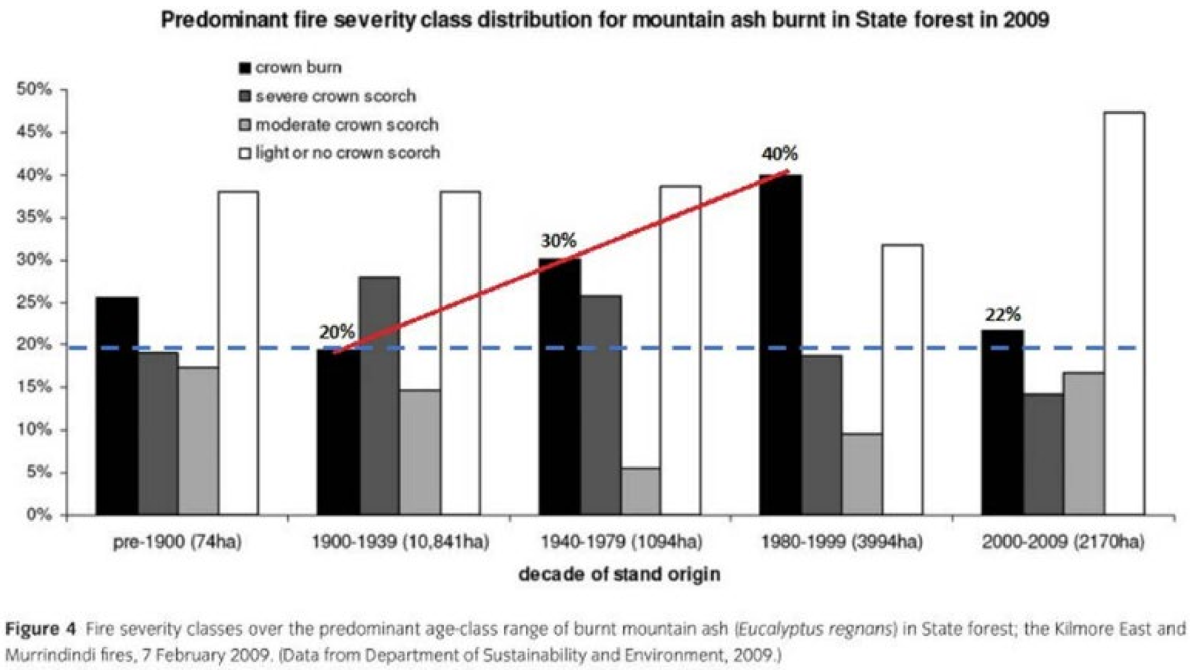


**Figure 12 |** Reproduction of Figure 4 from Attiwill et al (2013), annotated to show the likelihood of crown fire (black columns) measured from the graph, the comparative likelihood of crown fire in 1939 regrowth (dotted blue line), and the declining likelihood of crown fire in older forests (solid red line).

## Marketing using flawed modelling

An overview paper in Australian Forestry examining the effects of thinning on flammability identified that these may include changes to fuels in all plant strata, but also alterations of the microclimate by allowing greater wind and light access [38]. Proposed research involved measurement of fuels using subjective visual scores [46] along with modelling.

Two studies stand out in this field, both funded by VicForests. In the 2017 study [40], the authors showed that eight years after a thinning operation, a *E. delegatensis* forest had marginally lower surface fuel loads, but increased density of understorey plants – consistent with the ecological expectations described earlier in this submission. To model the effect of this on fire behaviour, the authors used Project Vesta [10] to model rates of fire spread under defined conditions, but instead of using the flame height model that forms part of Project Vesta, they changed models midway through the analysis to instead calculate Byram fire intensity [47]. This measure estimates intensity based on the assumption that all fine dead materials on or near the ground surface all burn with perfect efficiency within the active flame front, and that structure and arrangement have no effect. These assumptions have long been known to be incorrect [48]. In contrast, the flame height model of Project Vesta includes the height of the understorey. By changing models midway through the process, the study was able to exclude the influence of the increased understorey growth on fire behaviour, and capitalise on the small decrease in surface litter.

The 2019 study [39] examined a *E. sieberi* forest immediately after thinning, comparing the effects of prescribed burning, thinning, and a combination of the two treatments. Rather than modelling the outcomes this time, the study utilised the overall fuel hazard score[46]. The findings were that prescribed burning reduced the score from extreme to low immediately afterward, but that thinning made no change to the score. The effect of thinning and prescribed burning was the same as prescribed burning without thinning. The authors, however, argued that the inclusion of thinning was an improvement because it resulted in less trees and reduced carbon storage which, they asserted, were good things and should be added to the scoring system. They did not provide any argument as to why this was the case.

These studies demonstrate the weakness of findings based on modelling that do not address the relevant mechanisms driving flammability. As a form of disturbance increasing light access to the forest floor and disturbance of the soil, mechanical thinning of trees results in woody thickening at the understorey level. This was demonstrated in the 2017 study, but its effects on flammability were excluded by changing models. Less tree cover also results in faster drying of surface litter, so that fires can spread on more days. It also results in increased wind access, so that fires burning beneath the canopy are exposed to stronger winds, although the models chosen were unable to assess this impact. All of these factors result in an overall increase in flammability, consistent with the broadscale empirical measurements and long-held understanding.

If spurious modelling exercises are put to the side, all evidence so far indicates that – through the same mechanisms as fire, forestry operations increase landscape flammability. The most likely case at this stage is that the 2019-20 fire season was exacerbated by historical forestry operations.

## Toward effective hazard management

Hazard reduction efforts in Australia have focused on disturbance-based methods intended to lower flammability by removing biomass, either through fire or by using mechanical means. These methods ignore biotic responses, but inadvertently set in course what are reasonably well-understood pathways of regeneration. Although the initial removal of biomass may have the desired effect (a short period of low flammability), this is followed by a long period of high flammability while the vegetation regenerates, before returning to an indefinite period of low flammability in the mature forest.

Empirical analyses historically failed to identify these trends due to study designs which incorrectly treat post-fire regrowth as if it is mature forest. Recent advances have now quantified the mechanistic drivers and developed empirical study techniques that are free of these biases, confirming that this three-stage flammability trend (low flammability *young* forest, high flammability *regrowth*, low flammability *mature* forest) is the likely trend for most Australian forests.

This has significant implications for effective hazard management. Our current paradigm dictates hazard *reduction* through disturbance, that the hazard is least where we have altered it. As a result:

1. Activities intended to reduce hazard may have been systematically increasing it
2. Areas with naturally low hazard may have been providing us with opportunities that we have missed

Effective hazard management will involve:

- the identification of areas that are natural fire advantages
- protection of those areas from unnecessary disturbance
- identifying the limits of those advantages – i.e., under what conditions will they burn, and under what conditions will fire behaviour be difficult to control?
- development of strategies and placement of resources to take advantage of these areas. E.g., rapid detection and deployment of RART and RAFT
- development of strategies to protect regrowth areas from disturbance, to allow them to advance into a mature state.

The following case study illustrates how a more scientific understanding of fire and flammability may equip decision-makers in an operational setting.

## Case study: fire on the Dorrigo plateau

On the 9th September 2019, the Bees Nest fire north of Dorrigo, NSW reached an area of very long-unburnt (~700 years) North Coast Wet Sclerophyll Forest (Keith, 2004) with a canopy of tallowwood and brushbox. The long-unburnt history of the forest had enabled a rainforest understorey to develop, with a dense sub-canopy dominated by coachwood over a tall but sparse shrub layer. It had also allowed a litter layer of about 20 tonnes per hectare to be maintained. Considering this along with the tall shrubs, both the McArthur and Vesta models predict flame heights of 4-6m for the mild weather conditions of the 9th.

However, the weight of surface litter has no bearing on overall flame height (Zylstra et al., 2016). Old-growth tallowwood forest is also markedly different to the regrowth jarrah being modelled by Project Vesta; the shrubs for example are more open because there has been no recent disturbance. They are also mesic species with high moisture contents that make them slow to ignite. Their foliage is sparse because they grow in shade, and the base of the shrub canopies is high above the ground. Based on these and other factors such as the slow wind speeds beneath the dense midstorey, FRaME modelling indicates that the shrubs were very unlikely to ignite, so that flame heights would generally be less than one metre in height.

Following the event, satellite measurements of fire severity (Fig. 13) found that fire impacts on vegetation were undetectable through the tallowwood forest and the core of true rainforest[1]. Heat signatures were however detected by other satellites [49] through the tallowwood, but not the rainforest. Together, these indicate that the tallowwood did likely burn, but at a severity that was undetectable by the post-fire satellite measurements of vegetation.

The contrast between predictions made using McArthur and Vesta and what was modelled in FRaME and measured by satellite underpin contrasting options for controlling such a fire. The small flames predicted by FRaME and shown by satellite measurements can be contained using direct or parallel attack by RAF crews, or by using tankers along fire trails. If large flames as predicted by McArthur and Vesta were expected, these would generally need to be contained with an indirect backburn. Backburning can be less successful than direct attack and more likely to inadvertently advance the fire front through escapes. A decision to backburn rather than direct attack would result in the burning of the long-unburnt tallowwood forest, and the destruction of its fire advantages.

FRaME modelling indicates that, even though many of the rainforest trees would not have been scorched, heat would have penetrated through the thin bark into the cambium, resulting in girdling and death of coachwood and other such trees. This would significantly increase the flammability of the site for decades. Tree death allows more sunlight to reach the forest floor to stimulate shrub growth, create

[1] Data available from https://datasets.seed.nsw.gov.au/dataset/fire-extent-and-severity-mapping-fesm

drier conditions allowing more frequent fire spread and favouring drier, denser shrubs. Reduced canopy and understorey density will allow more wind access when fires are burning. The impact of burning this forest with a slow, low-severity fire is that the next fire is likely to be far more severe.

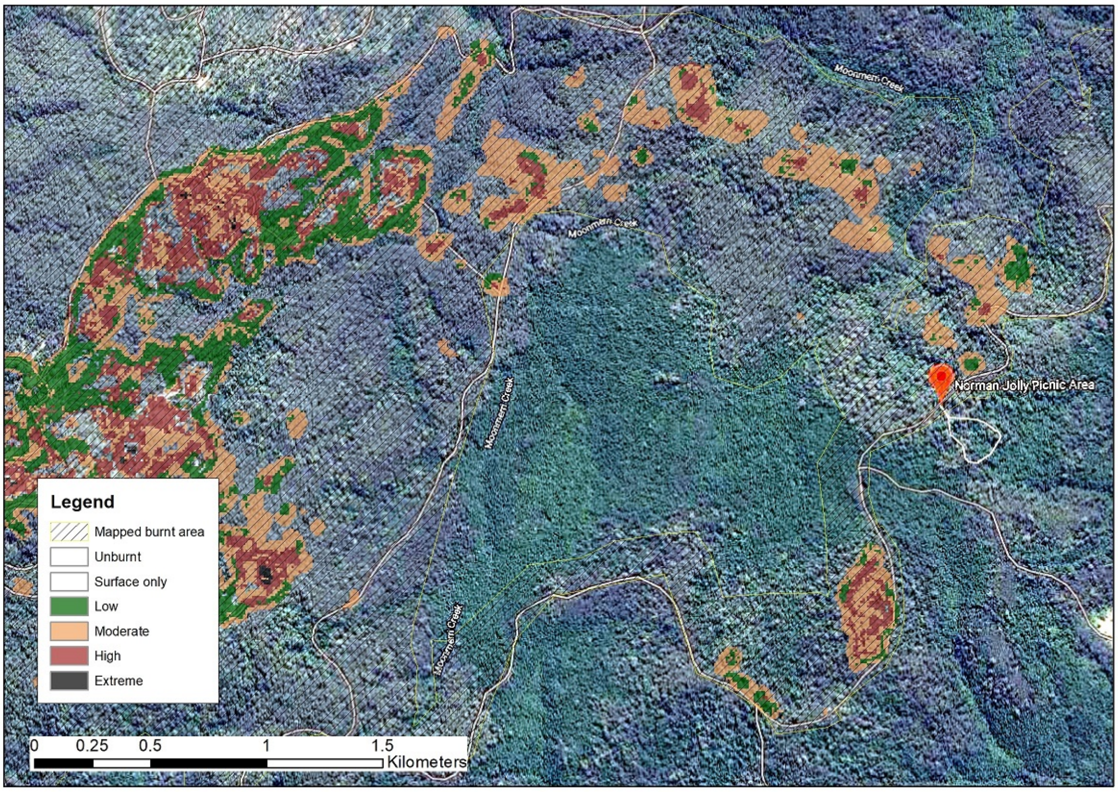


**Figure 13 |** Fire impacts in the tallowwood study area. Dark green areas in the air photo show rainforest patches, predominantly surrounded by the lighter coloured wet sclerophyll. The hatching indicates the area that was mapped as burnt, and the coloured overlay indicates the areas where the severity of the burn was detectable and could be mapped by satellite.

This case study illustrates that the old-growth tallowwood forest acted as a fire advantage, but this advantage could only be identified and utilised with a sound understanding of fire behaviour.

## The crisis of fire management

The terms of reference in this inquiry refer directly to 'fuel loads', despite the fact that no peer-reviewed evidence has ever shown the claimed relationship of fuel load to fire risk, and decades of evidence have refuted it. This reflects a broader reticence in the fire management community to embrace science over tradition, a reality that is evident at the highest levels of organisation. In 2019, for example, the opening keynote address to a Sydney international fire conference held by the Bushfire and Natural Hazards CRC and the International Association of Wildland Fire criticised scientists in general as being "far-left", and openly denounced the peer-review process for its failure to block papers that falsified long-held beliefs in the fire management community [50]. The CRC and the IAWF invited this speaker, despite the fact that he had delivered a similar keynote address contrasting the peer-reviewed science with what he referred to as "the reality" at a conference held by the Australasian Fire Authorities Council in the preceding year [51]. In this speech he had urged fire and land managers to "question the science", and journal editors to "include professional fire and land managers in the peer review process".

Having worked in fire management for the NSW State Government myself, I appreciate that this can confer important perspectives that may be missed otherwise. There are other effects, however.

Professional fire managers are employed by Government agencies, and are therefore tasked with meeting benchmarks that have been assigned to them. Despite what may be enormous levels of expertise, they have limited freedom to employ this if it conflicts with the policy of the current Government.

My experience of this was that, early in my career, I was taken aside and told by a manager: "you think that you are here to manage fire risk, protect houses and the environment, but as a public servant, your sole purpose is to get the current Government re-elected." More recently, I was required to complete an internal ethics course, in which we were taught that it was unethical to provide any information to the public that reflected poorly on the current Government policies. The purpose of my role in management was, however, "to evaluate the effectiveness and environmental acceptability of current management measures, and to similarly investigate new measures" [52]. As well as developing the first and only peer-reviewed fire behaviour model for forests in NSW [11,12], I performed an analysis of mapped fire history records for the area we managed, providing evidence at the highest level of statistical confidence for effective fire management [20]. This paper is one of the most read publications for the journal *Austral Ecology* and I provided it to my managers along with a simple summary of its implications. I have never yet received a response, see no evidence that it has affected management, and was made redundant shortly afterward.

These are the realities of the fire management environment: science poses a threat to Government policy if that policy has a poor evidential basis. Although stated in stronger terms than most would use, the former NSW Government Whip Peter Phelps expressed the objection to the fact that science can provide direction that does not align with existing authority: "At the heart of many scientists - but not all scientists - lies the heart of a totalitarian planner… they can influence policy, they can set agendas, they can reach into everyone's lives; they can, like Lenin, proclaim what must be done" [53].

In the face of a mounting fire threat, this aversion to science presents a profound challenge, and indeed, a crisis for Australian fire management. Just as climate change does not cease to exist because someone denies it, the forests will continue to grow and change regardless of what the official policies say. There are many opportunities though if we adjust our thinking of fuels and flammability to accommodate the science.

The language of fuel loads implies fuel reduction burning as a solution. Thankfully though, there is room in the legislation for a more informed response. The NSW Rural Fires Act 1997 defines Hazard Reduction as:

*"…the controlled application of appropriate fire regimes or other means for the reduction or modification of available fuels within a predetermined area to mitigate against the spread of a bush fire".*

Critically, this refers to *appropriate fire regimes*. The deliberate introduction of fire at a certain timing and severity constitutes an appropriate fire regime *only if it reduces the hazard*. If it increases the hazard, it cannot be referred to as hazard reduction. On the other hand, managing a forest so that it matures to a less flammable stage is hazard reduction by definition.

More research is certainly needed. There may be exceptions to these trends in some communities, or the response may be stronger or weaker if other aspects of the fire regime such as severity or time of year are varied. In particular, there is the reality that – due to the scale of these fires, so much area of forest will enter a flammable regrowth period in the coming few years. This will increase landscape flammability to unprecedented levels, so we will need to rapidly change our thinking to find ways in which areas can be nursed through regrowth to maturity. On the other hand, some low-flammability areas still remain, and recognising these provides us with opportunities for fire control that we did not realise we had.

One thing is clear, however. As the climate continues to warm, this task will become increasingly difficult. We may be facing our final chance to act.

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