BUSHFIRE RECOVERY PROJECT

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BUSHFIRE SCIENCE REPORT NO. 1: HOW DOES CLIMATE AFFECT BUSHFIRE RISKS IN THE NATIVE FORESTS OF SOUTH-EASTERN AUSTRALIA?

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This report is one of a series of Bushfire Science Reports prepared by the Bushfire Recovery Project (see www.bushfirefacts.org). The reports aim to present the latest evidence from the peer-reviewed scientific literature about bushfires, climate change and the native forests of southern and eastern Australia.

Reports in the Bushfire Science series are:

No. 1 How does climate affect bushfire risks in the native forests of south-eastern Australia?

No. 2 How do the native forests of south-eastern Australia survive bushfires?

No. 3 What are the relationships between native forest logging and bushfires?

No. 4 What are the ecological consequences of post-fire logging in the native forests of south-eastern Australia?

No. 5 What is the role of prescribed burning of native forests in reducing the risk of infrastructure loss to bushfires?

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INTRODUCTION

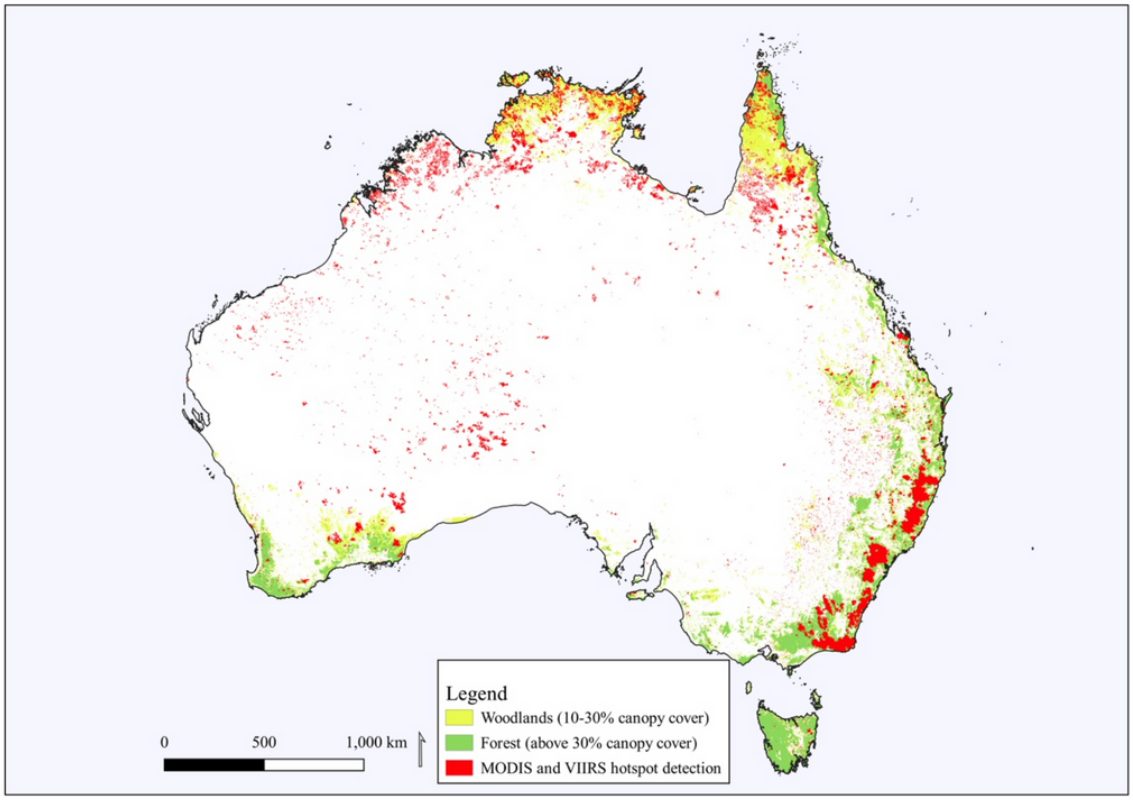


Figure 1. Location of all bushfires on the Australian continent between August 2019 and February 2020. Also shown is the distribution of forests (defined by canopy cover 30-100%) and woodland (10-30%). The megafires of south eastern Australia (eastern Victoria, eastern NSW, and southeast Queensland) are the large contiguous areas coloured red. Source: time series analysis of Sentinel satellite data accessed through Google Earth Engine and tree cover data [*1*].

In the wake of the ongoing impacts from the eastern and southern forest mega-fires of 2019-2020, questions arise as to the role of weather conditions, climate variability, and climate change in bushfire risks (Figure 1). Here we assess the published scientific literature to address four related questions:

1. How do weather and climate affect bushfire risk?
2. How do climate variability and extreme weather events influence bushfire risk?
3. How much is climate change contributing to bushfire risk?
4. How will projected climate change affect bushfire risk?

Our focus here is on bushfire risk for the native forests of eastern and southern mainland Australia.

KEY POINTS

- The 2019-2020 spring and summer bushfires in eastern and south-eastern Australia were unprecedented in terms of their geographic location, spatial extent, severity and the forest types burnt. They were driven by extreme weather conditions including winter drought and high spring and summer temperatures.
- Drought is linked to fire risk through fuel dryness which is a key constraint on the occurrence of large bushfires in the region, resulting in low fuel moisture content, triggering leaf senescence and shedding in eucalypt forests, an increase in surface fine fuels, and as well as resulting in normally damp gullies and rainforest patches being unable to impede fire spread across the landscape.
- The world is already experiencing 1˚C of global warming above pre-industrial levels. This is associated with an increase in the frequency and severity of dangerous bushfire conditions in Australia, particularly in southern and eastern Australia over the last 50 years, including a lengthening of the fire season.
- Projected climate change will further increase dangerous fire weather danger over most of Australia and particularly in south-eastern Australia, with longer and more severe fire seasons, more days of high, very high and extreme fire danger, more area burned, and increased fire control difficulty. Mega-fires present a new category of hazard that demands a new approach to bushfire risk management in Australia.

1. How do weather and climate affect bushfire risk?

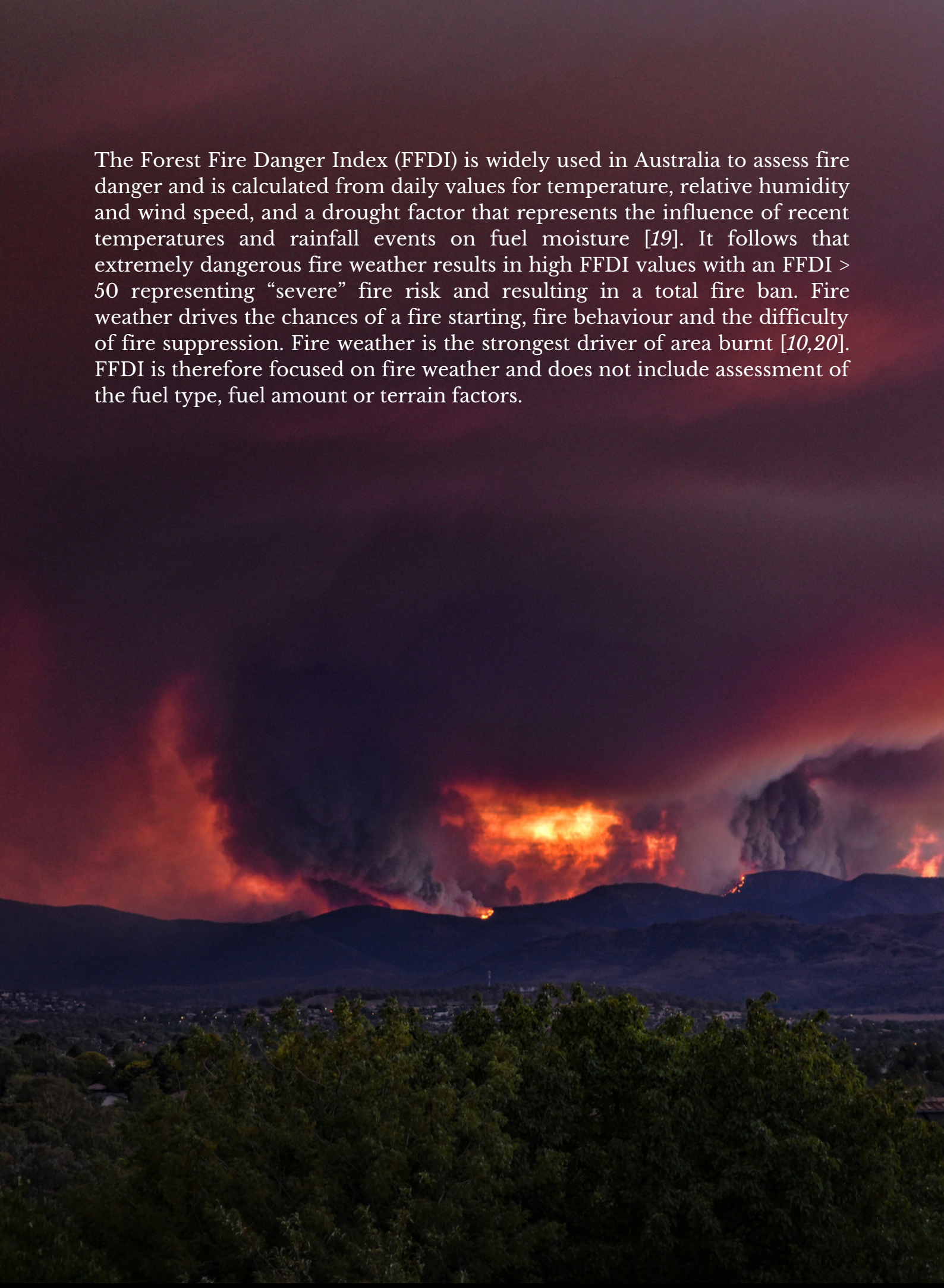
Climate – the typical weather conditions experienced over a 30-year period in a region - is the primary driver of fire regimes in two respects. First, climate is a key environmental determinant of the distribution of vegetation types (e.g. forest, woodland, shrubland, savanna) [*2*], the type of fuel produced, rates of fuel production, equilibrium fuel loads, and fuel moisture [*3-6*]. Second, climate determines fire weather [*5,7,8*]. Fire weather is the most important influence on fire behaviour, fire severity and the amount of area burned in a fire [*9-11*].

Extremely dangerous fire weather periodically occurs in south-eastern Australia as a result of compound extreme events. The 2019-2020 mega-fires were associated with compound extreme events in which drought conditions interacted with heat waves and anomalous atmospheric conditions. This was also the case with previous notable fire events including 1939 (Black Friday), 1967 (Hobart), 1983 (Ash Wednesday), 2003 (Canberra) and 2009 (Black Saturday) [*12*]. The combination of drought and extreme heat results in abundant fuel that is at high risk of burning [*6*].

Weather anomalies superimposed on these conditions such as wind anomalies [*13*], low overnight values of relative humidity, lightning storms [*14*], pyrogenic lightning [*15*], and frontal systems [*12,16*] can then create extremely dangerous fires. Atmospheric instability can drive extreme fire development with the development of violent pyrocumulonimbus clouds and associated whirlwinds, tornadoes, long-range spotting and cloud to ground lightning strikes [*17*]. Pyrocumulonimbus (pyroCb) phenomena have been confirmed for at least 65 fires in Australia [*18*]. Historically, extreme fires have occurred on only a few days per decade [*16*].

1. The weather of any place refers to the atmospheric variables for a brief period of time. Climate represents the atmospheric conditions for a long period of time, and generally refers to the normal or mean course of the weather; see Bureau of Meteorology Climate Glossary; http://www.bom.gov.au/climate/glossary/climate.shtml

The Forest Fire Danger Index (FFDI) is widely used in Australia to assess fire danger and is calculated from daily values for temperature, relative humidity and wind speed, and a drought factor that represents the influence of recent temperatures and rainfall events on fuel moisture [*19*]. It follows that extremely dangerous fire weather results in high FFDI values with an FFDI > 50 representing "severe" fire risk and resulting in a total fire ban. Fire weather drives the chances of a fire starting, fire behaviour and the difficulty of fire suppression. Fire weather is the strongest driver of area burnt [*10,20*]. FFDI is therefore focused on fire weather and does not include assessment of the fuel type, fuel amount or terrain factors.



2. How do climate variability and extreme weather events influence bushfire risk?

The most damaging bushfires in Australia's history have occurred after extended or intense drought [*21*] which is a natural feature of the Australian climate due to high rainfall variability from year to year, and decade to decade [*22,23*]. Rainfall variability is associated with multiple long term climate modes operating in the region [*23-25*] with variability in fire weather also influenced by interactions between these large scale climate drivers [*23*].

For much of Australia, the probability of daily high fire danger is markedly increased during drought (El Niño) years [*26*]. The influence of ENSO is greatest in the south-eastern corner of NSW with a significant increase in forest fire danger during El Niño years [*25*]. When El Niño coincides with negative phases of the Inter-decadal Pacific Oscillation (IPO), there is a substantial increase in forest fire danger, especially along the east coast of Australia and in the south-east corner of the continent [*25*]. The impact of El Niño on fire weather in Victoria and Tasmania is exacerbated by positive Indian Ocean dipole (IOD), and negative phases of the Southern Annular Mode (SAM) which increase the risk of fire along the NSW coast in winter and spring [*26*].

The link between drought and fire is fuel dryness as this is a key constraint on the occurrence of large bushfires in the region. Drought results in: (a) low fuel moisture content particularly in foliage and twigs (b) triggering of leaf senescence and leaf shedding in eucalypt forests; (c) an increase in surface fine fuels which can increase the rate of fires spread in the region [*27*] and (d) drying of normally damp gullies and rainforest patches enabling fire spread across the landscape [*11*].

The impact of drought on bush fire risk was manifest in the eastern and southern Australian mega-fires of 2019-2020. Eastern Australia had been experiencing severe drought in the lead up to and during the 2019-2020 fire season with much of north-eastern NSW having the lowest rainfall on record and above average temperatures over the 6 months prior to November 30, 2019 [*6,28*].

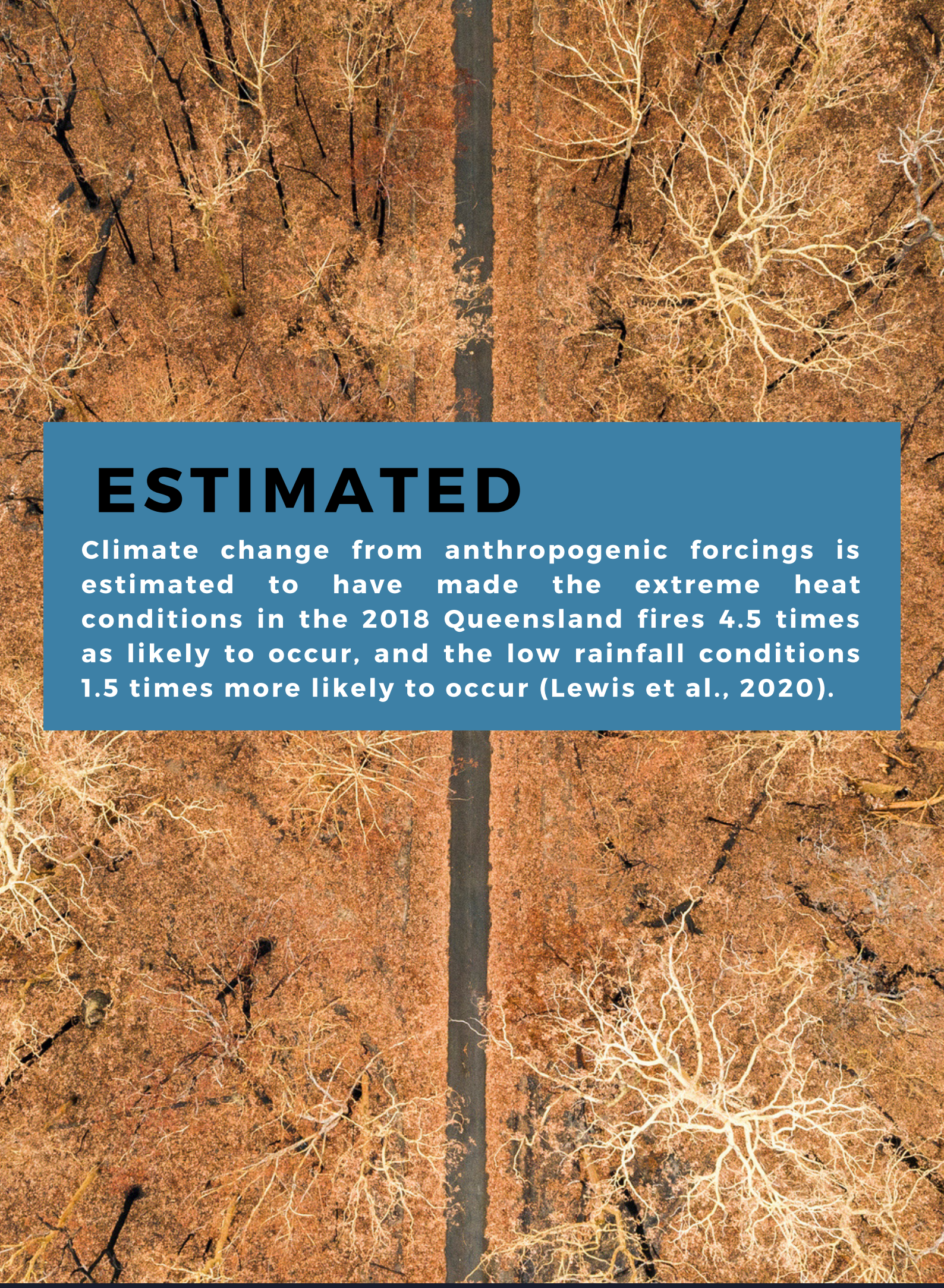
The unprecedented fires of 2019-2020 were therefore primed by the preceding weather conditions which resulted in dead fuel moisture content at the lower range of historical values throughout 2019; and from September onwards were at levels associated with the historical occurrence of large wildfires in south-eastern Australia's forests [*6*].

3. Is a changing climate contributing to bushfire risk?

A changing climate is driving fire weather conditions away from the expected range of variability for a large portion of the globe [*29,30*]. Wildfire frequencies, for example, have increased in North America since the 1980s [*31*]. Approximately 1°C of warming is currently being experienced globally. In Australia this is associated with dangerous changes in fire weather conditions. Analysis of long-term change in fire weather conditions since the 1950's has revealed a substantial increase in FFDI during spring and summer in southern Australia[*32*]. FFDI values are higher than previously recorded, consistent with observed long term trends in rainfall and temperature, especially reduced winter rainfall, increasing daily maximum temperatures [*33,34*] and an increase in the intensity, frequency and duration of heatwaves [*35*].

The worsening fire weather conditions have resulted in a need to update fire hazard warnings. When the FFDI was introduced in the 1960s, the values ranged from 1 - 100 (calibrated against the most intense fires at the time). In 2009, the system was revised nationally to include index values above 100 and a new 'catastrophic' level was adopted (called 'Code Red in Victoria) [*36*]. In spring 2019, Australia saw record high FFDI values for this time of year in areas of all States and Territories. On 6 September, values for FFDI for almost 60% of the country were the highest on record, reaching the catastrophic category (100 or above) at some locations in New South Wales [*37*].

Climate change from anthropogenic forcings is estimated to have made the extreme heat conditions in the 2018 Queensland fires 4.5 times as likely to occur, and the low rainfall conditions 1.5 times more likely to occur [*13*]. Climate change is also implicated in changing large-scale rainfall patterns [*26*].



ESTIMATED

Climate change from anthropogenic forcings is estimated to have made the extreme heat conditions in the 2018 Queensland fires 4.5 times as likely to occur, and the low rainfall conditions 1.5 times more likely to occur (Lewis et al., 2020).

4. How will future climate change affect bushfire risk?

Climate change is projected to impact on fire regimes in Australia primarily through increased fuel dryness, longer fire seasons and through its impacts on fire weather [*32,38*]. Future climate projections to 2100 point to an increase in dangerous fire weather conditions in south-eastern Australia [*38*]:

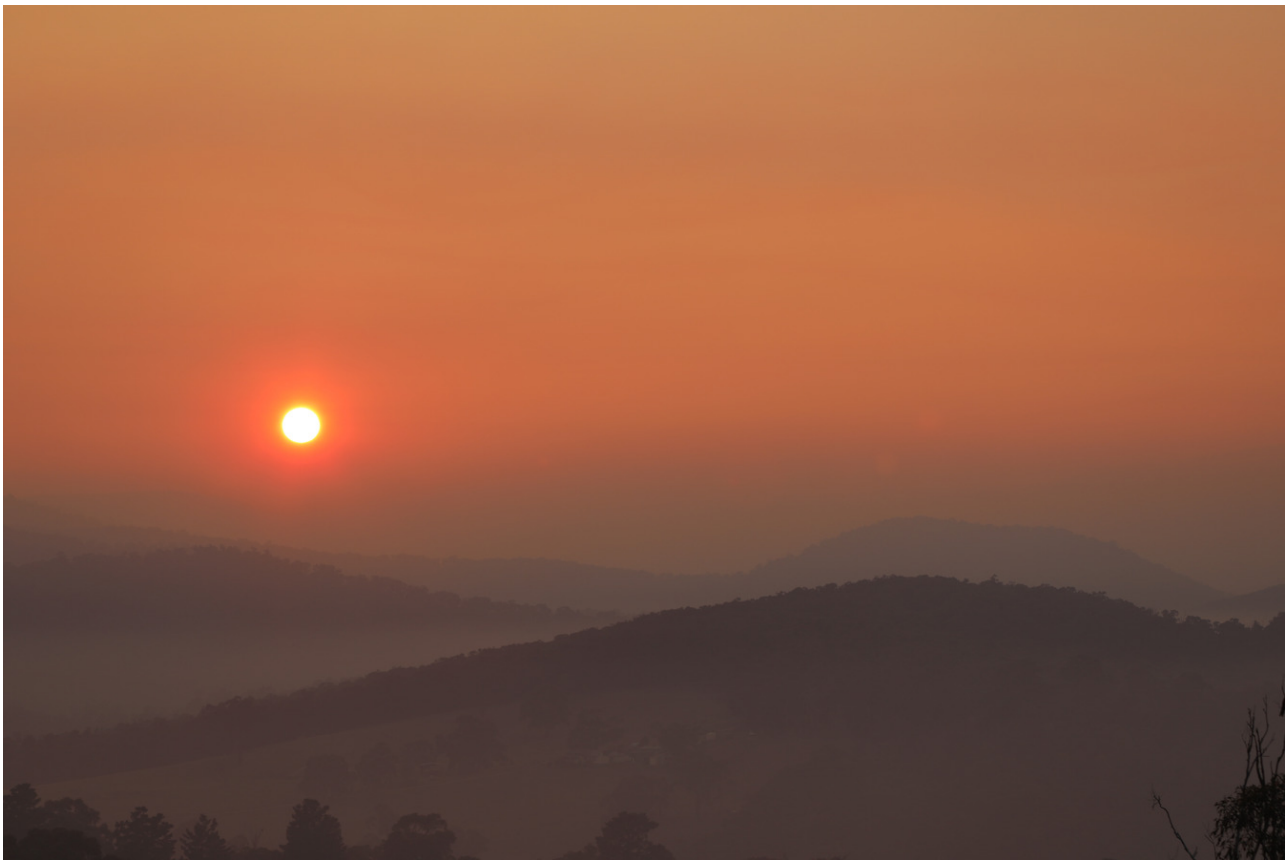
- Fire seasons are projected to start earlier, last longer and be more intense throughout their length [*40,41*];
- Increasing the Forest Fire Danger Index [*40-45*];
- Increasing the pyroconvection risk factors for some regions of southern Australia, particularly in forested areas with rugged terrain [*39,46*].

These future projections will be avoided only if the global community succeeds in achieving the deep, rapid and enduring reductions in greenhouse gas emissions needed to limit global warming to well below 2°C above pre-industrial levels, in line with the Paris Agreement on climate change [*47*].

Continental-scale changes in the climatic water balance under future climate are projected to lead to transformational shifts in fire regimes within or near the transition zone from productivity limited to dryness limited fire regimes, with modelling indicating that transformational shifts may occur on some parts of the continental divide of eastern Australia characterised by temperate eucalypt forest [*8*]. Modelled projections of future climate are robust regarding the direction of change for Australian temperatures (i.e. increasingly hot) [*48*].

However, greater uncertainty surrounds future rainfall regimes due in no small part to the more complex processes governing rainfall, the different weather systems that bring precipitation to regions around Australia, the inherent year to year variability in Australian rainfall [*49*] and the spread of estimates from the available ensemble of global climate models [*50*].

Nonetheless, latest global [*48,51*] (Figure 2) and NSW/ACT Regional Climate Modelling (NARCliM) project dynamically downscaled projections [*52*] (Figure 2) point to the persistence of the observed trend in depressed winter rainfall. Further modelling using NARCLiM data also suggest a significant increase in the number of days with conditions conducive to pyrcumulonuimbus development during the spring and summer of 2060-2079 relative to 1990-2009. This indicates an increased risk of pyrocumulonimbus events during November and December [*46*]; recognizing pyrocumulonimbus wildfires are extreme wildfire events.



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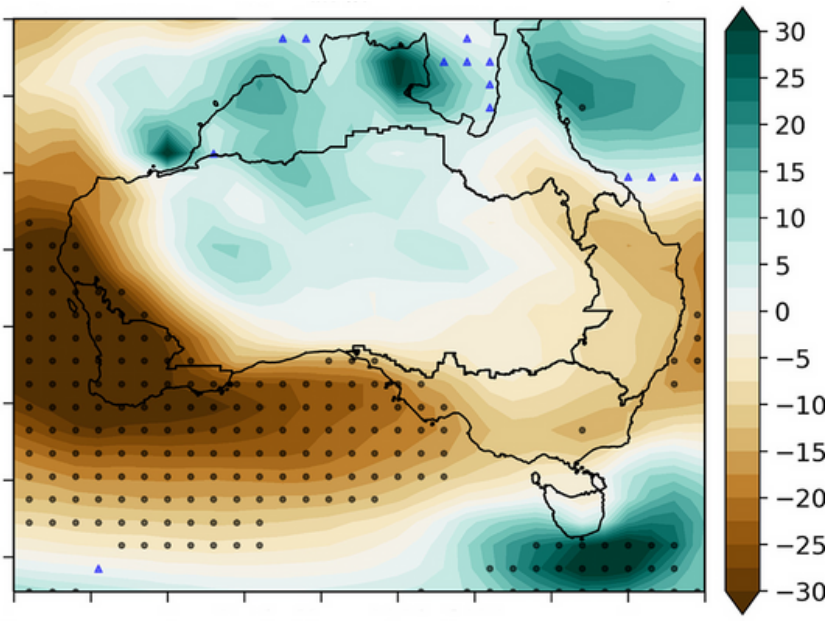

Figure 2. Relative change (%) in winter/spring (JJASON) rainfall from CMIP6 projections for 1995–2014 to 2080–2099 under high emissions (RCP8.5 and SSP5-85). Outputs from new state-of-the-art climate models under the Coupled Model Inter-comparison Project phase 6 (CMIP6) provide improvement and enhancement of climate change projections information for Australia. Source: Grose et al. 2020

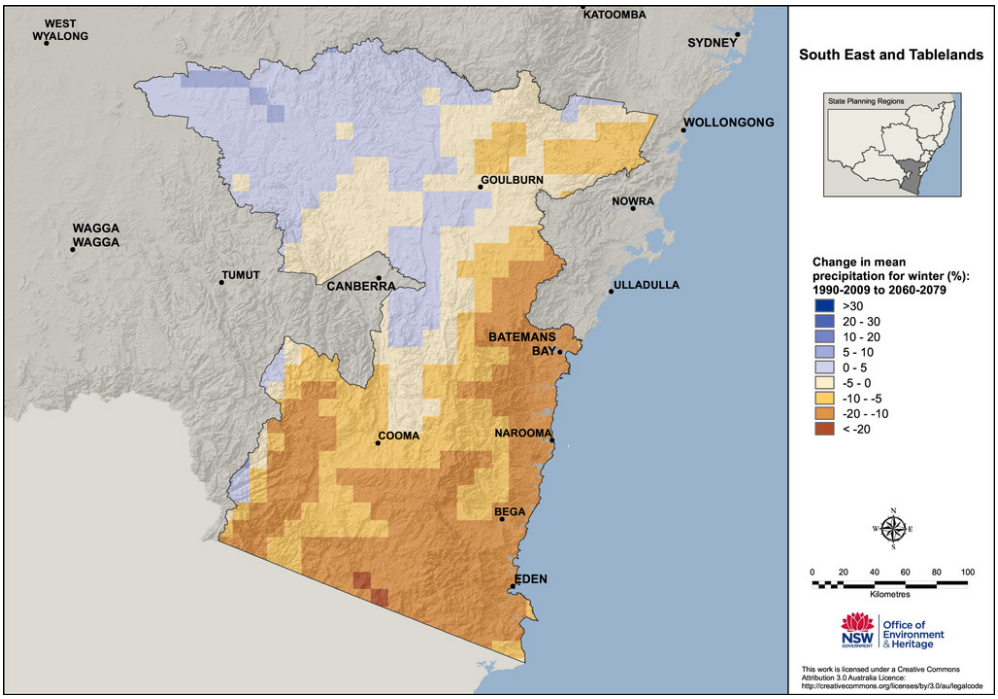

Figure 3. Projected percentage change in mean precipitation for winter comparing 1990-2009 with 2060-2079 for south east and tablelands of NSW. These NARCliM projections have been generated from four global climate models (GCMs) dynamically downscaled by three regional climate models (RCMs). The NSW and ACT Regional Climate Modelling (NARCliM) Project is a research partnership between the NSW and ACT governments and the Climate Change Research Centre at the University of NSW, For further details see Link .

"These future projections will be avoided only if the global community succeeds in achieving the deep, rapid and enduring reductions in greenhouse gas emissions needed to limit global warming to well below 2°C above pre-industrial levels, in line with the Paris Agreement on climate change" - UNEP, 2019

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