

Climate change and bushfire incidence

Dr Geoff Cary

**School of Resources, Environment and Society
Australian National University**

This presentation describes the relationship between climate change and bushfire incidence, including the implications for air quality.

Bushfires and emissions

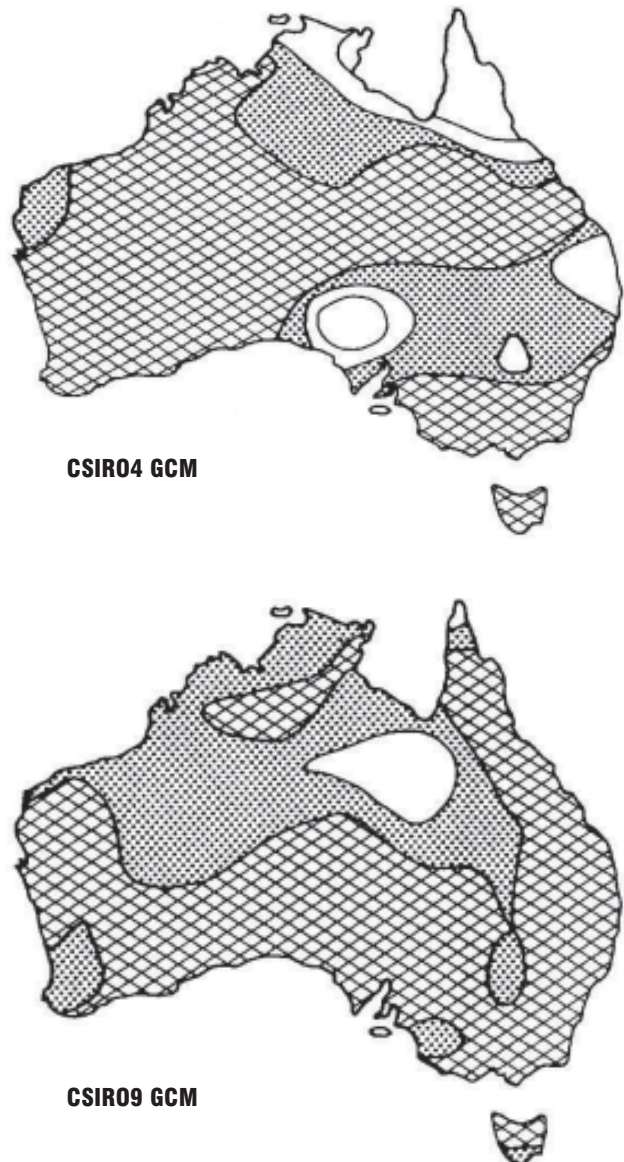
The complete combustion of vegetation comprised of pure cellulose would release only carbon dioxide, water vapour and thermal energy. Vegetation is not comprised purely of cellulose however, and its combustion is almost never complete. Every fire that you see has a smoke plume, which is the emission of particulate matter, or the incomplete products of combustion, into the atmosphere.

Smoke particles have a life of hours to weeks and they generally become adhered to surfaces or are intercepted by rainfall. Fire emission rates are affected by fire behaviour and the amount of fuel being burnt. Head fires (particularly fast moving fires burning heavy fuel loads) might emit up to 1% of the fuel load as particulate matter to the atmosphere. Bushfires therefore clearly have a significant effect on air quality. Given this relationship between bushfires and air quality, we need to know how fire regimes will change with time and with climate change.

Climate change and bushfire danger

The forest fire danger index (FFDI), which was developed in the mid 1960s, is a measure of the likelihood of a fire starting, its rate of spread and its difficulty of suppression on any particular day.

Beer & Williams (1995) analysed the likely changes in the annual sum of the FFDI between a current carbon dioxide concentration climate ($1 \times \text{CO}_2$) and that where the carbon dioxide concentration doubles ($2 \times \text{CO}_2$). They found an increase in the annual sum of FFDI across much of Australia, particularly in the South East (Figure 1).



**Figure 1: Changes in the annual sum of FFDI:
 $1 \times \text{CO}_2$ to $2 \times \text{CO}_2$ (Beer & Williams 1995)**

Cross-hatched areas indicate an increase in expected annual sum FFDI of greater than 10%

Dotted areas indicate a likely increase of up to 10%

Blank areas indicate a decrease

Williams et al. (2001) also looked at the distributions of fire danger rating days for a range of specific sites in southern and northern Australia and found a general trend towards a decreasing frequency of low and moderate fire danger rating days, but an increasing frequency of very high and in some cases extreme fire danger days.

The FFDI can be used to predict the likelihood of having destructive events. Bradstock & Gill (2001), for example, studied 40 years of newspaper records from 1955 to 1995 and found that the probability of a house being destroyed by bushfire in the Sydney region rises to 100% once the forest fire index reaches 40.

Knowing the FFDI will not enable us to predict the effects of bushfire on everything we value, including biodiversity and vegetation. *Banksia ericifolia* for example, which is a common species in the vegetation around the Sydney region, will survive under a particular suite of favourable fire regimes (i.e. frequency, intensity, seasonality of fire occurrence), whereas other (adverse) fire regimes may lead to the loss of the species from a site.

Air quality and fire regimes

Air quality and the way that we respond to it should be thought of in the terms of the fire regime—how frequently will there be bad air quality days because of bushfires and how intense will the impact on air quality be?

We can use simulation models (e.g. FIRESCAPE) to do this. Data including terrain type, empirical models of lightning fire and other fire locations, fuel dynamics, well-accepted algorithms of fire behaviour, and weather dynamics are inputs used to simulate the spread of fires across landscapes.

Fires are ignited in the landscape, they spread and become a discrete fire event that burns faster when the fire danger index increases, and slower when the fire danger index decreases. Fires also respond to wind direction, terrain slope, and fuel load and availability. They will eventually extinguish. These fire events can be overlaid through time to gain an understanding of likely spatial patterns of fire frequency, fire intensity and season of fire occurrence. Figure 2 is an example from a FIRESCAPE simulation for the ACT region. The warmer colours indicate intervals between fires of less than 20 years while the cooler colours indicate longer intervals of greater than 70 or up to 100 years.

Model output can be evaluated against things like dendrochronology studies and what we know about forest fire behaviour, to try and validate and generate confidence in these output predictions. We can also

use these simulation models to consider the effect of climate change scenarios on bushfires.

In collaboration with CSIRO Division of Atmospheric Research, I analysed 1 x CO₂ and 2 x CO₂ climate scenarios for the ACT region in terms of monthly changes in temperature, daily wind speed, precipitation and humidity. Our conclusions were that we are expecting a warmer climate, and a decline in precipitation over the summer months and late autumn, but an increase in precipitation in spring and early summer. We are also going to see a decrease in non-relative humidity. Wind speed and wind direction remain largely unchanged. These are all factors that affect fire behaviour, fire danger and subsequently fire regimes in the landscape.

We next developed four climate change scenarios—no change in climate and small, moderate and large changes in climate—using maximum temperature increases of +0, +0.6, +2.0 and +3.4 degrees Celsius respectively. Minimum temperature, precipitation and relative humidity were scaled equivalently to the scaling of maximum temperature, and wind speed and direction remained unchanged.

Running the model with our current climate (i.e. from the 1980s up to 2000) to parameterise the climate and the weather generator in the model, we saw a particular pattern in fire intervals (Figure 2).

We can then change the weather parameters on a monthly basis according to the predicted changes in monthly climate averages for the moderate change in climate, and re-run the model holding all other parameters constant (Figure 3).

The frequency of fire is predicted to increase across all of the study landscape. This not an entirely unexpected result given that for warmer, drier fire seasons we would expect a larger area burned and a reduction in inter-fire interval.

Perhaps the most interesting result is the mechanism responsible for this increase in fire frequency. It is not the high-intensity fires that burn across the landscape, but the very low-intensity fires that are no longer as easy to suppress or self extinguish naturally because of the change in the fire weather over time with climate change.

Empirical evidence also supports these hypotheses. Ross Bradstock (unpublished data) looked at the relationship between soil dryness index on the day of ignition of a fire and the cumulative area burnt in the Blue Mountains between 1960 and 2003.

The soil dryness index is a measure of soil dryness and tells you how much soaking rain is needed to bring the

soil back to field saturation. It can also be considered a measure of the severity of a drought and can be related to the flammability of live vegetation, coarse woody debris and deep litter beds.

In the Blue Mountains study, a phase change was detected between a soil dryness index of about 60 and 70. We know from our own observations going back many decades that larger fires occur when droughts are more severe, but Bradstock's study quantifies what we might expect under climate change. The climate change scenarios for southern Australia are mostly increasing the soil dryness index, raising the question of how often will it increase above a threshold of larger fires given the particular climate change scenarios?

Bushfire emissions and management

Karen King (unpublished data), from the Bushfire Cooperative Research Centre, is studying the sensitivity of fire regimes to management and climate change in a mix of vegetation types across Tasmania. Some of these, like button grass moorland, are highly flammable while others, like rain forest, are relatively non-flammable.

An initial part of King's analysis is to use simulation models to investigate the relationship between the percentage of the button grass moorland subject to annual prescribed burning, as a management practice to reduce the area of unplanned fires, and the area of unplanned fires that actually occur. With increased fire management in the landscape there is a reduction in the area of unplanned fire.

When the 2070 climate is used in the model, the same basic relationship between management and area of unplanned fire is observed (i.e. the more you burn the landscape the lower the area of the unplanned fire). However, to maintain the same level of unplanned fire in 2070 as in 1980–2000, you need to burn more of the landscape with prescribed fire. The interaction between climate change and the amount of required fire management is therefore very important.

Management burning will also contribute to particulate emissions, possibly more than the bush fires that you are trying to prevent. Air quality is, therefore, affected by unplanned bushfires, and by the smoke from planned fires which are designed to try and reduce the risk of those higher intensity unplanned fires.

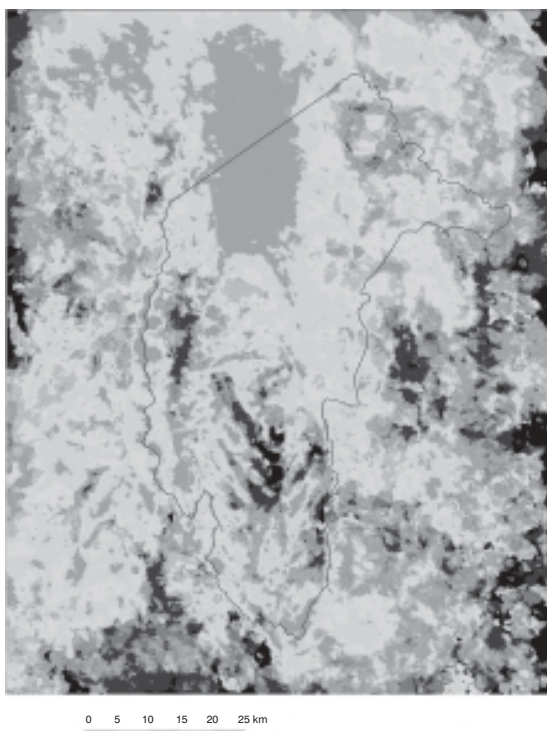


Figure 2: Average inter-fire interval from 500 year FIRESCAPE simulation assuming current climate from the Australian Capital Territory Region (Cary 2002)

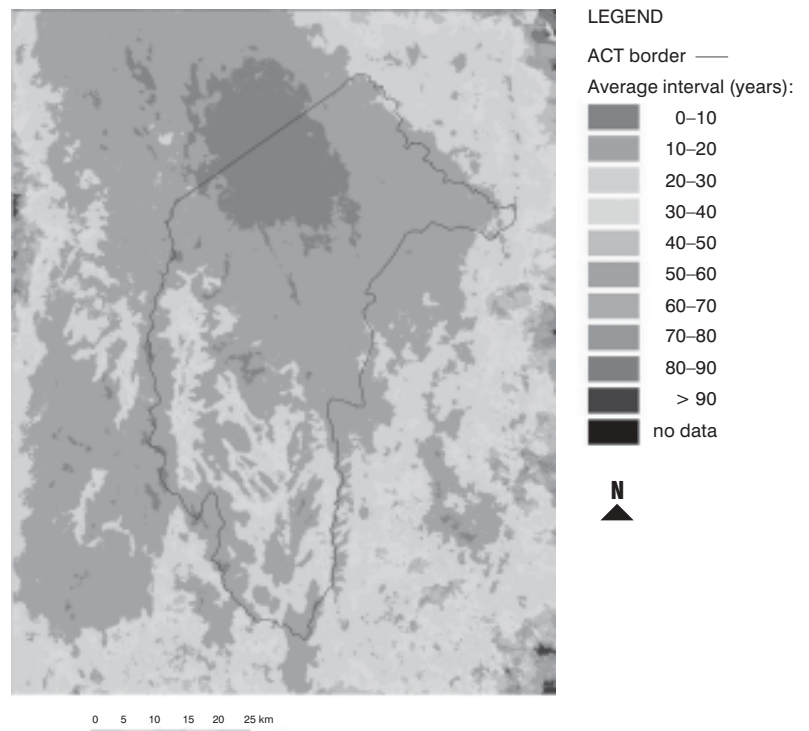


Figure 3: Average inter-fire interval from 500 year FIRESCAPE simulation assuming a moderate change in climate from the Australian Capital Territory Region (Cary 2002)

Optimal fire management research

The Bushfire Cooperative Research Centre, which is a joint venture between the Department of Environment and Conservation (NSW), the Australian National University and the University of NSW, is undertaking a seven year research project on managing bush fire risk in a changing world. The study areas—the Sydney region, the NSW southern tablelands, south-west Tasmania and central or arid Australia—give a range of climates and, importantly, a range of different values at risk, and different management solutions that might be applied to the fire management problem.

In the Sydney region there are many things we value and wish to protect—including people and property, water yield and quality, air quality and biodiversity to name a few. Fire management options include prescribed burning and fire suppression, and alternative suppression tactics, and interface management.

Our knowledge of simulation models is growing and is matched by parallel research in the US, Canada and Europe. We have an evermore sophisticated understanding of the potential impacts of increased CO₂ and other greenhouse gases on the world's climate. We also have knowledge on particulate emission rates from bushfires and models for the transport of air pollutants across large air sheds like the Sydney basin. In the near future we will be able to develop scenarios for air quality in the Sydney region with respect to fire management in the context of the broader things that need to be managed—people and property, biodiversity, water quality and yield—and given the influence of a changing climate.

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