THE AUSTRALIAN NATIONAL UNIVERSITY

The Fenner School of Environment & Society

Changed patterns in fire regimes

Geoff Cary, Karen King, Ian Davies,
Rob de Ligt, Amy Davidson

- Fire danger/regime modelling
- Ignition
- Spread
- Extinguishment
- Management
- Fuel

Fire danger

- A number between 0 and 100 that is directly related to the chances of a fire starting, its rate of spread, intensity and difficulty of suppression according to various combinations of temperature, relative humidity, wind speed and both long and short term drought effects.

A.G. McArthur 1973

CSIRO

Australian Government
Bureau of Meteorology

Climate change impacts on fire-weather in south-east Australia

K. Hennessy, C. Lucas* N. Nicholls* J. Bathols, R. Suppiah and J. Ricketts

CSIRO Marine and Atmospheric Research
* Bushfire CRC and Australian Bureau of Meteorology

Australian Government
Department of the Environment and Heritage
Australian Greenhouse Office

NEW SOUTH WALES

Victoria
The Place To Be

Tasmania

ACT Government

2006

bushfire CRC

ANU
THE AUSTRALIAN NATIONAL UNIVERSITY

Average number of days when the FFDI rating is "very high" or "extreme" under present conditions (1974-2003) for the years 2020 and 2050.

Site	Present	CCAM (Mark2)				CCAM (Mark3)			
		2020 low	2020 high	2050 low	2050 high	2020 low	2020 high	2050 low	2050 high
Canberra	23.1	25.6	27.5	27.9	36.0	26.0	28.6	28.9	38.3
Bourke	69.5	75.2	83.3	84.0	106.5	73.9	80.3	80.6	96.2
Cabramurra	0.3	0.3	0.4	0.4	0.7	0.4	0.4	0.5	1.0
Cobar	81.8	87.9	96.2	96.6	118.3	86.6	92.8	93.0	108.6
Coffs Harbour	4.4	4.7	5.1	5.1	6.3	4.7	5.6	5.6	7.6
Nowra	13.4	13.9	14.7	14.8	17.5	14.2	15.6	15.6	19.9
Richmond	11.5	12.9	14.0	14.1	17.5	13.1	14.3	14.4	19.1
Sydney	8.7	9.2	9.8	9.8	11.8	9.5	11.1	11.3	15.2
Wagga	49.6	52.7	57.3	57.6	71.5	52.8	57.4	57.7	71.9
Williamtown	16.4	17.2	18.2	18.4	20.9	17.3	19.4	19.4	23.6
Bendigo	17.8	19.5	21.3	21.4	27.3	19.7	21.9	22.0	29.8
Laverton	15.5	16.4	17.3	17.3	21.2	16.6	17.8	17.8	22.3
Melbourne	9.0	9.8	10.7	10.8	13.9	9.8	11.1	11.2	14.7
Mildura	79.5	83.9	89.5	89.9	104.8	84.6	90.7	90.9	107.3
Sale	8.7	9.3	10.0	10.1	12.1	9.6	10.7	10.8	14.0
Hobart	3.4	3.4	3.4	3.4	3.4	3.4	3.5	3.5	3.5
Launceston	1.5	1.5	1.5	1.6	2.0	1.6	1.9	1.9	3.1

- 21 – 65% increase in VH/Ex FDR days for Canberra by 2050
- See also Pitman et al. 2007, Climatic Change

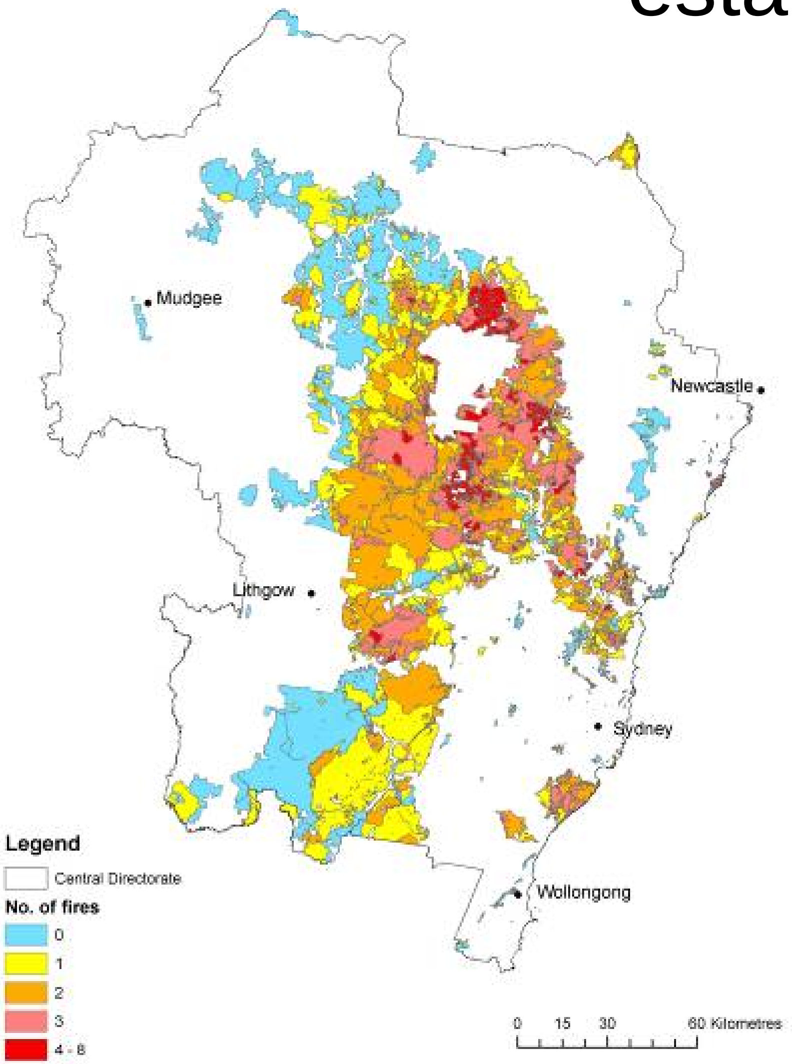
Fire Regime

"The components of a fire regime are the variables fire intensity, frequency of fire, and season of occurrence."

A. Malcolm Gill (1975) Fire and the Australian Flora: a review. *Australian Forestry* 38:4-25.


Geoff Cary

GLM of fire frequency in conservation estate, Sydney region

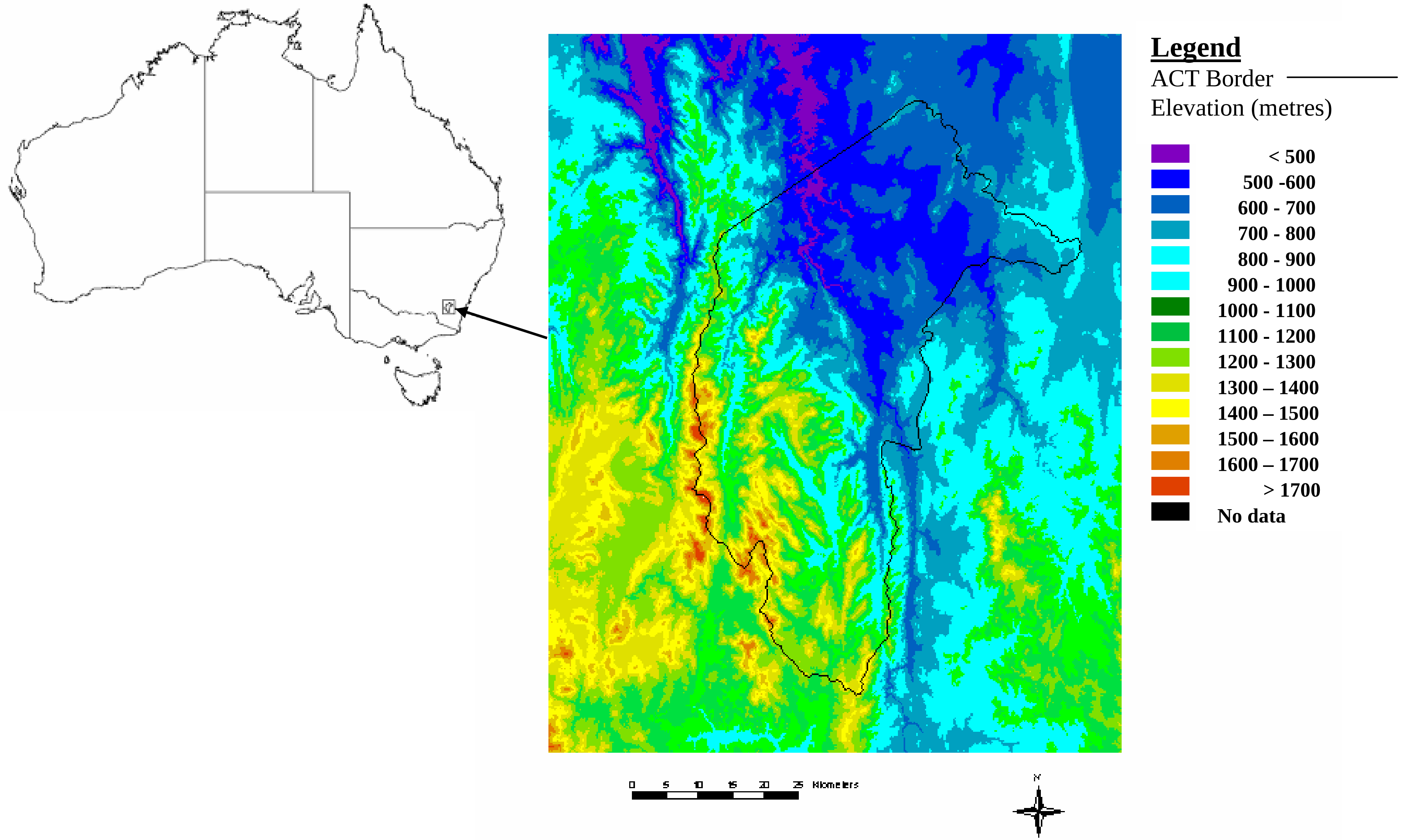


Variance explained (%):

- Radiation 9
- Precipitation 13
- Temp/Elev. 9
- Unexplained ~ 50

i) Rob de Ligt (2005) Probability of burning with time-since-fire in the Sydney region. Honours Thesis, SRES, ANU
ii) Amy Davidson (2006) Key determinants of fire frequency in the Sydney region, Honours Thesis, SRES, ANU

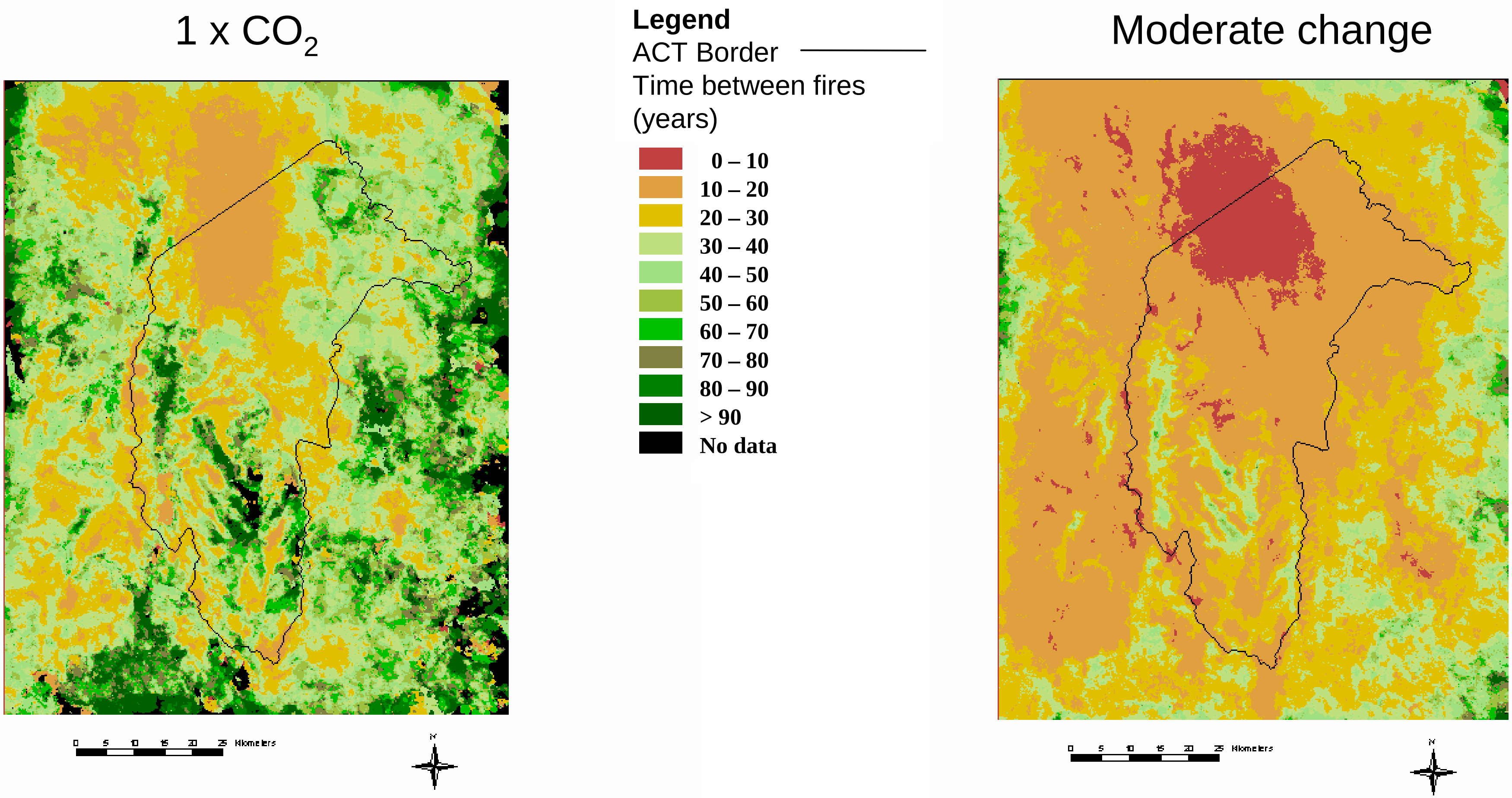
Elevation: Australian Capital Territory Region



Climate change scenarios

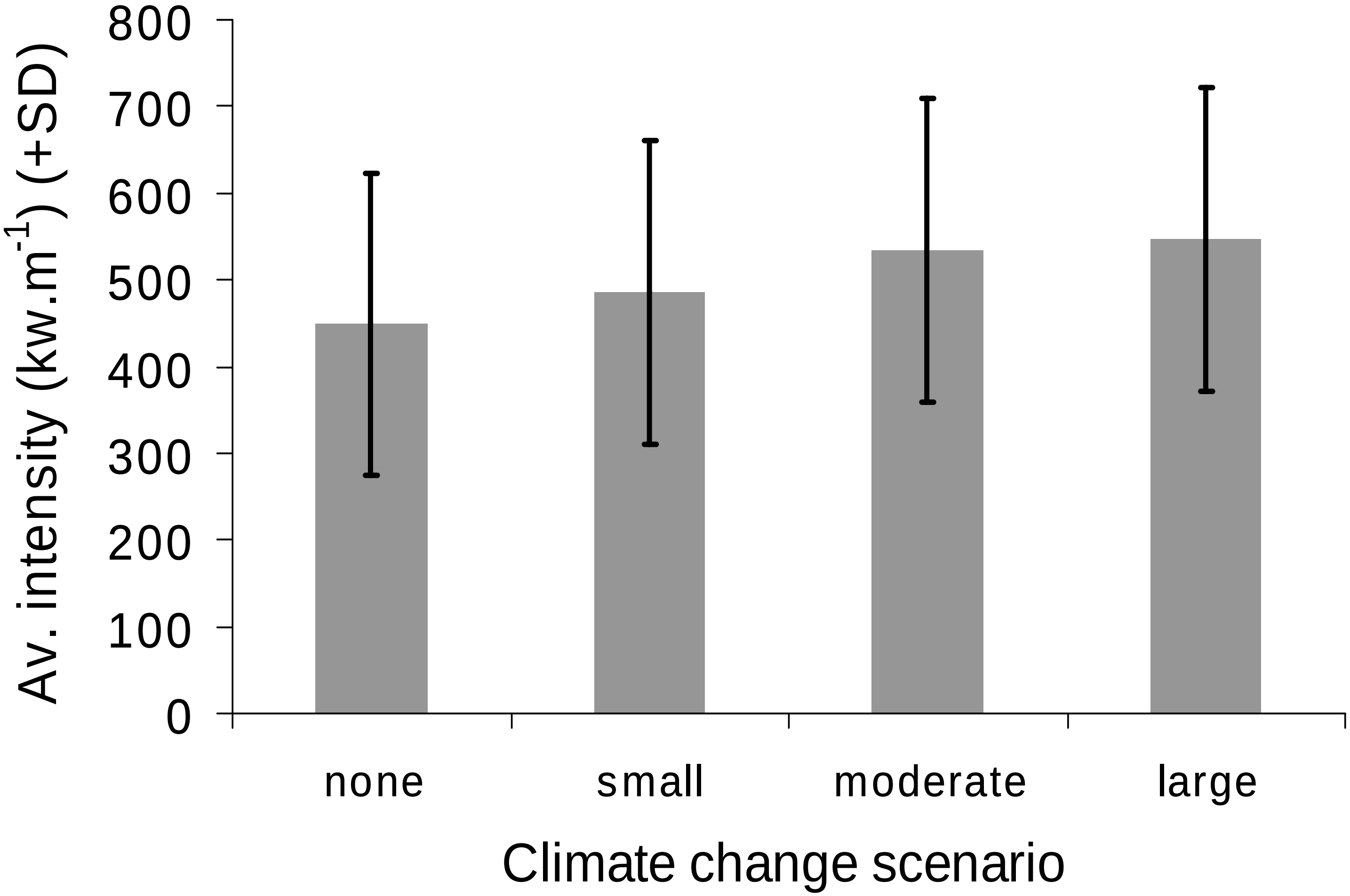
Maximum increase in average monthly temperature	No change in climate (current) + 0	Small change in climate + 0.6	Moderate change in climate + 2	Large change in climate + 3.4
Min temp PPT RH	Scaled consistently with change in temperature			
Wind speed	Unchanged			

Inter-fire interval & climate change

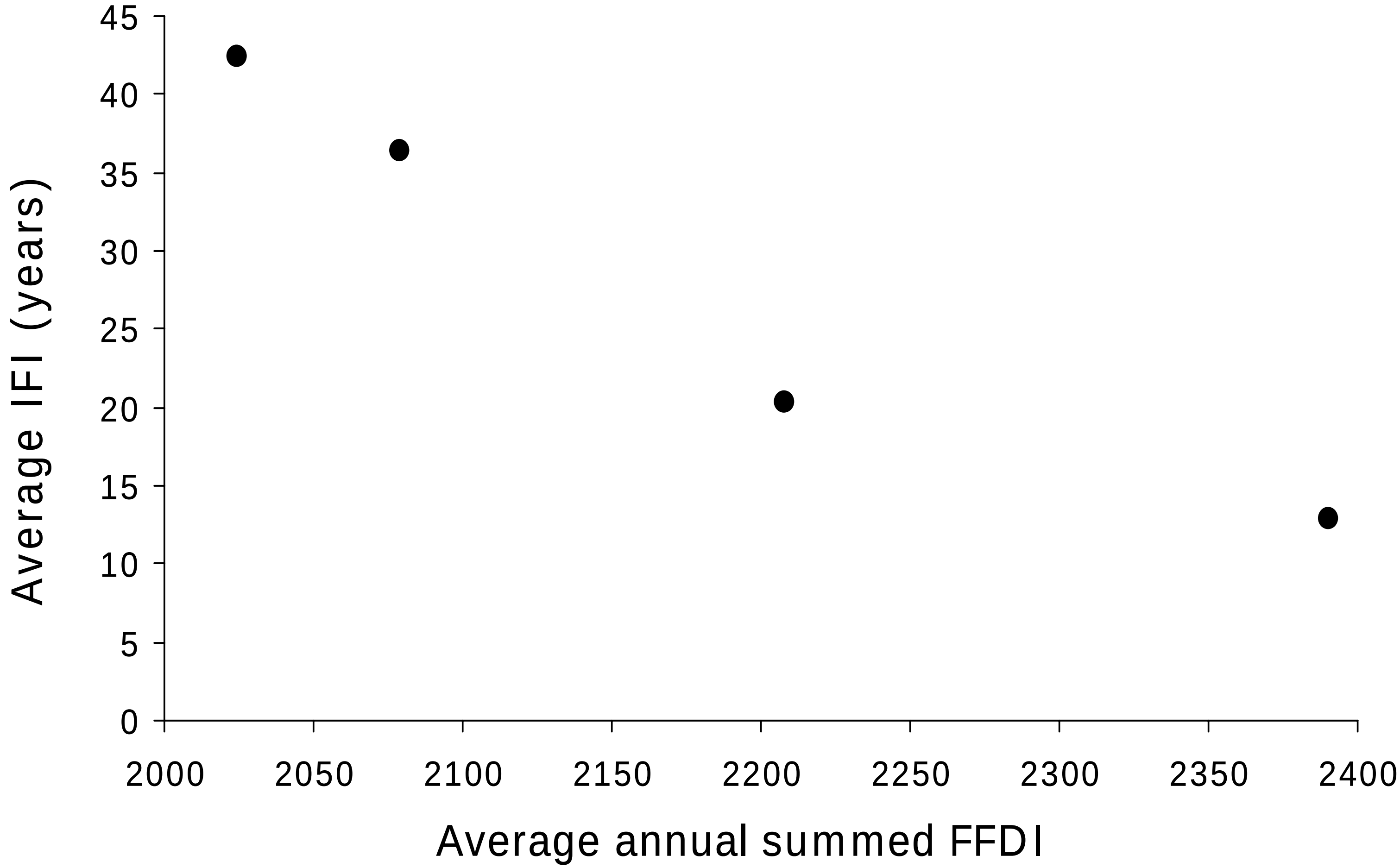


Cary, G.J. (2002) Importance of a changing climate for fire regimes in Australia. In *Flammable Australia: The Fire Regimes and Biodiversity of a Continent.* (Eds R.A. Bradstock, A.M. Gill, J.E. Williams). Cambridge University Press.

Average intensity for all cells



Σ FFDI versus IFI



THE AUSTRALIAN NATIONAL UNIVERSITY

Model concensus ?

Table 3. Relative Sums of Squares attributed to different sources of variation in the comparison of sensitivity of ln-transformed area burnt to terrain (Terrain), fuel pattern (Fuel), climate (Climate) and weather factors (Weather), and their interactions.

Source	Model					
	DF	EMBYR	FIRESCAPE	LAMOS	LANDSUM	SEM-LAND
Terrain	2		0.293*			
Fuel	1	0.217*	*		*	*
Terrain × Fuel	2		*			
Climate	2	*	0.418*	0.278*	0.178*	0.370*
Terrain × Climate	4		*			
Fuel × Climate	2	*				*
Terrain × Fuel × Climate	4		*			
Weather	9	0.329*	0.087*	*	0.333*	0.542*
Terrain × Weather	18		0.025*		*	
Fuel × Weather	9	0.031*	*			*
Terrain × Fuel × Weather	18	*				
Climate × Weather	18	0.096*	*	*	0.224*	0.046*
Terrain × Climate × Weath	36		0.025*			
Fuel × Climate × Weather	18	*				
Terr × Fuel × Clim × Weath	36					
Model	179	0.744	0.905	0.401	0.766	0.971

Factors and their interactions are considered important if they explain more than 0.05 and 0.025 of total variance respectively. Factors and interactions considered unimportant are blank. Significant factors and interactions ($P < 0.05$) are indicated by *. Note that not all significant sources are considered important.

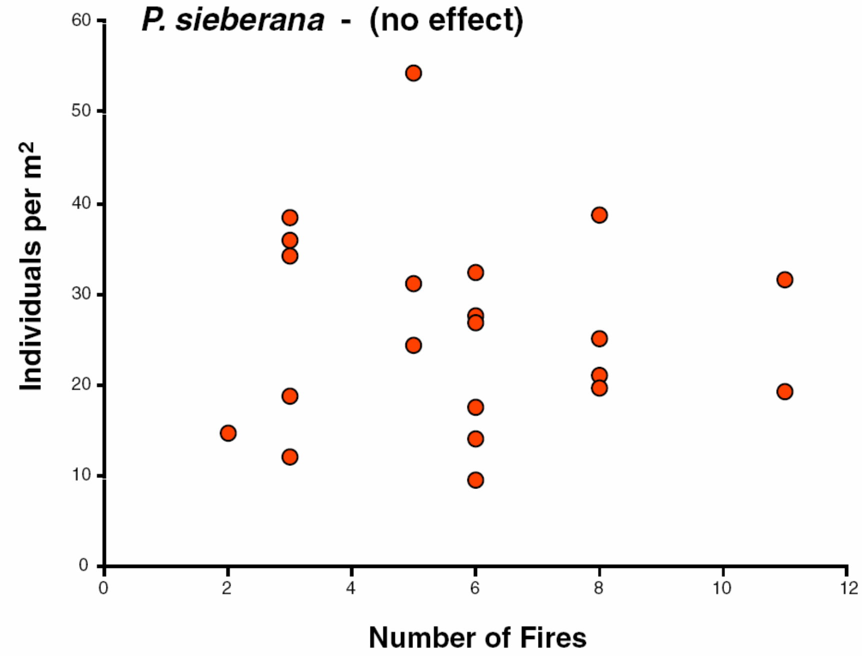
Cary et al. (2006) Landscape Ecology 21: 121-137

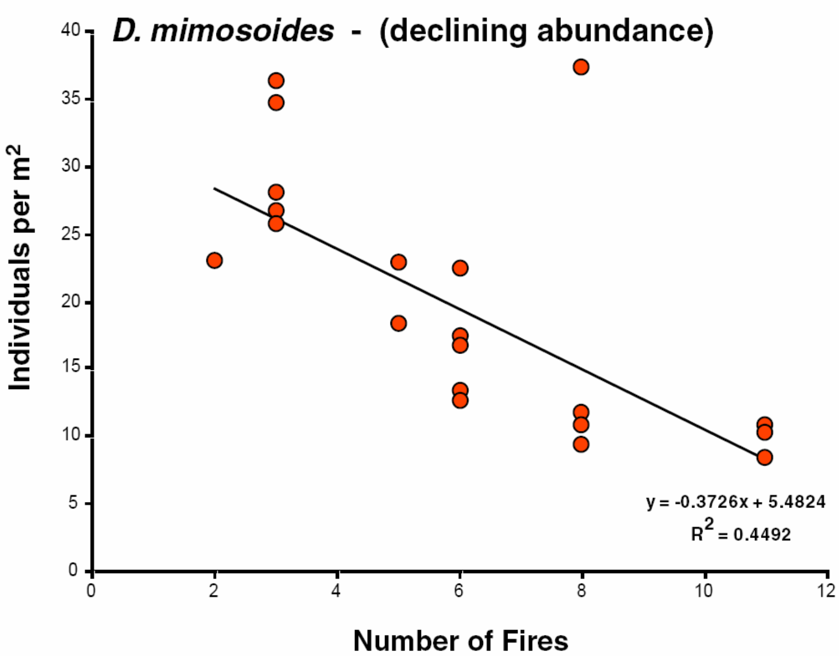
THE AUSTRALIAN NATIONAL UNIVERSITY

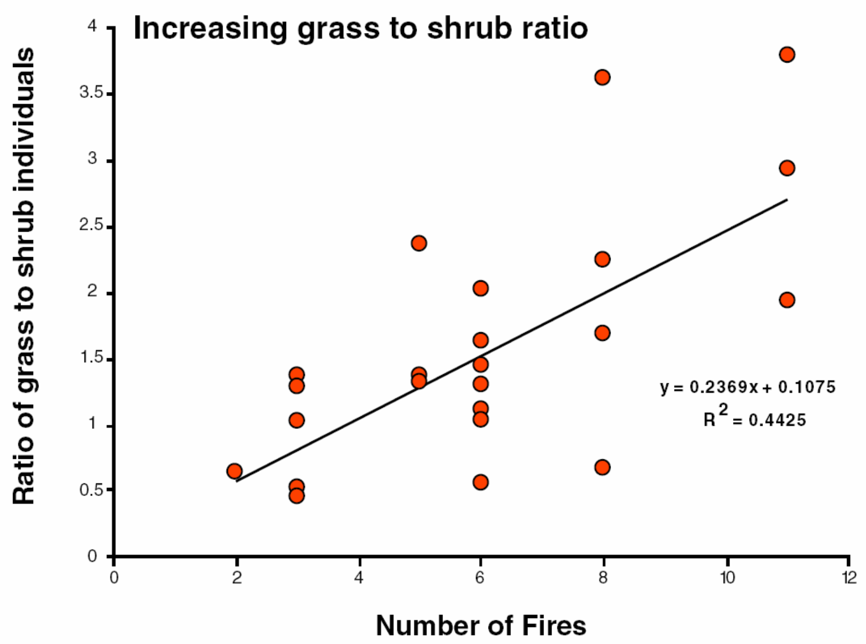
The Effects of Fire Frequency on Subalpine Snow Gum Forest Understorey

Geoffrey Cary[1,2], Christine Kelly[1,2], Ross Bradstock[2,3], Malcolm Gill[1,2] & Clive Hilliker[1]

1 School of Resources, Environment and Society, The Australian National University, Canberra 0200
2 Bushfire Cooperative Research Centre, Australia
3 Department of Environment and Conservation (NSW)



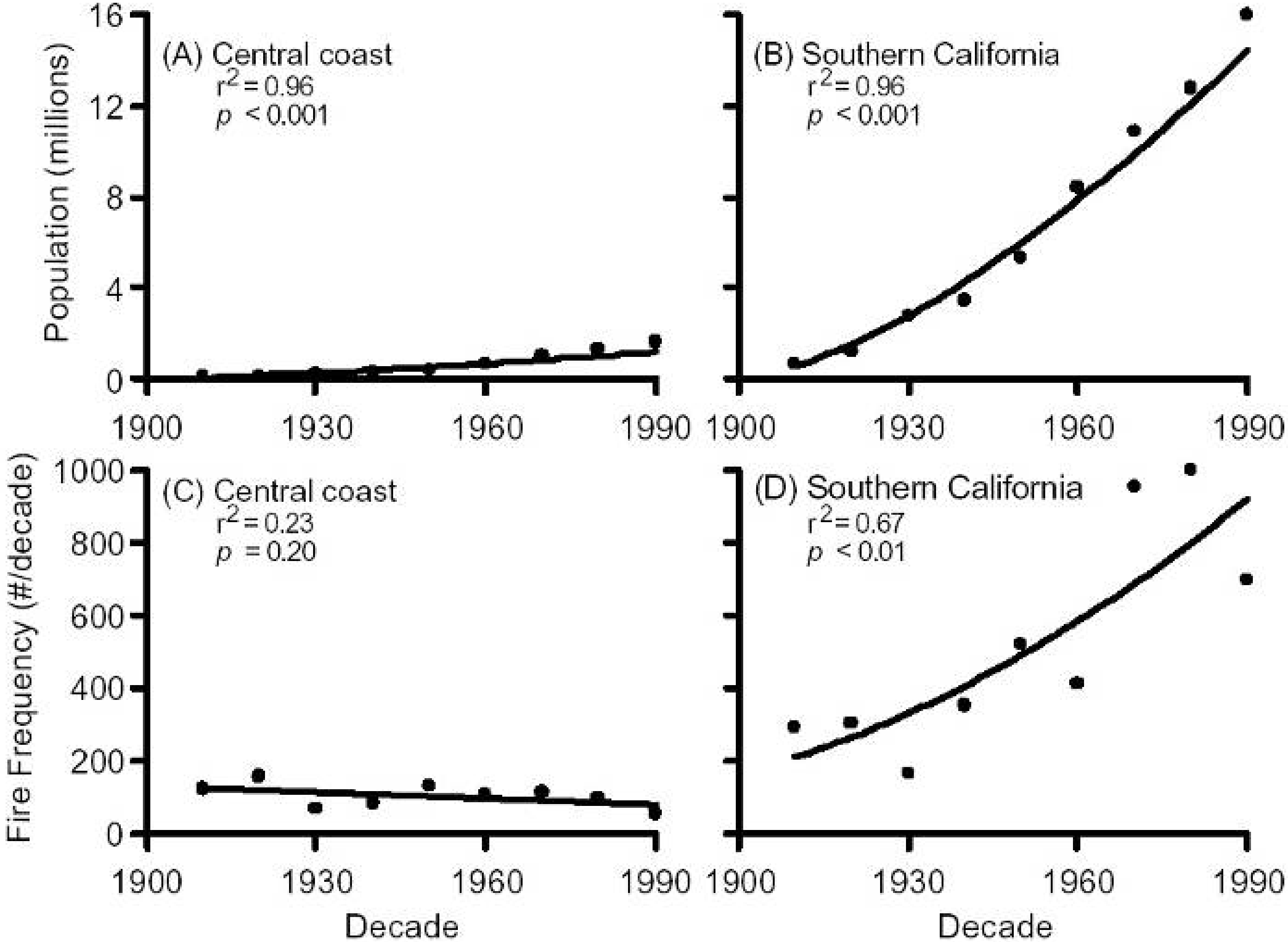




Examples of fire in DGVMs

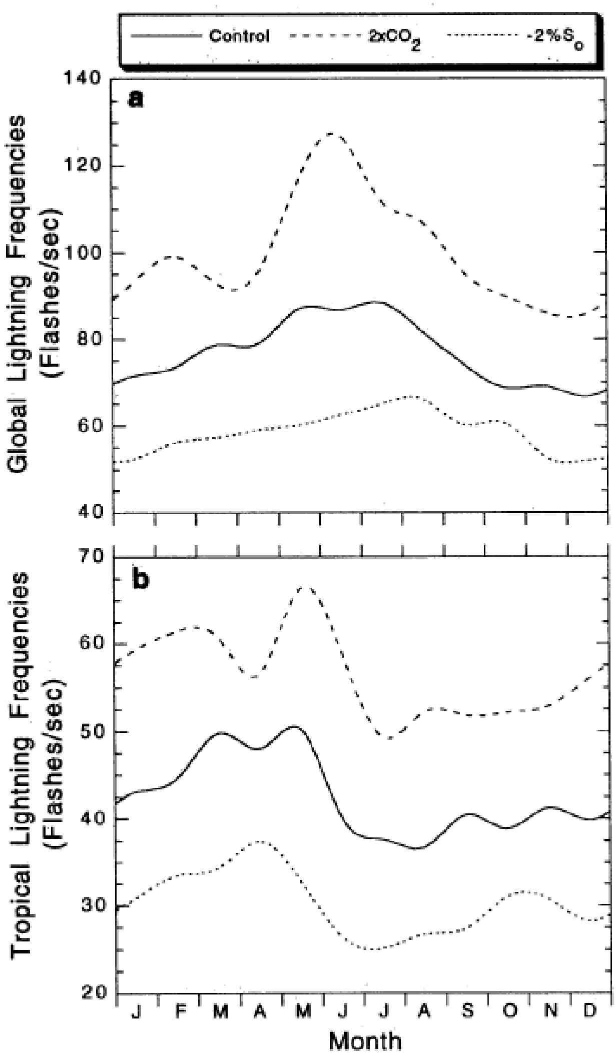
Model	DGVM	Authors	Drivers of area burned
MCFIRE	MC1	Lenihan et al. 1998 Northwest Science	• MC of 1-, 10-, 100-, 1000-hour dead (& live) fuels • Biomass of above-ground pools • Surface fire behaviour – Rothermel • Crown fire initiation – Van Wagner • Lightning ignition
GLOB-FIRM	LPJ	Thornicke et al. 2001 Global Ecology & Biogeography	• Minimal fuel load threshold • Litter moisture main driver of fire probability • Length of fire season drives % of gridcell burned
Reg-FIRM	LPJ	Venevsky et al. 2002 Global Change Biology	• Minimal fuel load threshold • Number of fires vary with population density/lightning • Area burned – windspeed, available fuel • Stochastic fire duration • Explicit fire spread (assuming elliptically-shaped fire)
SPITFIRE	LPJ (JULES)	Spessa et al. in prep	• Human-caused ignitions • Lightning-caused ignitions • Explicit fire spread (assuming elliptically-shaped fire) • ROS (based on Rothermel) - fuel moisture (fire danger index) - fuel bulk density - wind speed - curing • Fire duration

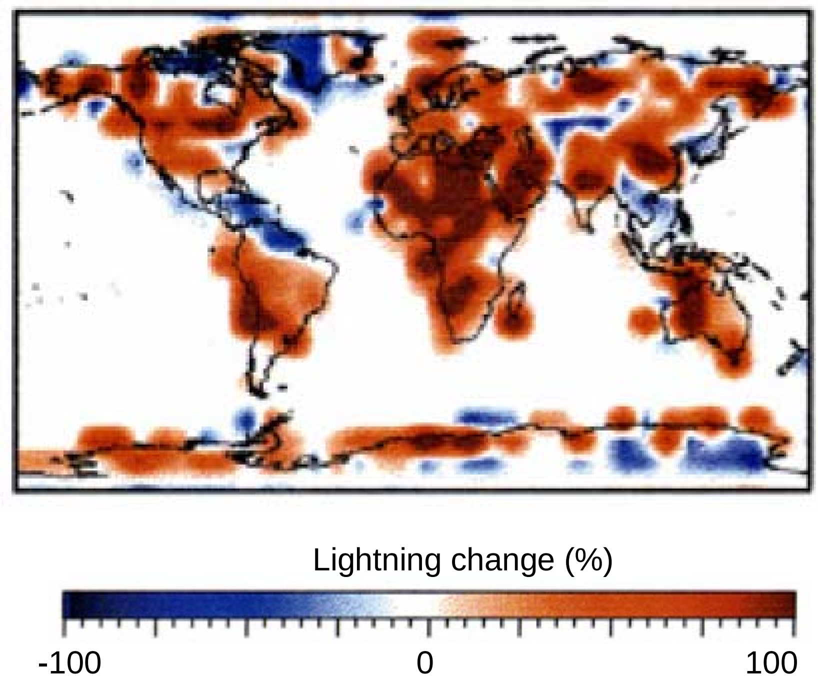
Population and fires per decade for central coast and southern California



Keeley, J.E., Witter, M.S. & Taylor, R.S. (2003) Challenges of managing fires along a wildland-urban interface – Lessons from the Santa Monica Mountains, Los Angeles, California. *Proceedings of the 3rd International Wildland Fire Conference*, October, Sydney.

Lightning



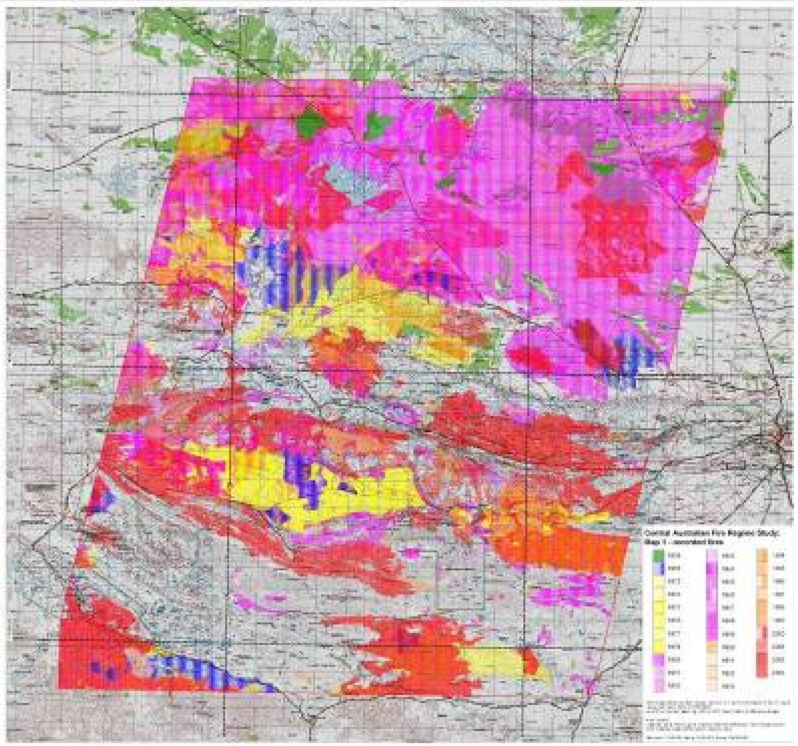


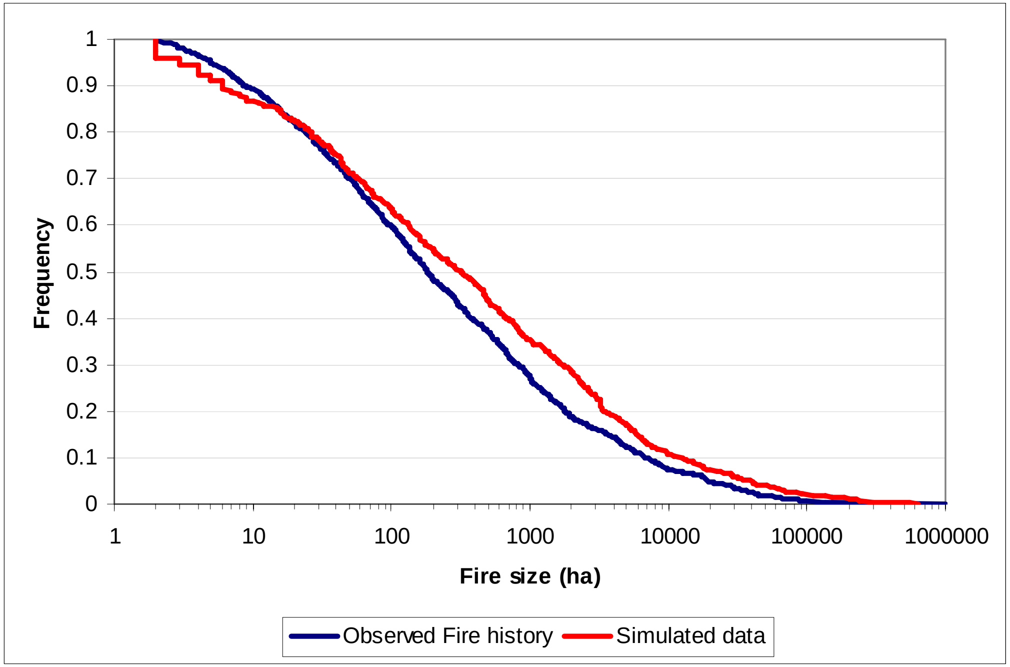
Price C, Rind D (1994) Possible implications of global climate change on global lightning distributions and frequencies. Journal of Geophysical Research 99 (D5): 10823-10832

Weather

- Process models require daily weather & can handle sub-daily for fire spread
- Replication fundamental to analysis of models with stochastic elements
- Bias in 1 x CO_2 simulated climate problematic for validation of fire models
- “the preferred method to incorporate climate change into landscape models is via a weather generator” (Cary 2002)
- Pitman et al. (2007, Climatic Change) presents case for re-evaluation given recent developments in climate modelling

Current climate validation





Fire spread

- Forest - McArthur 1967

  ROS Under-prediction

- Dry forest - Project Vesta

  1. Weather domain (plot experiments vs. landscape fires)
  2. Fuel ‘Hazard’ approach

- Shrubland

$$R = aU_2^b H^c$$

- Moist forest ?

Consumption/emission

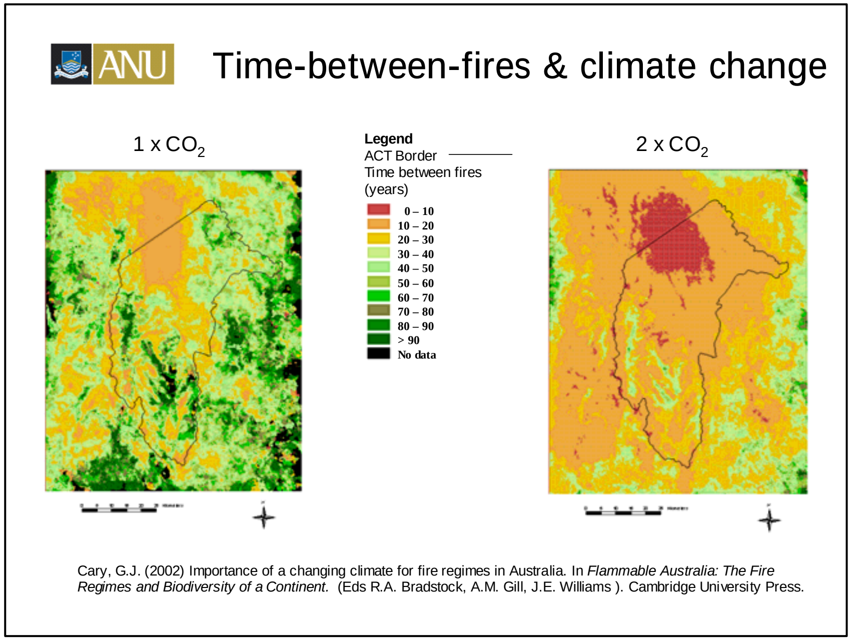
Considerable knowledge gaps in:

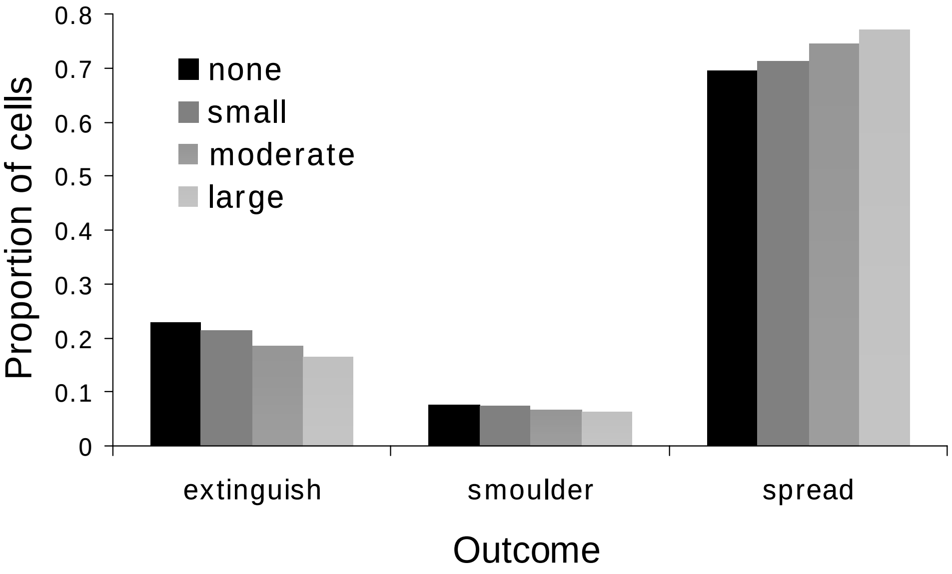
- combustion/emission fraction;
- variation with fire intensity

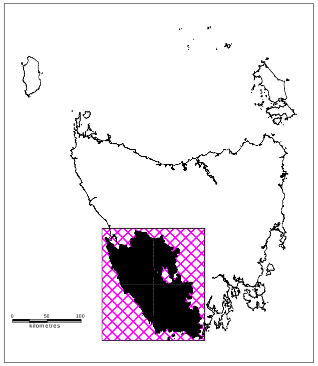
(Rob de Ligt, AGO High-country fire/carbon/climate change project)

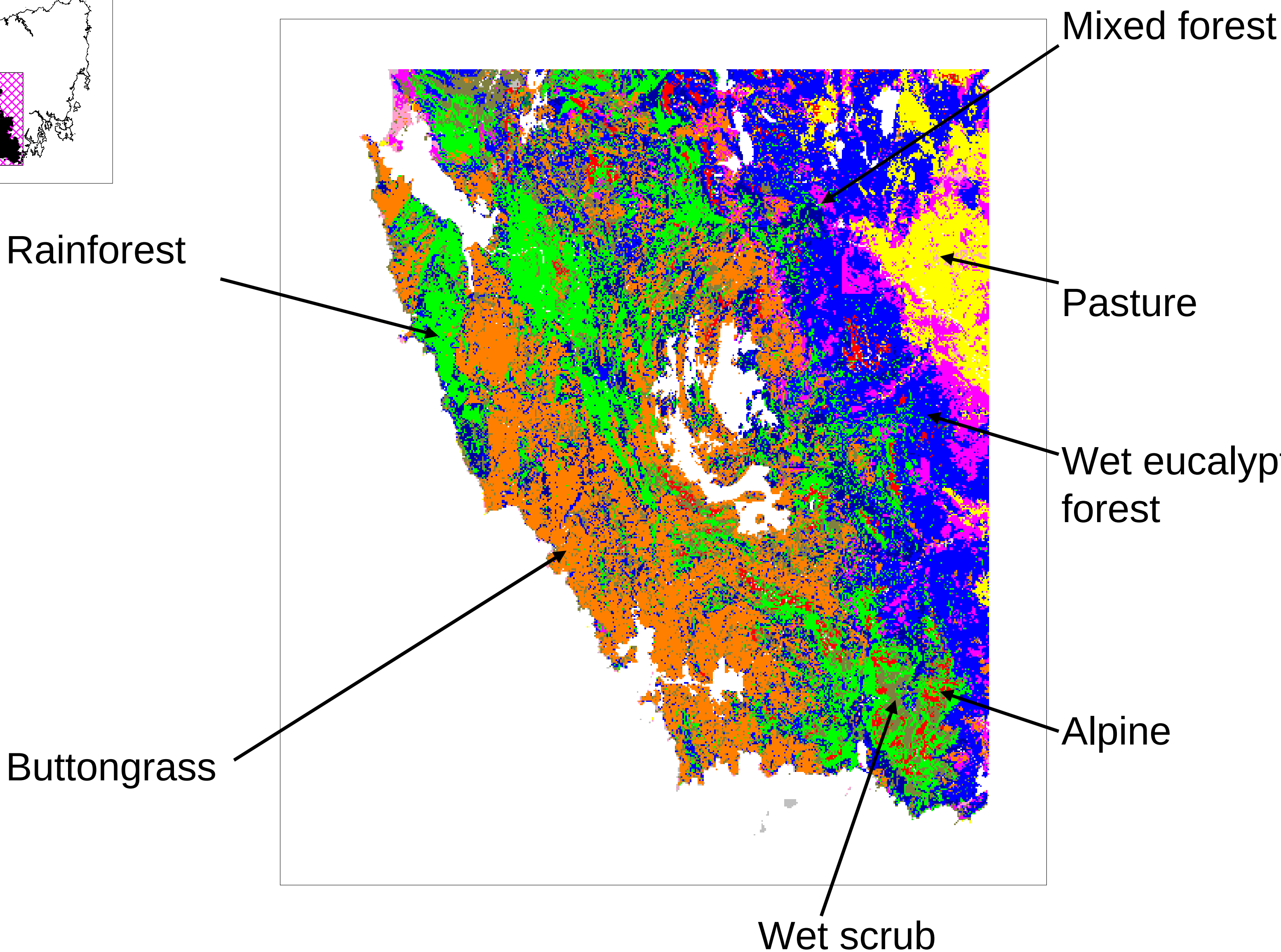
Geoff Cary

Extinguishment



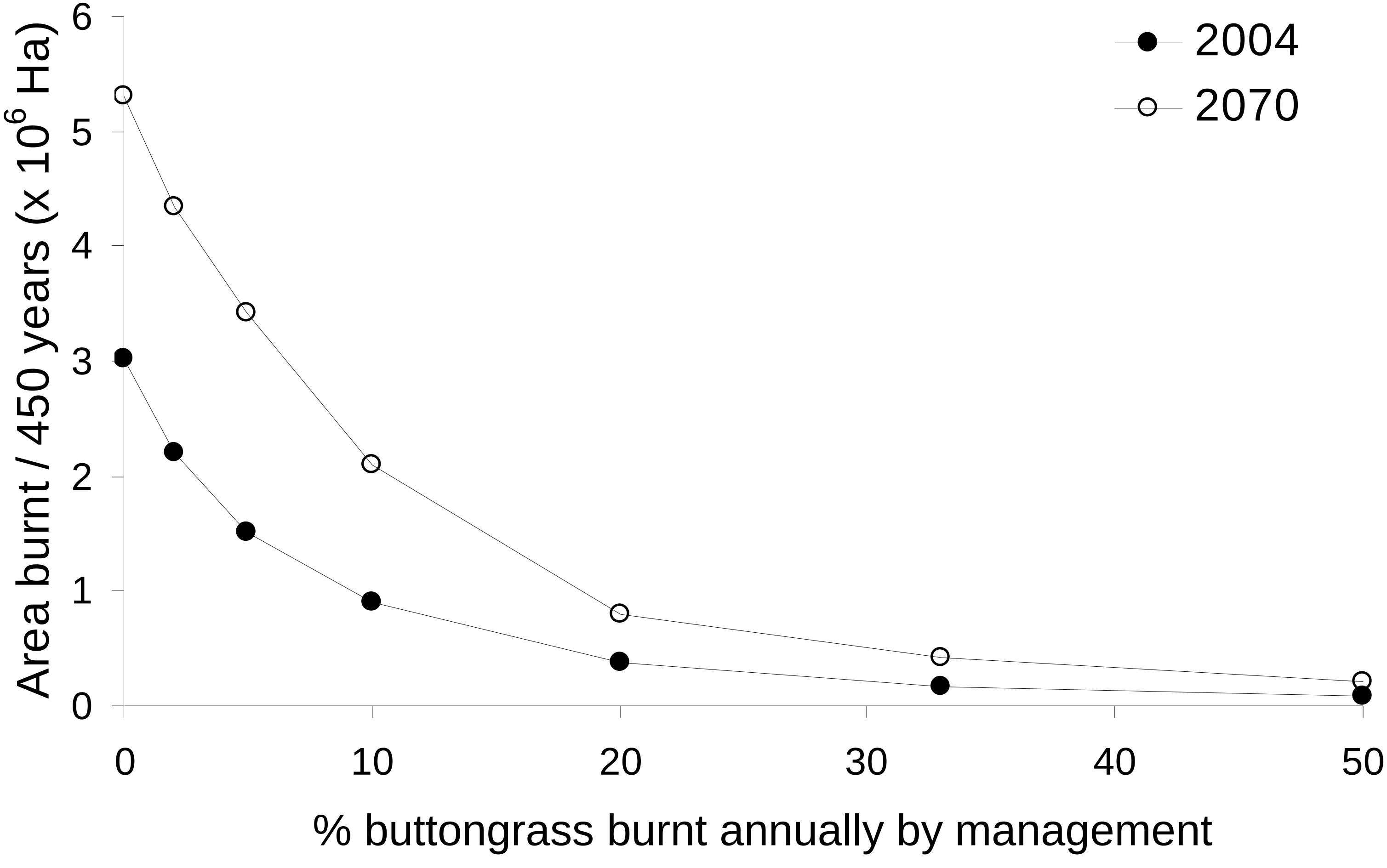






Source: Dr Karen King, Postdoctoral Fellow, Bushfire CRC

Simulation of fire risk



Source: Dr Karen King, Postdoctoral Fellow, Bushfire CRC

Summary

- Approaches to modelling fire regimes include statistical to mechanistic; scales vary from landscape to globe
- Fire Danger and fire frequency likely increase in many places with climate change (and other aspects of global change)
- Consensus amongst independent models for forest systems
- Key issues in Australia include:
  - Modelling lightning and human ignitions
  - Dealing with 1 x CO_2 weather
  - Appropriate algorithms for fire spread
  - Determining combustion and emission fractions
  - Understanding fire extinguishment
  - Representing management
- Fuel addressed by *Fuel Dynamics Workshop*, Shine Dome, 15-16th August, 2007

THE AUSTRALIAN NATIONAL UNIVERSITY

THE AUSTRALIAN NATIONAL UNIVERSITY

The Fenner School of Environment & Society

Changed patterns in fire regimes

Geoff Cary, Karen King, Ian Davies,
Rob de Ligt, Amy Davidson

Model concensus ?

Table 1. Important sources of variation (●) in area burned in five spatial models of fire and vegetation dynamics. Variation in terrain (Terrain), fuel pattern (Fuel), climate (Climate) and weather (Weather) factors, and their interactions, was considered important if they explained more than 0.05 and 0.025 of total variation within a model respectively.

SOURCE OF MODEL VARIATION	EMBYR	FIRESCAPE	LAMOS	LANDSUM	SEM-LAND
Terrain		●			
Fuel	●				
Terrain x Fuel					
Climate		●	●	●	●
Terrain x Climate					
Fuel x Climate					
Terrain x Fuel x Climate					
Weather	●	●		●	●
Terrain x Weather		●			
Fuel x Weather	●				
Terrain x Fuel x Weather					
Climate x Weather	●			●	●
Terrain x Climate x Weather		●			
Fuel x Climate x Weather					
Terrain x Fuel x Climate x Weather					

Cary et al. (2006) Landscape Ecology 21: 121-137; iLeaps Newsletter Issue 4, June 2007