8TH INTERNATIONAL WILDLAND FIRE CONFERENCE
GOVERNANCE PRINCIPLES: Towards an International Framework

NSW Bushfire Risk Management Research Hub

Landscape fire and smoke exposure

A 5-year attempt to estimate the prescribed fire trade-off

(Using Empirical Evidence)

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Understanding Smoke Exposure

Understanding this

And This

And How they Interact

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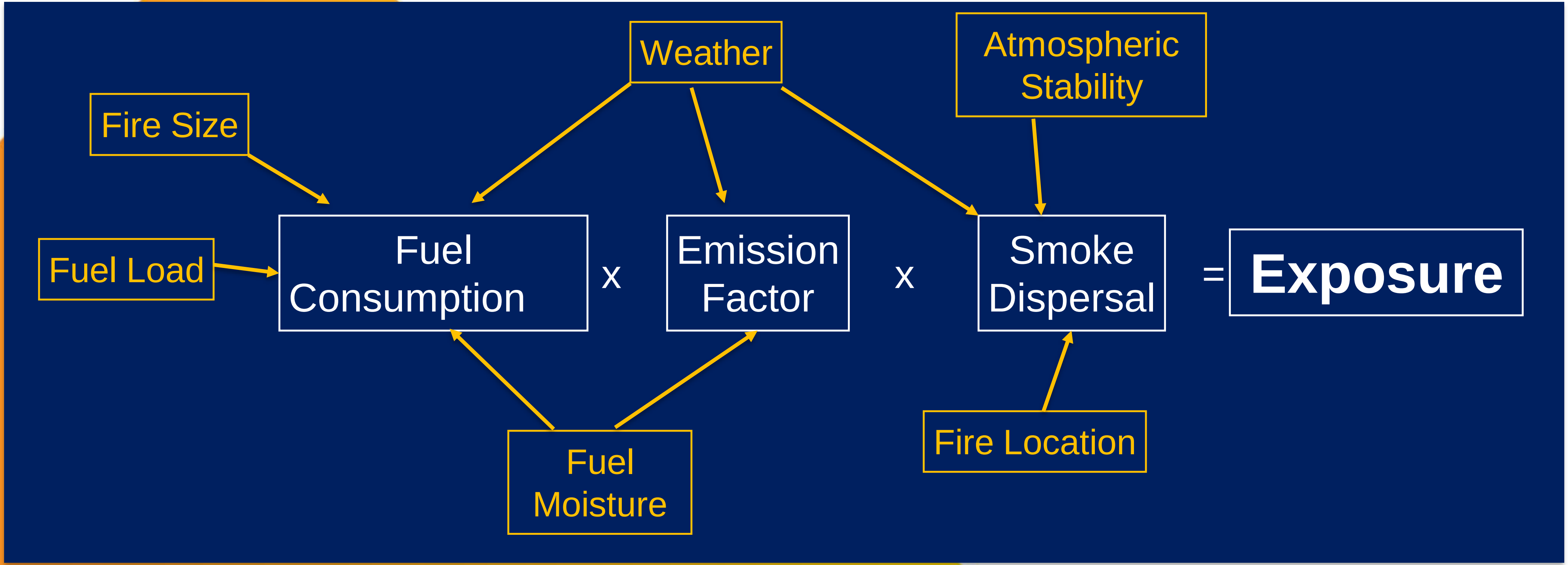
Components of the exposure calculation



- All of these factors differ by Fire Type (Prescribed or Wildfire)
- And we need to consider the cumulative effect of fires (the regime)

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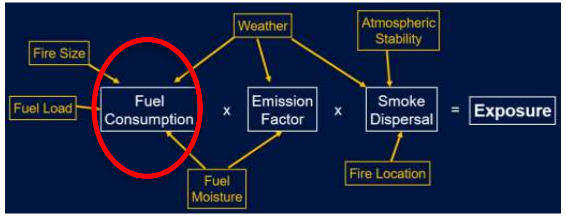
Fuel Consumption



44 sites with pre-and post fire fuel measurements
From 11 Hazard Reduction, 3 Cultural Burns and 6 Wildfires


Forest Ecology and Management

ELSEVIER

Fuel consumption rates in resprouting eucalypt forest during hazard reduction burns, cultural burns and wildfires

Owen H. Price, Rachael H. Nolan, Stephanie A. Samson

ARTICLE INFO

ABSTRACT

Price, O, Nolan, RH, Samson, SA (2022) Fuel Consumption rates in eucalypt forest during hazard reduction burns, cultural burns and wildfires *Forest Ecology and Management* ***505, 119894.***

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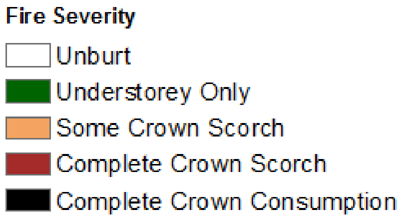
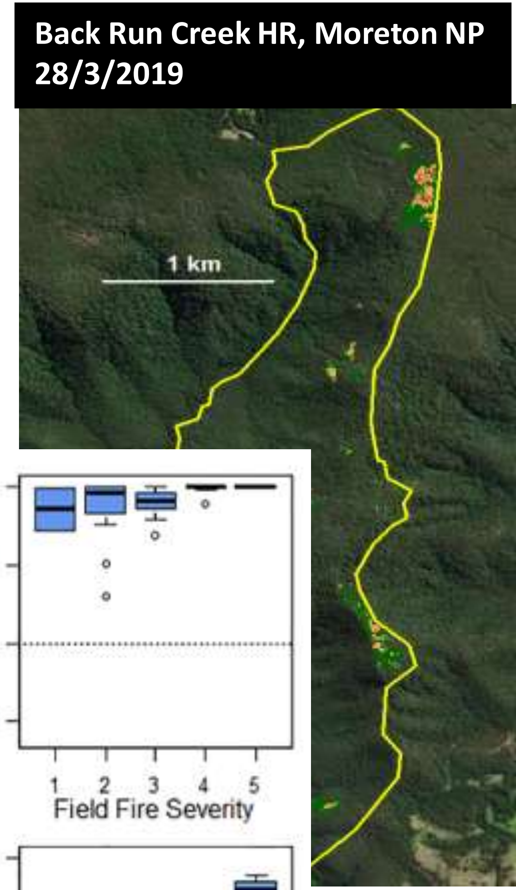
Fuel Consumption results

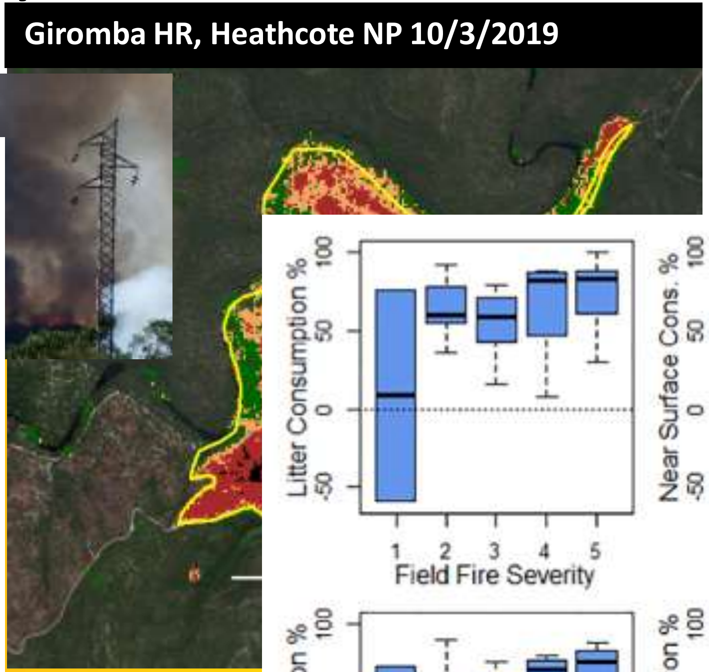
Variation by fire type and severity

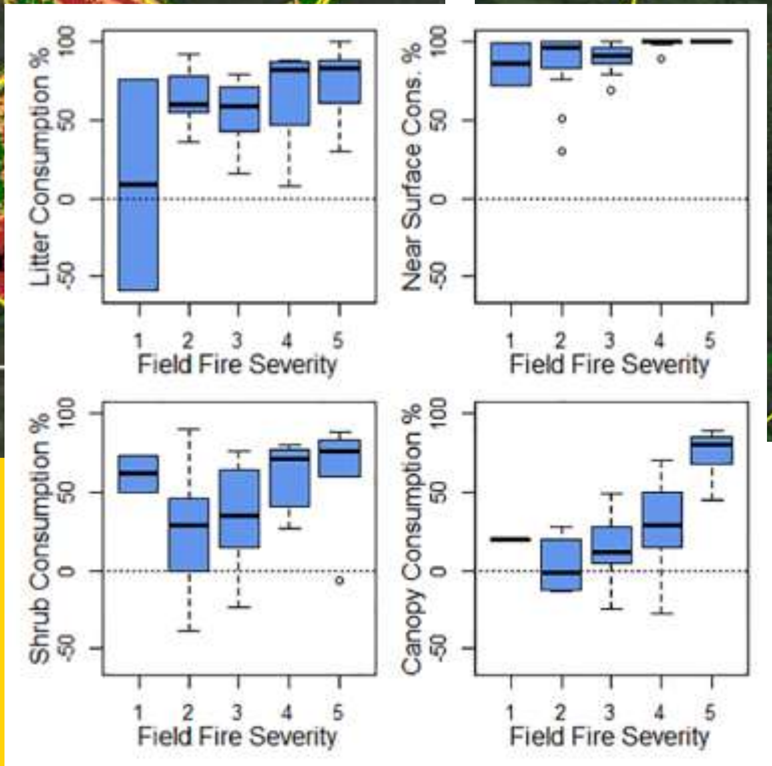
Table 4
Fuel consumption for fire types, broken into each fuel component.

Component	Pre-Fire Mean	s.e.	Median	Consumption Mean	s.e.	Median	% Consumption	Median % Consumption
Cultural Burns	n = 4							
Fine Fuels								
Litter	14.10	3.43	12.46	7.11	4.78	7.17	50.45	57.50
Near Surface	1.81	0.80	1.27	1.79	0.00	1.24	98.55	97.32
Shrub Fuel	0.63	0.23	0.58	0.29	0.11	0.22	46.07	37.99
Canopy Fuel	NA	NA	NA	NA	NA	NA	NA	NA
Total Fine Fuel	16.54	2.91	15.10	8.98	4.12	8.53	54.27	56.48
Course Fuels								
Twigs	2.67	0.58	2.64	0.46	0.65	0.20	17.10	7.57
CWD	4.43	1.23	4.84	1.61	0.48	1.45	36.31	30.04
Shrub Wood	2.67	0.73	3.06	1.24	0.66	1.43	46.35	46.69
Tree Wood	115.13	29.85	101.29	0.00	0.00	0.00	0.00	0.00
Total Biomass	142.07	25.94	120.77	12.57	5.10	12.60	8.85	9.79
Hazard Reduction	n = 29							
Fine Fuels								
Litter	16.05	0.97	15.58	11.70	1.03	11.55	72.94	74.12
Near Surface	2.14	0.20	2.18	1.95	0.20	1.99	90.73	91.30
Shrub Fuel	1.55	0.19	1.48	0.57	0.12	0.42	36.63	28.60
Canopy Fuel	4.32	0.28	4.39	0.65	0.24	0.70	15.14	15.93
Total Fine Fuel	23.76	1.03	22.77	13.75	1.05	13.42	57.84	58.94
Course Fuels								
Twigs	3.38	0.21	3.36	1.64	0.38	1.74	48.61	51.78
CWD	13.56	5.74	5.66	7.31	5.96	1.14	53.91	20.21
Shrub Wood	4.93	0.94	3.33	0.95	0.69	0.05	19.16	1.54
Tree Wood	234.88	23.01	196.99	50.49	18.37	22.40	21.50	11.26
Total Biomass	282.07	23.67	283.93	75.38	18.94	38.23	26.71	13.47
Wildfire	n = 11							
Fine Fuels								
Litter	13.00	1.36	13.85	12.60	1.39	13.10	96.96	94.59
Near Surface	3.00	0.50	2.68	3.00	0.50	2.68	100.00	100.00
Shrub Fuel	0.99	0.25	0.77	0.69	0.24	0.41	69.29	53.72
Canopy Fuel	5.17	0.68	5.41	3.07	1.17	3.68	59.34	67.91
Total Fine Fuel	19.68	2.18	20.14	13.91	2.21	14.40	70.70	71.49
Course Fuels								
Twigs	3.56	0.48	3.69	1.70	0.58	1.03	47.82	27.96
CWD	16.60	6.16	9.51	15.58	6.30	9.51	93.84	100.00
Shrub Wood	3.19	1.27	1.81	−1.37	1.69	−1.20	−43.05	−66.41
Tree Wood	201.61	71.55	190.88	91.42	67.39	78.07	32.46	40.90
Total Biomass	317.06	84.66	223.17	106.56	77.88	102.93	33.61	46.12









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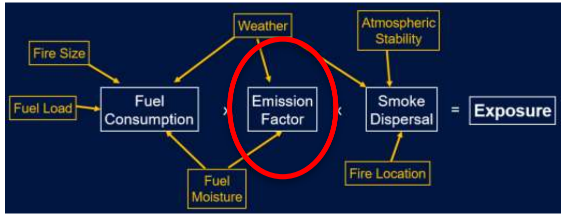
Emission Factors

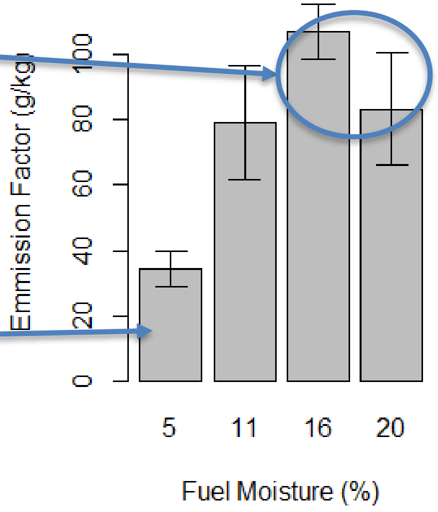


- The amount of Particulates emitted for each kg of fuel consumed
- Reisen et al 2018 found 17 g/kg for flaming but 39 g/kg for smouldering (1)
- Depends on fuel moisture (2)
- Prescribed Burns probably have higher emissions than Wildfire

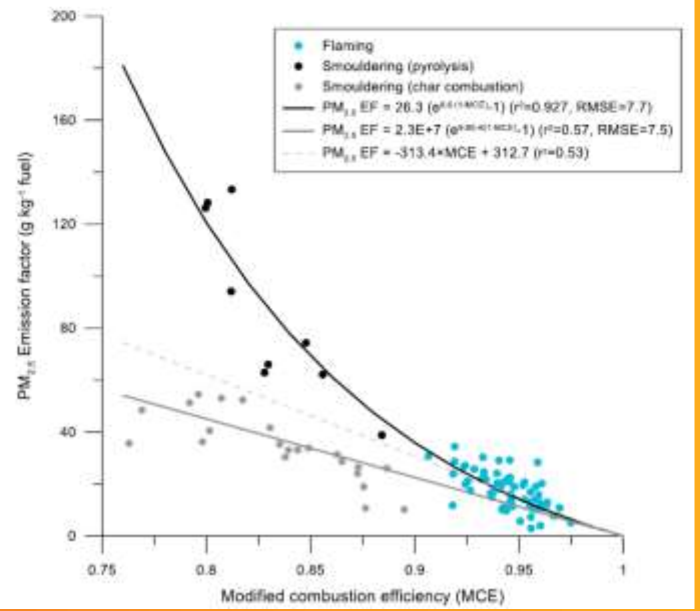
2) Reisen unpub.

Typical of HR

Typical of Bushfire



1) Reisen et al 2018



1) Reisen, F, Meyer, CP, Weston, CJ, Volkova, L (2018) Ground-Based Field Measurements of PM2.5 Emission Factors From Flaming and Smoldering Combustion in Eucalypt Forests. *Journal of Geophysical Research-Atmospheres 123, 8301-8314.*

2) Fabienne Reisen's experiment: emissions v moisture content

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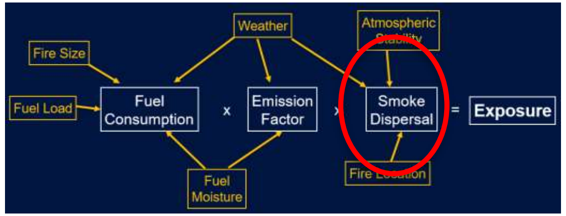
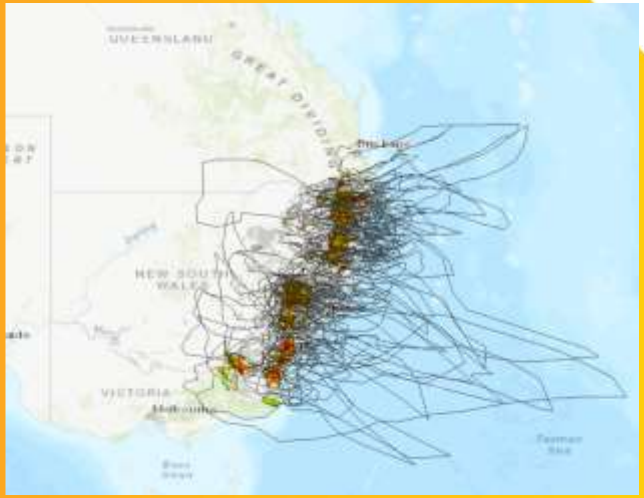
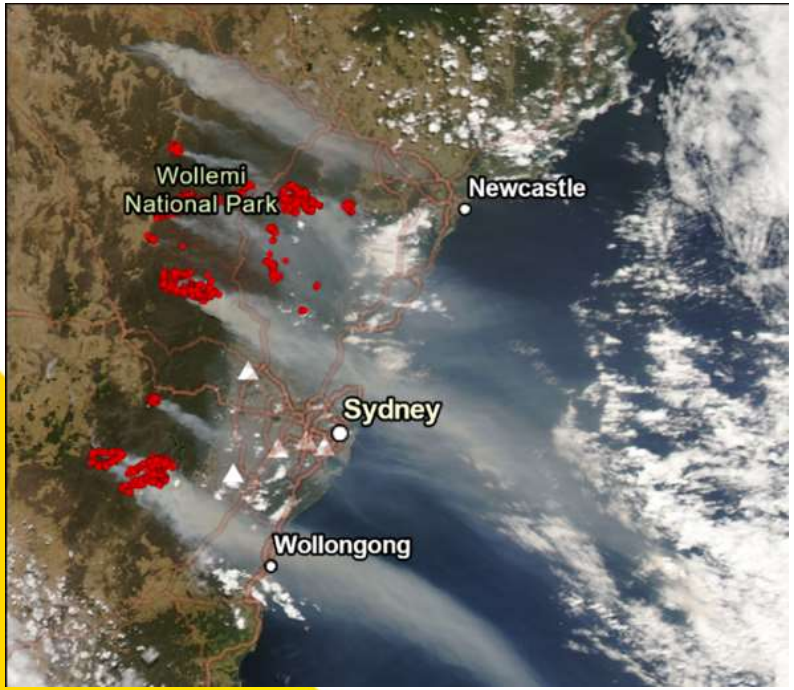
Smoke Dispersal



Three different studies:

1. Low cost monitors near fires
2. Historical analysis of smoke plumes from satellites
3. Historical analysis of fires and AQ network





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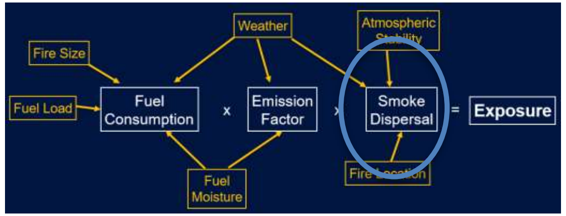
1) Low-cost Monitors



- 18 Prescribed Burns, including 3 cultural
- Up to 12 low-cost $PM_{2.5}$ monitors at each, including mobile ones
- Hourly summary data

atmosphere
MDPI
Article

Smoke Patterns around Prescribed Fires in Australian Eucalypt Forests, as Measured by Low-Cost Particulate Monitors

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Abstract: Prescribed burns produce smoke pollution, but little is known about the spatial and temporal pattern because smoke plumes are usually small and poorly captured by State air-quality networks. Here, we sampled smoke around 18 forested prescribed burns in the Sydney region of eastern Australia using up to 11 Nova SDS011 particulate sensors and developed a Generalised Linear Mixed Model to predict hourly $PM_{2.5}$ concentrations as a function of distance, fire size and weather conditions. During the day of the burn, $PM_{2.5}$ tended to show hourly exceedances (indicating poor air quality) up to ~2 km from the fire but only in the downwind direction. In the evening, this zone expanded to up to 5 km and included upwind areas. $PM_{2.5}$ concentrations were higher in still, cool weather and with an unstable atmosphere. $PM_{2.5}$ concentrations were also higher in larger fires. The statistical model confirmed these results, identifying the effects of distance, period of the day, wind angle, fire size, temperature and C-Haines (atmospheric instability). The model correctly identified 78% of hourly exceedance and 72% of non-exceedance values in retained test data. Applying the statistical model predicts that prescribed burns of 1000 ha can be expected to cause air quality exceedances over an area of ~3500 ha. Cool weather that reduces the risk of fire escape, has the highest potential for polluting nearby communities, and fires that burn into the night are particularly bad.

Keywords: smoke plume; smoke exposure; $PM_{2.5}$; smoke dispersion; air quality; air pollution; prescribed burn

check for updates

Citation: Price, O.F.; Forehead, H. Smoke Patterns around Prescribed Fires in Australian Eucalypt Forests, as Measured by Low-Cost Particulate Monitors. Atmosphere 2021, 12, 1389. https://doi.org/10.3390/atmos12111389

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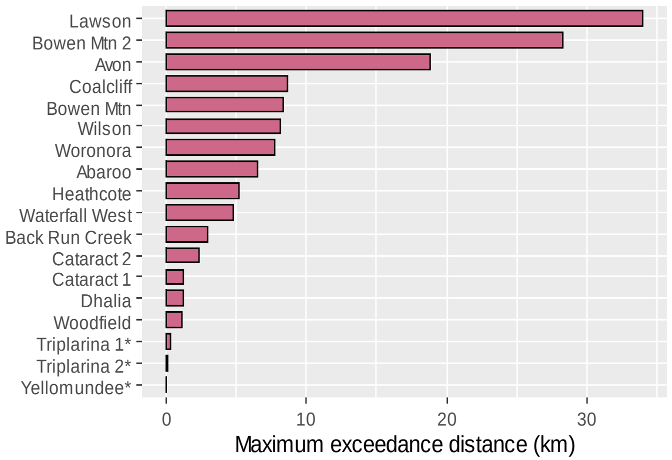
1. Introduction

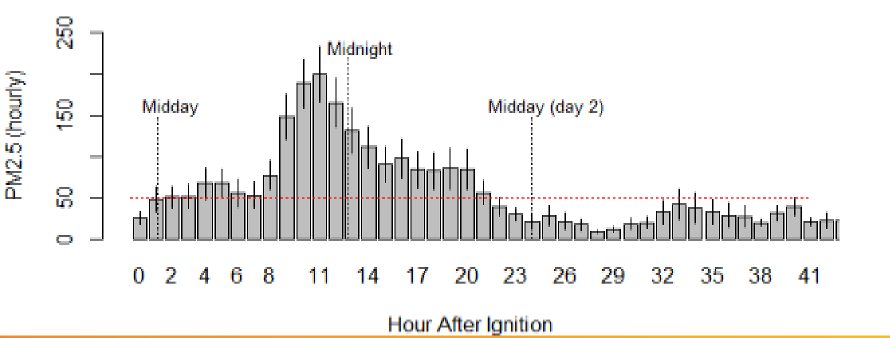
1) Low cost monitor Results

- Evening smoke is much worse than daytime
- Some fires much worse than others due to:
    - Fire Area
    - Wind Speed
    - Mixing Height

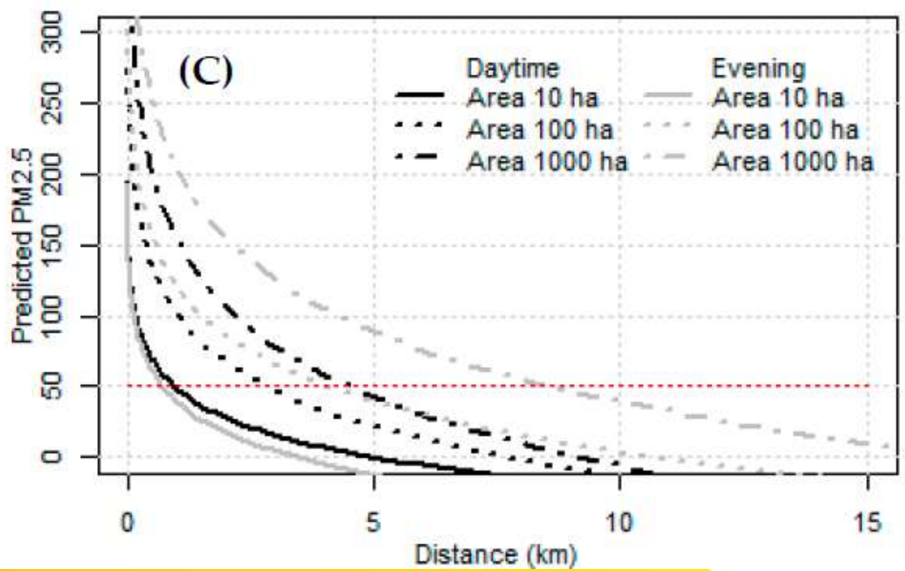
Particulate Spread v Fire



Time of Day



Statistical Model



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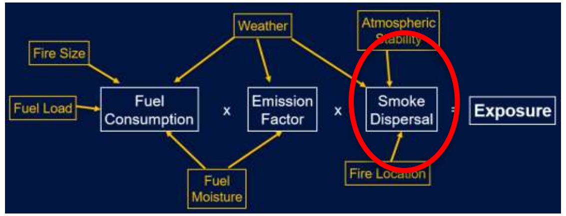
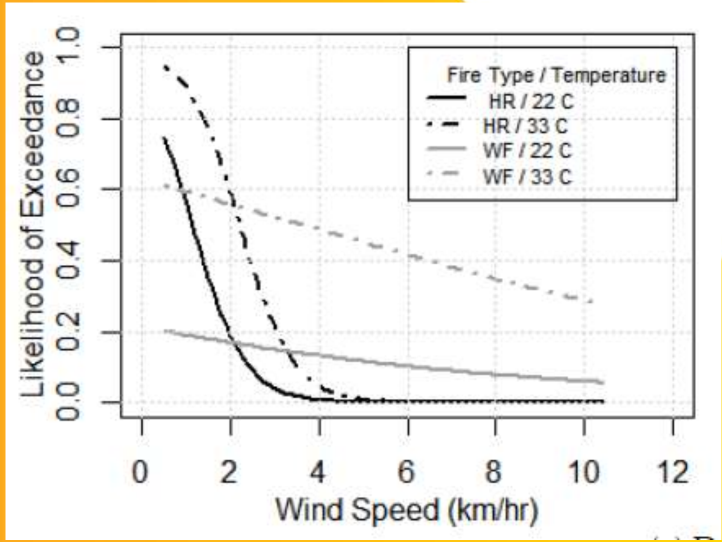
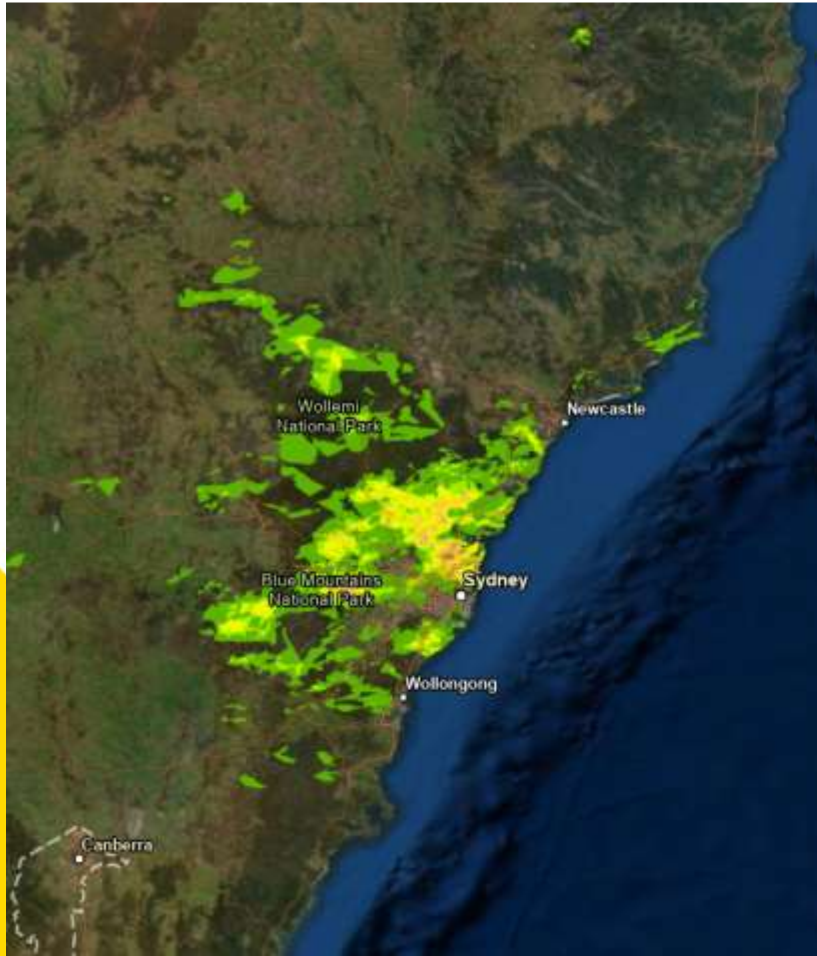
2) Smoke Plumes from satellites



- Digitised 1237 Plumes from 2003 -2020
- Wildfire Plumes focussed on Mountains, PB more on City
- 18% of WF plumes and 4% of PB Plumes went over an AQ Station
- 33% of PB plumes and 48% of WF caused $PM_{2.5}$ > 25 μgm^{-3}
- So most plumes stayed aloft

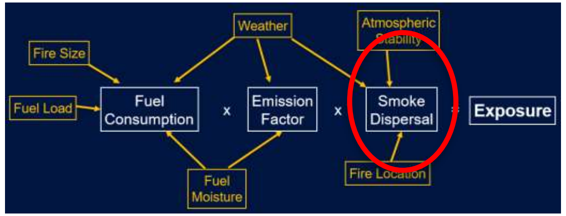

fire
MDPI
Article
Particulate Levels Underneath Landscape Fire Smoke Plumes in the Sydney Region of Australia





- Price, OF, Rahmani, S, Samson, S (2023) Particulate levels underneath landscape fire smoke plumes in the Sydney region of Australia. *Fire 86.*

3) Historical analysis of fires and AQ monitors



a) Model for Individual Fires
b) Model for Sydney Basin Prescribed Burns
c) Model for Prescribed v Wildfire Trade-off

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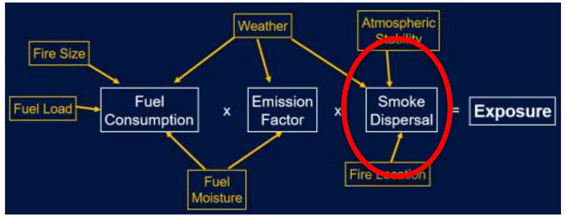
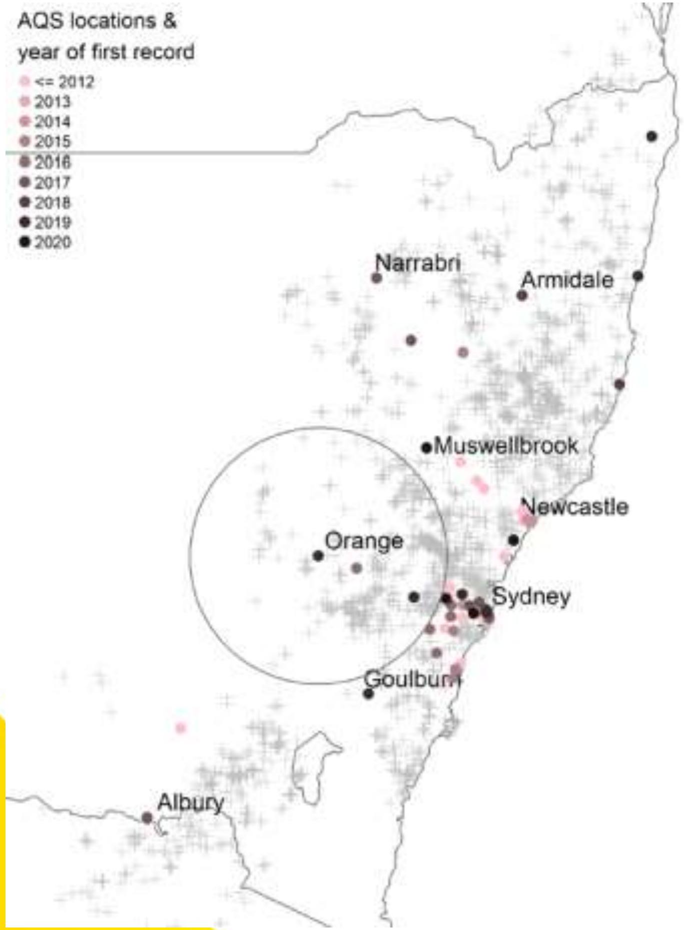
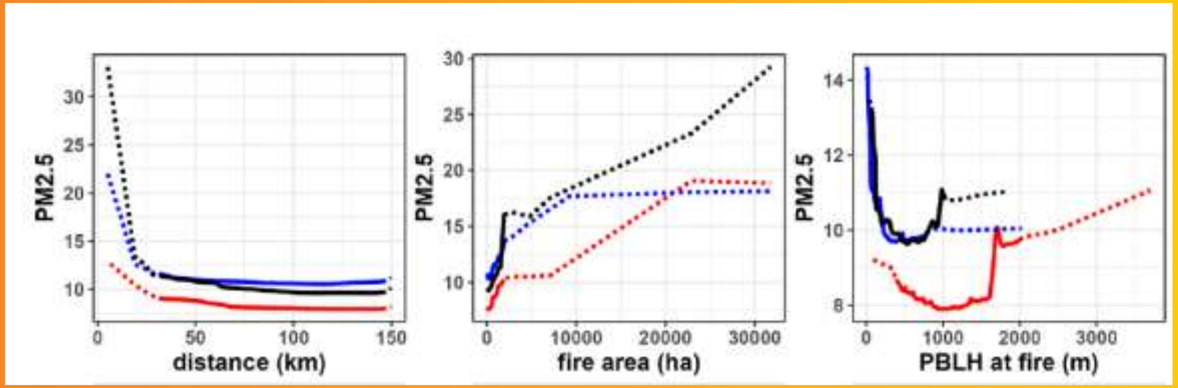
3a) Model for Individual Fires



- The ‘needle-in-a-haystack’ model
- 1400 days when only 1 fire was burning (PB or WF)
- Dependent = $PM_{2.5}$ at an AQ Station
- Predictors = Distance, fire size, weather
- Distance, Fire Area and Planetary Boundary Layer were the most important
- No real difference between WF and PB





- Storey, MA, Price, OF (2022) Statistical modelling of air quality impacts from 1500 individual forest fires in NSW, Australia. *Natural Hazards and Earth System Sciences* ***22, 4039-4062.***

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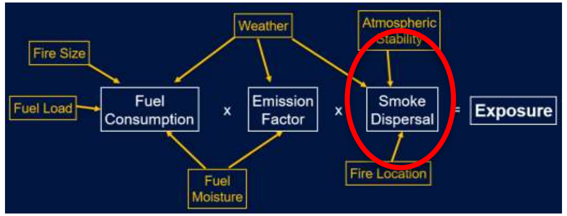
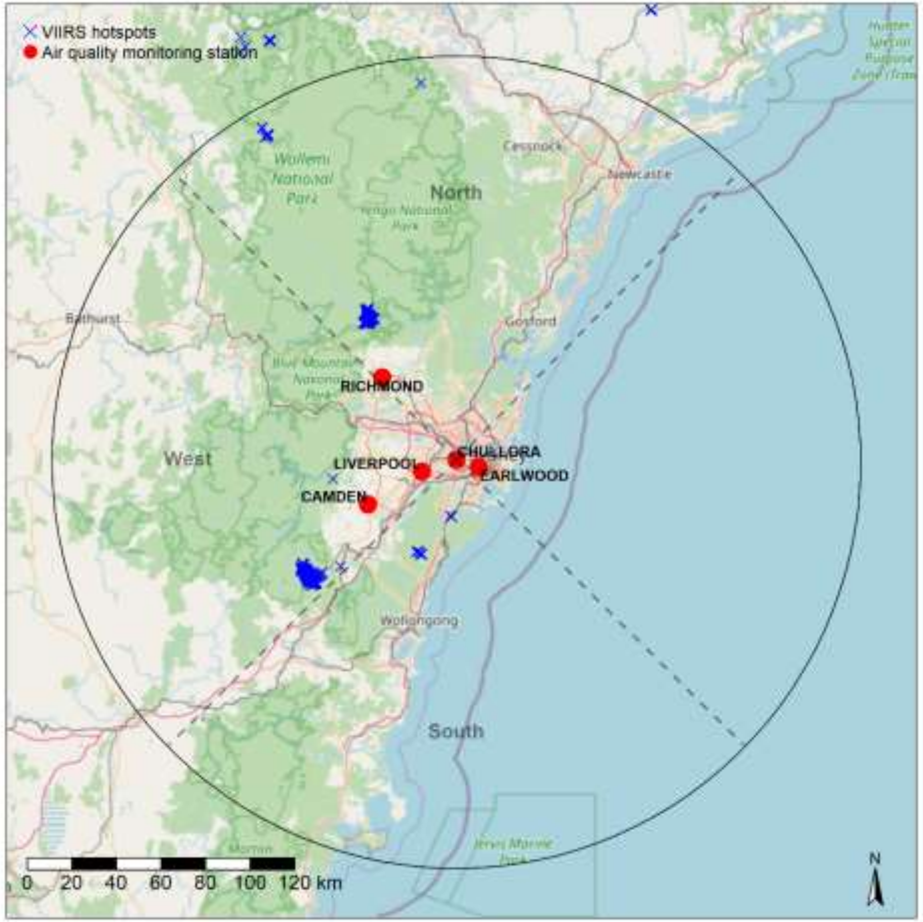
3b) Model for whole Sydney-Basin Prescribed Burns



- Daily $PM_{2.5}$ v area burned around Sydney for 2012-2020
- Prescribed Burn area in 3 zones from VIIRS hotspots
- $PM_{2.5}$ mean and max in 5 Sydney monitors
- Atmospheric data from ERA5
- Bayesian 'GAM' model with n = 597 active days



- Storey, MA, Price, OF (2022) Prediction of air quality in Sydney, Australia as a function of forest fire load and weather using Bayesian statistics. *PLOS One* ***17, e0272774.***

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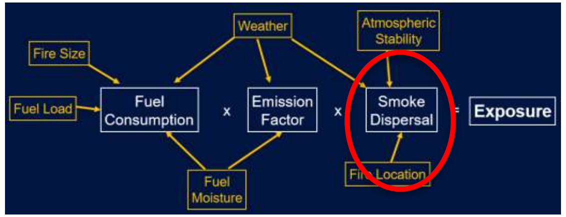
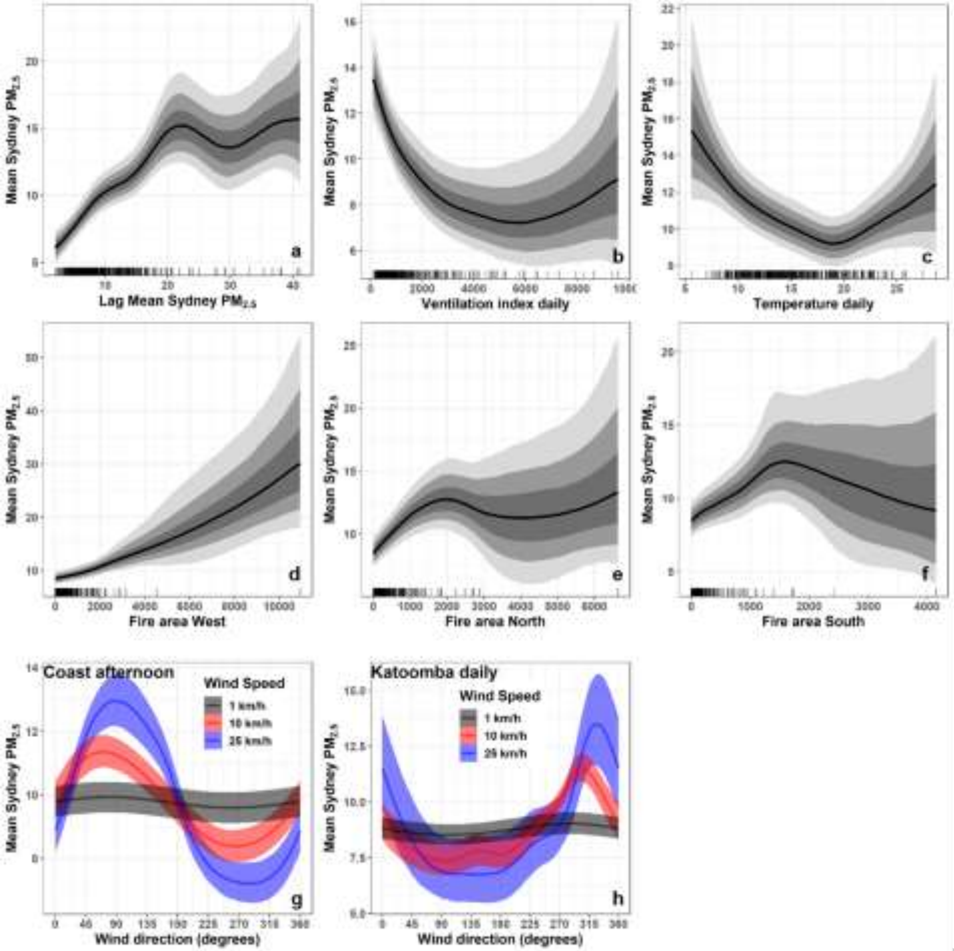
3b) Basin analysis Results



Model with $R^2 = 0.59$ and effects of:

- Yesterday's $PM_{2.5}$
- Ventilation Index
- Temperature
- Winds in the mountains and coast
- Area burnt (mostly to west)



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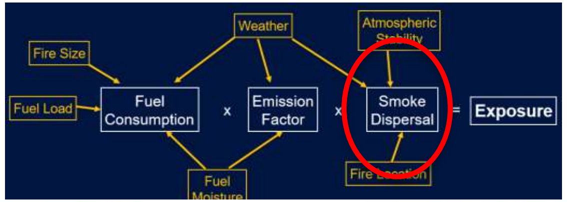
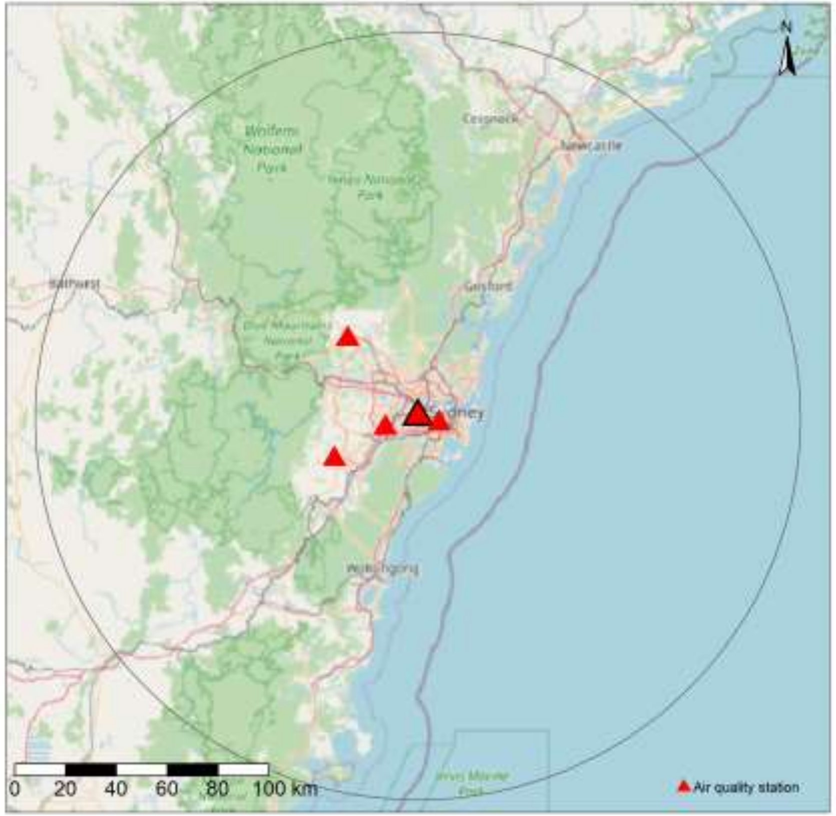
3c) Model for WF v PB Trade-off



- Total daily burnt area in 150 km radius (n=900)
- Dependent = Daily $PM_{2.5}$ in Sydney for days with fire
- Predictors = Fire Type*Area + Weather
- Used model to predict what would happen if PB increased



- Storey, MA, Price, OF (in review) Comparing the effects of wildfire and hazard reduction burning area on air quality in Sydney. *Environmental Pollution*

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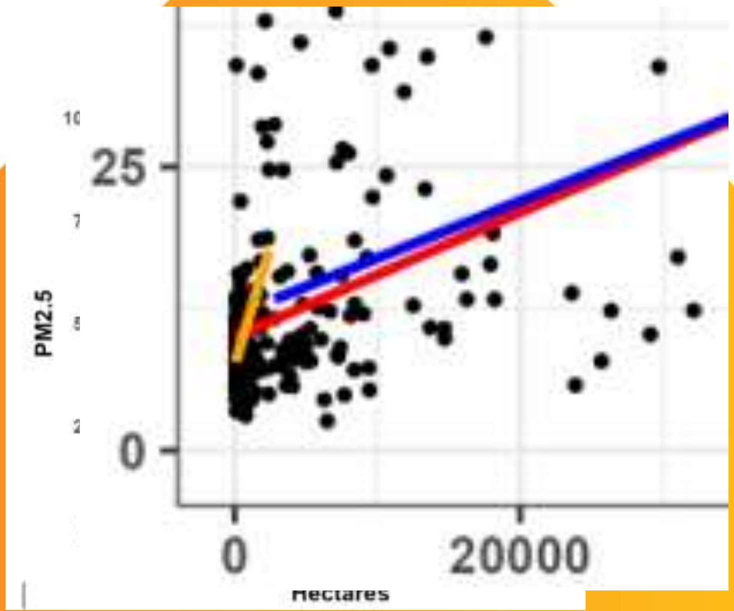
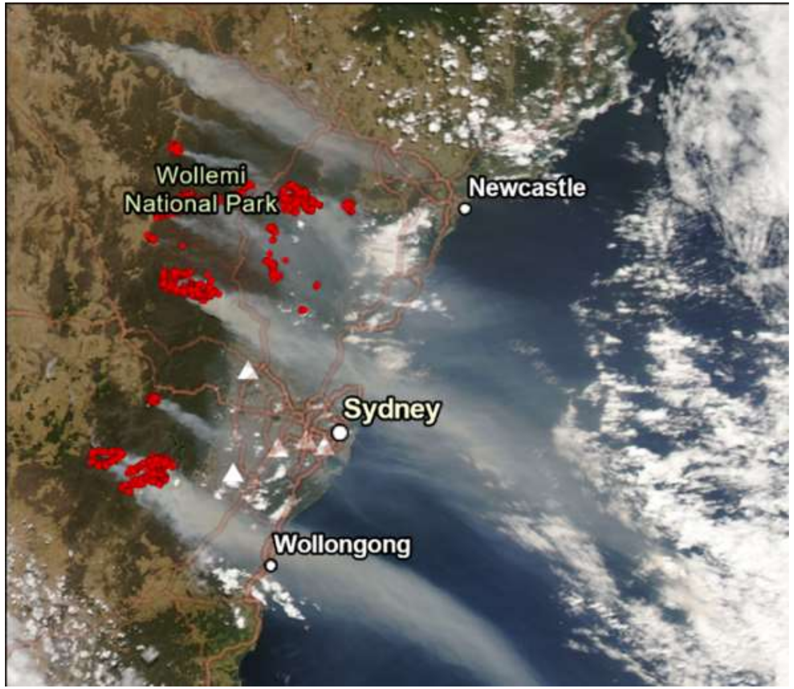
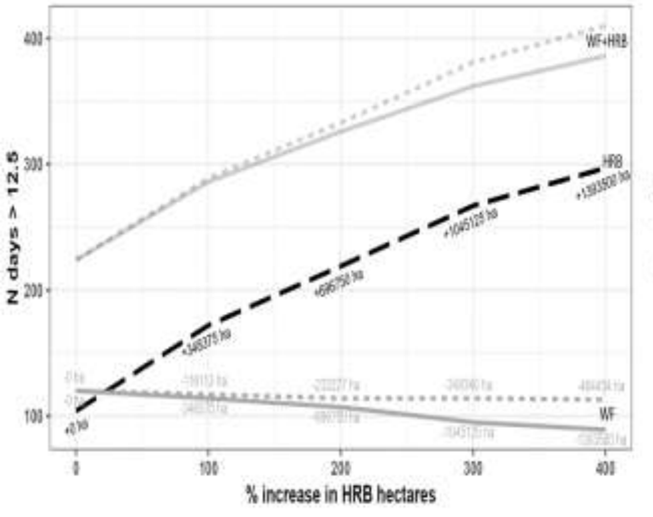
3c) Trade-off results



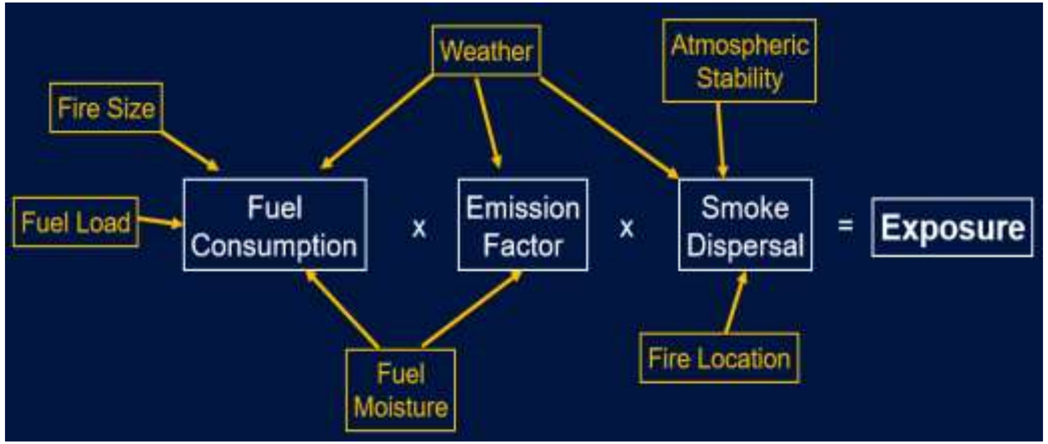




1. Non-linear effect of fire area on PM2.5
2. No fire-type effect
3. But overall PBs increase exposure
4. Probably because WF loft smoke higher and further away

5. Similar result to
Borchers-Arriagada, et al (2021) Smoke health costs change the calculus for wildfires fuel management. *The Lancet Planetary Health* ***5, E608-E619.***

Summary



	Components of Exposure				
	Smoke production		PM transport		PM observed
Determinants	Total fuel consumption	PM emission factors	Proportion of smoke transported near surface	Likelihood of transport over receiver	Surface PM concentration at receiver
Fire intensity	+	-	-	.	?
Fire area	+	.	-	.	+
Distance from fire	.	.	.	-	-
Fuel dryness	+	-	-	.	?
Wind speed	+	-	+-	+	+-
Instability	+	?	-	+	?

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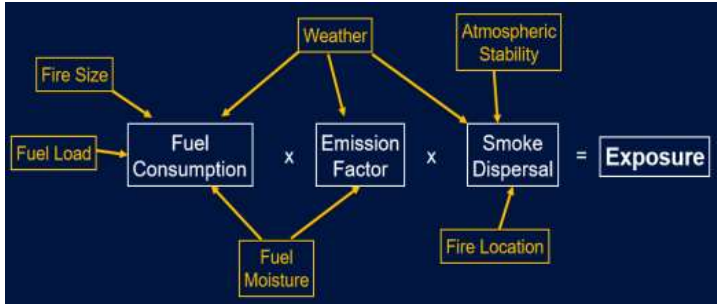
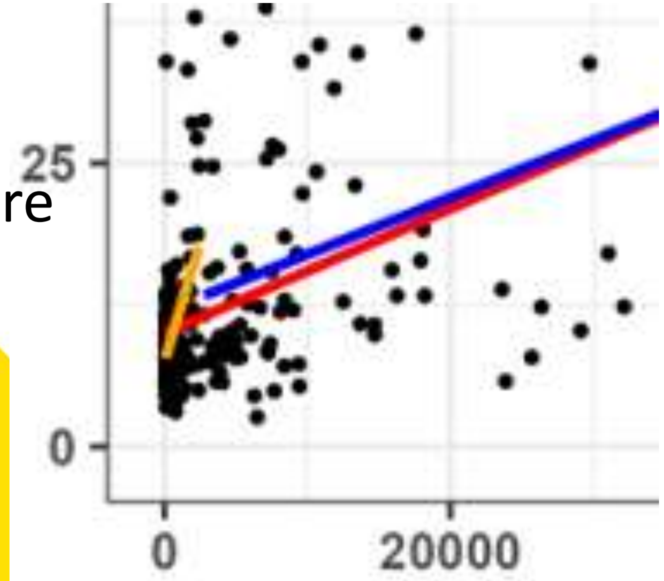
Conclusions

- Prescribed Burns make smoke worse
- Still air or sea breeze days are particularly bad
- We should be able to avoid some of the bad conditions
- We can probably improve predictions for local residents
- There is probably benefit in burning larger areas



Knowledge Gaps

- Gather more evidence that larger Prescribed Burns are better
- What burn windows are still available for managers?
- Exposure in rural areas
- Better emission factors (from within the plumes)
- The smoke ageing process



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