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ECONOMIC EVALUATION OF BUSHFIRE RISK MITIGATION POLICIES IN AUSTRALIA

Tyron J. Venn and John Quiggin

The University of Montana and The University of Queensland

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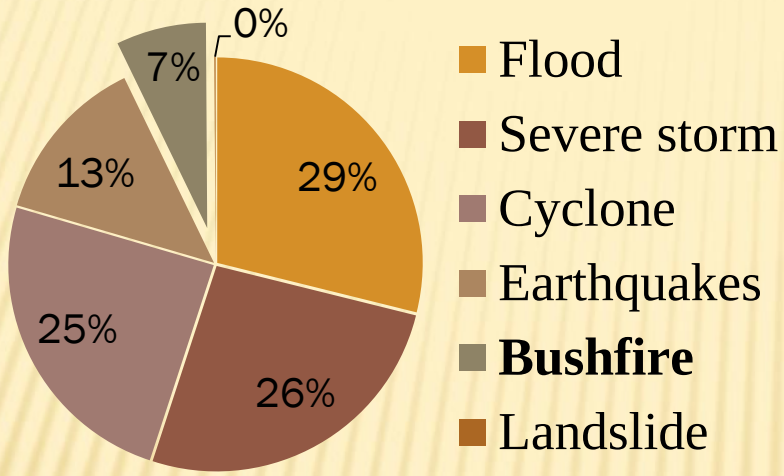
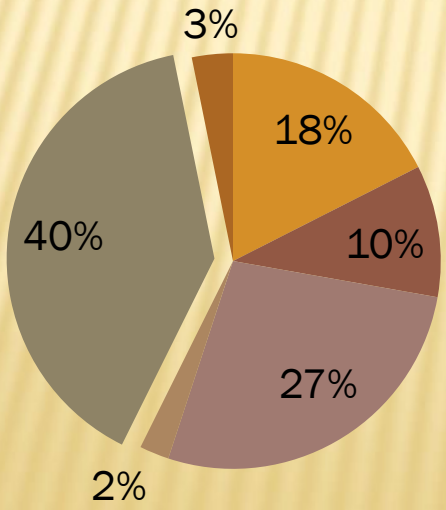
INTRODUCTION

Percent of Australian natural disaster costs



Percent of Australia natural disaster deaths

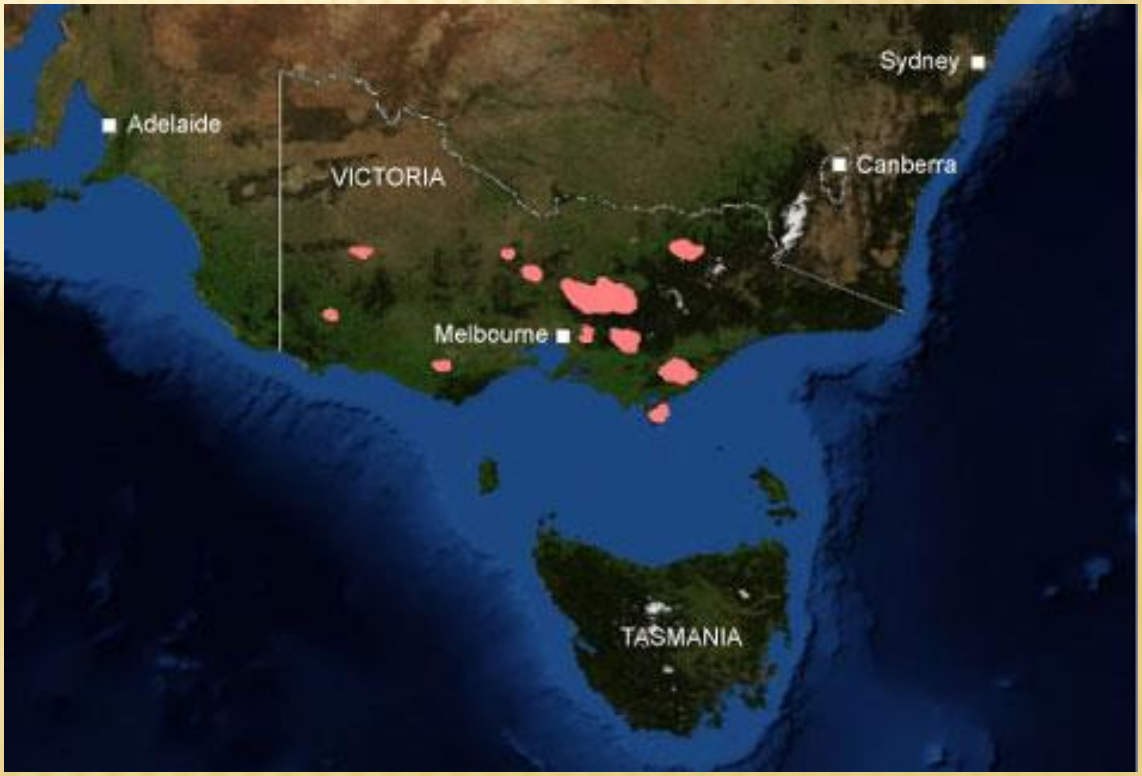


- Since 1900, 724 bush-fire deaths and >11,000 homes destroyed
- Six extreme events account for 60% of losses
- Growing WUI
- Climate change

BLACK SATURDAY, 7 FEBRUARY 2009

- Worst fire danger day in Victoria's history
- Melbourne 46.4 C (115.5 F)

- >400 fires
- 173 lives
- 2298 houses
- 440,000 ha



AD-HOC GOVERNMENT RESPONSE

- *Another* Royal Commission
- Repackaging of Australian bushfire policy
- A$380 M investment over 4 years in prescribed fire in Victoria
- No evaluation of expected return on investment

- Is landscape-scale prescribed fire economically efficient?
- Could an evacuation policy be more economically efficient?

RISK MITIGATION OPTIONS

- Landscape-scale prescribed fire and mechanical fuel treatments
- Home ignition zone (HIZ) vegetation treatments and structure modifications
- Evacuation
- Stay and defend

AUSTRALIAN BUSHFIRE POLICY

State government land management agencies have their own policies regarding prescribed fire, presently 0.5% to 1.5% of public forestlands per annum in southeastern Australia

Prepare. Act. Survive.

- Homeowners encouraged to perform HIZ treatments according to individual needs and the level of home protection desired
- Residents decide whether they will prepare to stay and defend their homes or leave early

- Australian policy contradicts evacuation-focused policy in USA and Canada

EVIDENCE IN FAVOUR OF EVACUATION?

- Australian fatality rates
  - **1 per 21** homes destroyed historically (Crompton *et al.* 2010)
  - **1 per 13** homes for the 2009 Black Saturday bushfires (Parliament of Victoria 2010)
- USA fatality rates
  - **1 per 40** homes destroyed historically (Thomas and Butry 2012)
  - **1 per 320** homes in the October 2007 Southern California fires where over 300,000 people were evacuated (Keeley *et al.* 2009; McCaffrey and Rhodes 2009)

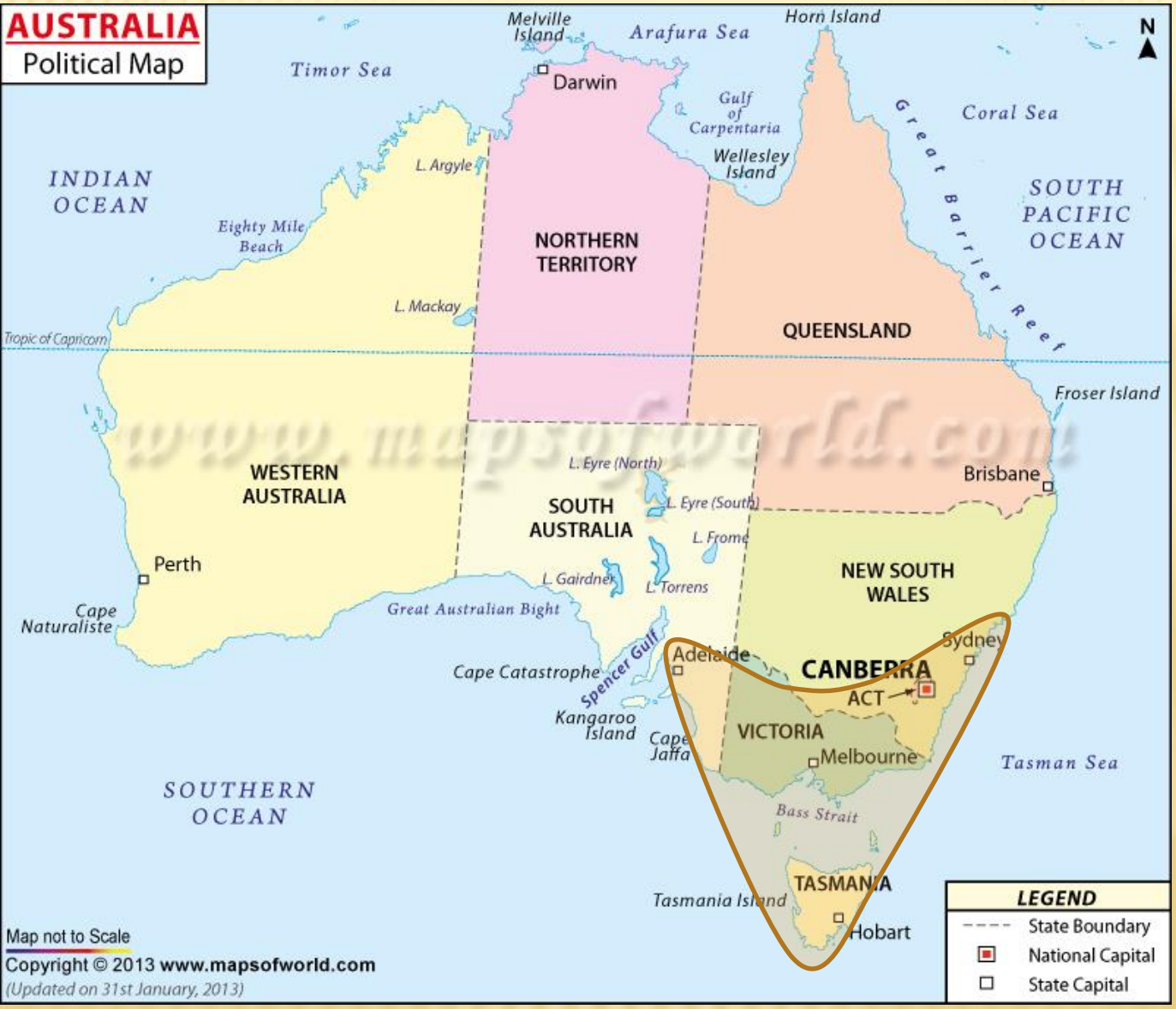
RESEARCH OBJECTIVES

- Support development of bushfire policy by economically evaluating three broad policies for existing at-risk communities:

1) **Expanded landscape-scale prescribed fire program**
2) **Home Ignition Zone (HIZ) treatments**
3) **Early evacuation on extreme fire danger days (FFDI ≥75) when a bushfire is burning**

- Focus on houses and lives
- Evaluations are relative to the status quo

STUDY AREA: BUSHFIRE-PRONE SOUTHEAST



20 M ha of eucalypt forests and woodlands in study area

≈ 60% national population

METHOD

- Aspatial benefit-cost analysis using:
  - Normalized historic probabilities of life and house loss
  - Economic values of lives and homes
  - Effectiveness estimates for each policy
  - Cost of each policy
  - Population-weighted return interval for extreme fire weather
- Estimate the **expected net annual benefits** of the three policies relative to the status quo

NORMALISED PROBABILITIES

- ≈90% of house losses are within 100 m of bushland
  - 550,000 homes (McAneney et al. 2009)
  - 1.43 M people

- Normalized annual rate of home loss and death:
  - 301 homes (1 in 1800)
  - 14 civilian deaths (1 in 102,000)

  (Crompton et al. 2010)

ECONOMIC VALUE OF LIFE AND PROPERTY

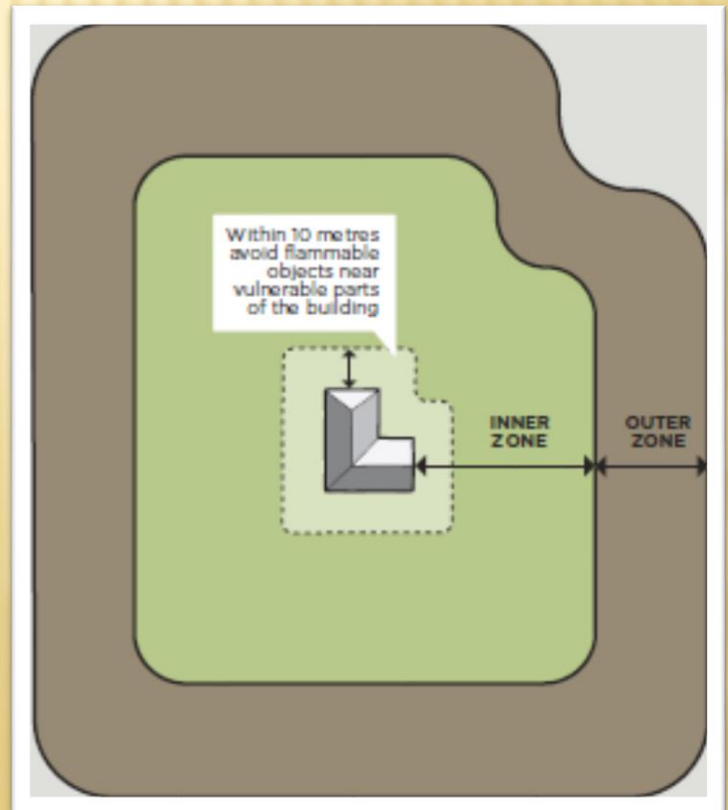
- Value of a statistical life: $7.1 M
  - (Access Economics 2008, adjusted to 2012 dollars with the Australian consumer price index).
- Value of structure and contents: $0.26 M
  - (Bureau of Transport Economics 2001; ABS 2011, 2013)

LANDSCAPE-SCALE PRESCRIBED FIRE

- Halve bushfire risk will require 5% to 15% (1 to 3 M ha per annum)
- We assume 10% (2 M ha) per annum @ $235/ha
- Current: 0.2 M ha

HIZ: STRUCTURAL MODS AND VEGETATION TREATMENTS

- Expensive and limited published evidence of effectiveness
- Best structural modification reduced home ignition probability by 14% (Stockmann et al. 2010)
- Black Saturday: reduce bushland within HIZ from 30% to 0% reduced probability of home loss by 15%. (Gibbons et al. 2012)



HIZ: BUSHFIRE DEFENSE SPRINKLER SYSTEMS

- Limited published evidence on effectiveness
- Structure fire sprinklers 40% to 64% effective
- Cost: A$13,000
  - Sprinkler system, fire-proof 30,000 l tank and pump

EARLY EVACUATION WHEN BUSHFIRES ARE BURNING ON EXTREME FIRE DANGER DAYS

Category	Forest Fire Danger Index
Catastrophic (Code Red)	100 +
Extreme	75 – 99
Severe	50 – 74
Very high	25 - 49
High	12 – 24
Low to moderate	0 - 11

- Clear, unambiguous trigger:
  - Residents within 100 m of bushland evacuate when a fire is burning on a day when FFDI is forecast ≥ 75
- 17 fires 1957-2009, FFDI ≥ 75: 78% of house loss and 79% of deaths
- Advice FFDI ≥ 75 (ACT Emergency Services 2009, p. 2):
  - *Thousands of embers will be violently blown into and around homes causing other fires to start rapidly and spread quickly up to 20 km ahead of the main fire.*
  - *People in the path of the fire will almost certainly die*

EARLY EVACUATION WHEN BUSHFIRES ARE BURNING ON EXTREME FIRE DANGER DAYS

Category	Forest Fire Danger Index
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Extreme	75 – 99
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Very high	25 - 49
High	12 – 24
Low to moderate	0 - 11

- FFDI ≥ 75 has a population-weighted mean return interval of 5.6 years (i.e. 9 days every 50 years) (Lucas 2007)
- Given that:
  - Annual normalized expected loss is 301 homes
  - 78% of all home losses are on days when FFDI ≥ 75
  - Historic level of home loss within bushfire perimeter is 30%
- And assuming that an evacuation zone 10 times the area encompassed by the final bushfire perimeter is declared
- Then, **7830 homes evacuate annually** (1.4% homes ≤ 100m)
- Equivalent to mean evacuation return interval of 70 years
- Assume 2-day evacuation @ cost of $500/household

EVACUATION: EFFECTIVENESS AT SAVING LIVES

- Fatalities 1900 to 2008
  - 32% late evacuation
  - 46% did not evacuate

(Haynes et al. 2010)

Black Saturday (Handmer et al. 2010, Whittaker et al. 2013)

Survival strategy	Proportion of all deaths (%)	Rate of death among those choosing this survival strategy (%)
Late evacuation	17	1.2
Did not evacuate	77	2.3

- Extrapolation suggests reduced fatalities had everyone evacuated
- USA experiences approximately half the rate of fatalities per home destroyed
- We assume early evacuation can **halve the number of bushfire fatalities**

EVACUATION: EFFECTIVENESS AT SAVING HOMES

- About 50% of homes were defended during Black Saturday
- A defended home was twice as likely to survive
- Assume early evacuation policy will increase home loss by 50%

BENEFITS AND COSTS OF RISK MITIGATION

- $E(NB_i) = \left[\sum_{j=1}^{N} p_j \, e_{ij}\left(A_j V_j\right)\right] - C_i$
- Status quo bushfire risk

Asset at risk (j)	V_j ($M)	A_j	p_j
Lives	7.10	1,430,000	1 in 102,000
Homes	0.26	550,000	1 in 1800

- Effectiveness of bushfire risk mitigation

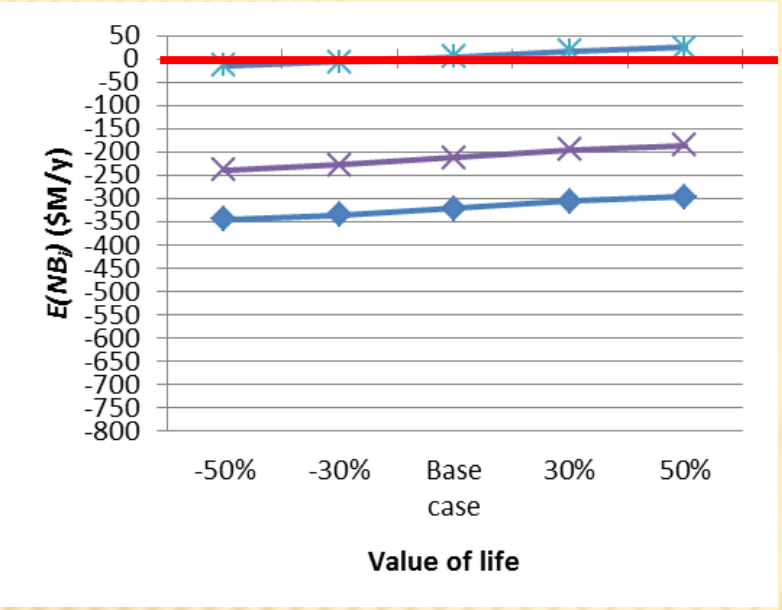
Bushfire risk mitigation policy (i)	e_{ij}		C_i ($ M/y)
	Lives	Homes	
Prescribed fire	0.50	0.50	423
Sprinklers	0.54	0.54	322
Early evacuation	0.40	-0.40	4

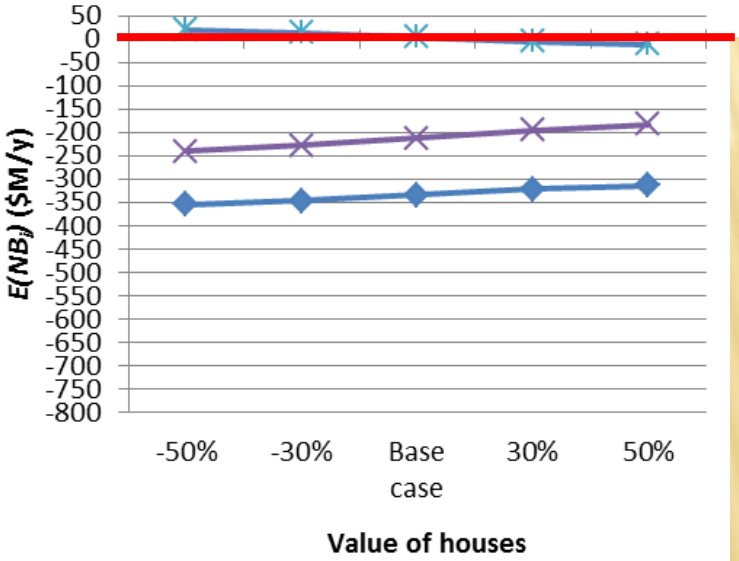
ECONOMIC PERFORMANCE

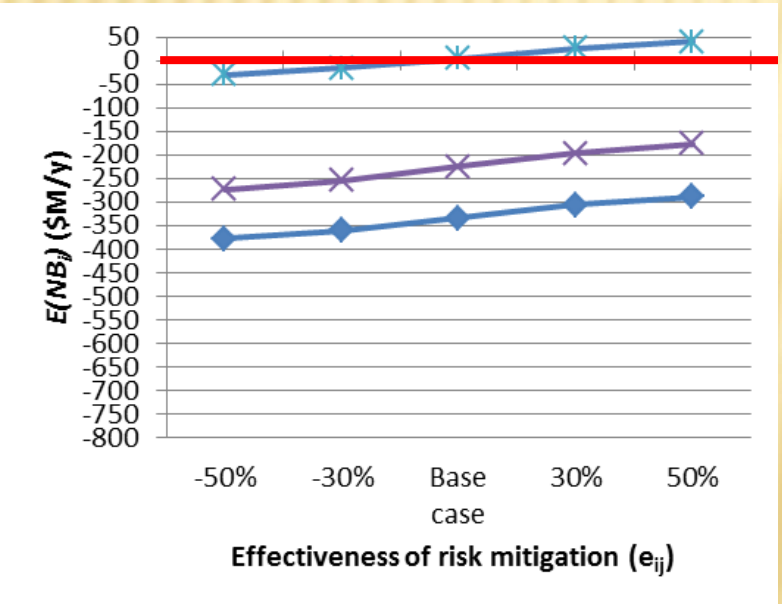
Bushfire risk mitigation policy	Expected annual avoided life loss	Expected annual avoided house loss	Cost per avoided life loss ($ M)	Cost per avoided house loss ($ M)	Annual avoided asset losses ($ M/y)	$E(NB_i)$ ($ M/y) [d]
Prescribed fire	7	151	54.8	2.5	89	-344
Sprinklers	7.6	163	36.9	1.6	96	-225
Early evacuation	5.5	-117	6.3	na	8	4

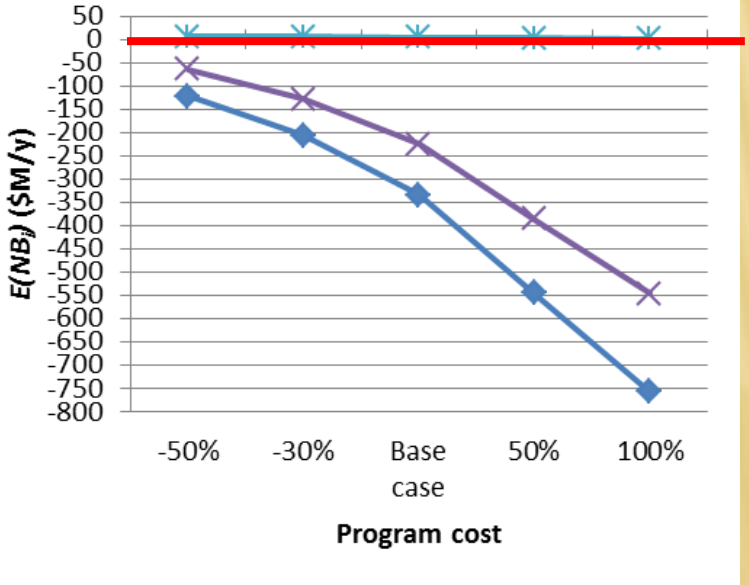
Zero *E(NB$_i$)* represents no change in expected annual net benefits relative to the outcomes from implementation of existing bushfire risk mitigation policy

SENSITIVITY ANALYSES









INEFFICIENCY OF MITIGATING THE RISK OF LOW PROBABILITY EVENTS

- Benefit of halving life and house loss is $90 M/y
- Equivalent to $162/house within 100 m of bushland per year
- Equivalent to investment of $3200/house today (r=5%)
- ($6400/house in communities affected by Black Saturday)

HIZ TREATMENTS

- No wonder HIZ policy is economically inefficient!
- Bushfire policy that **does not** mandate structural modifications, sprinkler systems or vegetation treatments in HIZ is efficient!
- Stockmann et al. (2010) arrived at similar conclusion for HIZ treatments in the WUI of Montana

INEFFICIENCY OF PRESCRIBED FIRE

- Increase in prescribed fire from 0.2 M ha/y to 2 Mha/y must generate $190/ha in additional benefits

- Consider:
  - Disamenity of smoke
  - Ecological desirability of 10-year fire return intervals in forest and woodland ecosystems
  - Impact on carbon storage
  - Technical feasibility of burning 2 M ha/y

INEFFICIENCY OF 'STAY AND DEFEND'

- Can 'Stay and Defend' be modified so that only capable people stay?
  - 5% (9) **Black Saturday** fatalities put up an effective defense
  - 25% of fatalities put up some defense
  - >50% of fatalities passively sheltered

- Post Black Saturday Surveys have revealed:
  - ≈33% would "*wait and see what happens during a fire, but leave if threatened*" (Rhodes 2011)
  - 60% indicated their survival strategy was to evacuate on a Code Red (FFDI ≥ 100) day, but only 2% did! (Whittaker and Handmer 2010)

INEFFICIENCY OF ‘STAY AND DEFEND’

- **History** (1900 to 2008) shows that more people have died staying than when evacuating late
- **Black Saturday:** people who did not evacuate were 2x more likely to die
- Deaths per house destroyed are 2x higher in Australia than the USA
- HIZ treatments to support ‘Stay and Defend’ are economically inefficient
- If tragedy of bushfires is loss of life, then evacuation appears to be the more efficient policy when FFDI ≥ 75

IMPLEMENTING EARLY EVACUATION

- Clear trigger to evacuate
- Television, radio and newspapers to report forecast FFDI
- Alert signals to interrupt broadcasts
- Sirens in more densely populated areas
- Organized government evacuation assistance

IMPLICATIONS OF CLIMATE CHANGE

- Losses occur in few extreme fires
- Australasia chapter in IPCC 2014:
  - Frequency of extreme fire weather will increase
  - Weather suitable for prescribed fire will decrease
  - Fuel loads may increase (CO_2 fertilization)
- Climate change strengthens the case for an evacuation policy

CONCLUSIONS

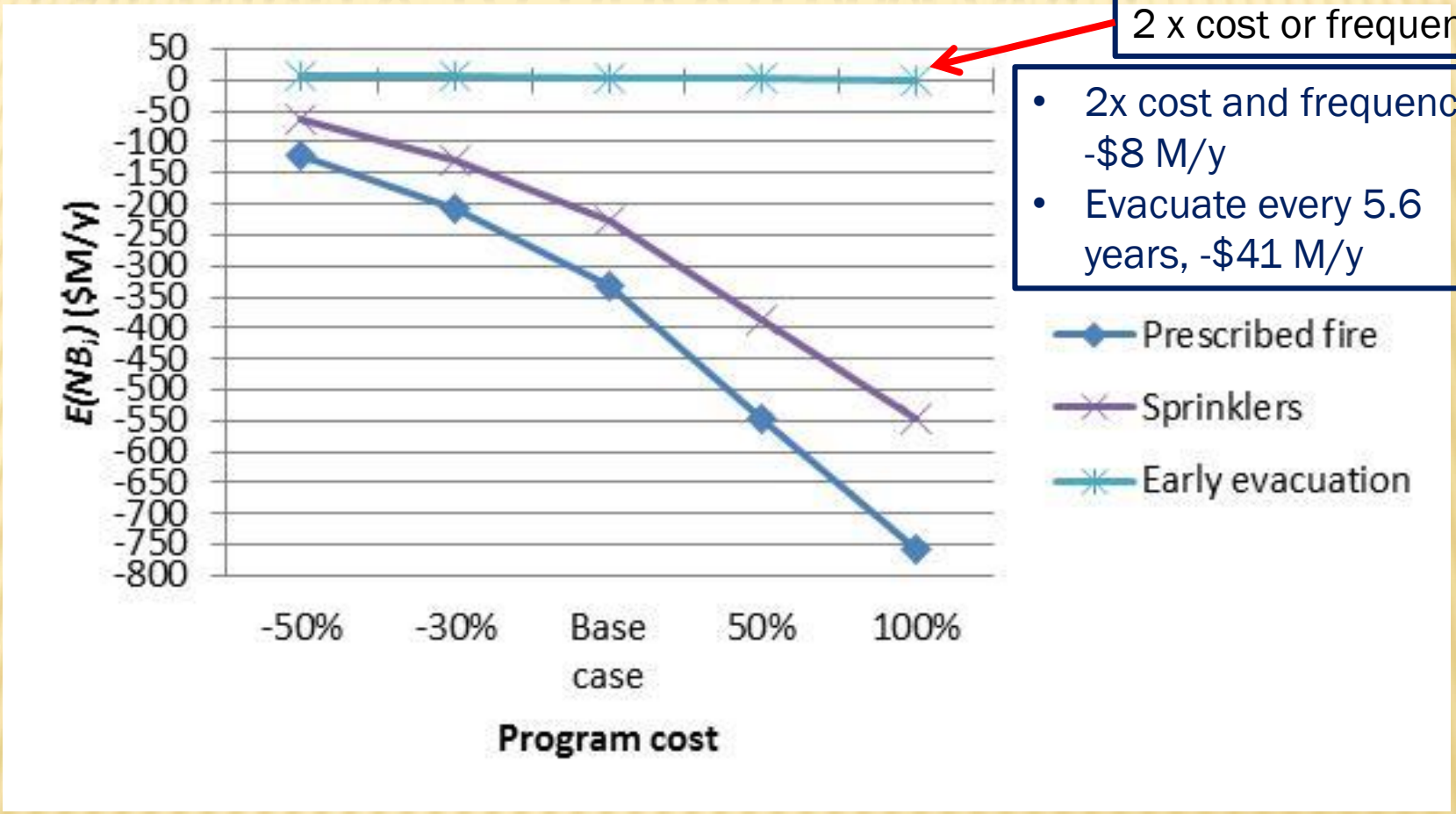
- Our findings do not unambibuously support any of the bushfire risk mitigation policies examined over the status quo
- However, if life is valued high relative to property, then an early evacuation policy can be justified over the status quo
- Large prescribed fire investments justifiable only if accompanied by substantial ecological benefits
- Mandating HIZ treatments is not economically justified
- Future research: Better quantify benefits and costs of bushfire risk mitigation strategies
- Future research: Examine the economic efficiency of restricting the growth of at-risk communities

BLACK SATURDAY FATALITIES

Survival strategy	% of residents	% of fatalities
Early evacuation	20	0
Late evacuation	23	17
Stay	57	**77** 65 passively sheltering 9 meagre or active defense 3 outside (e.g. caring for stock
Total	100	94*

* Other fatalities included campers, bushwalkers and travelers through the area

SENSITIVITY TO PROGRAM COST



- Changes in program costs can change ranking of sprinklers and prescribed fire

ROYAL COMMISSION

- >50% sheltered passively throughout the fire
- ≈33% in homes that were not defendable
- 44% were in one or more vulnerability groups
- 38% no basic knowledge of precautions to take
- 24% not aware they lived in an area at risk from bushfires
- Many appear to have waited until flames could be seen before acting

ROYAL COMMISSION

- Concluded *'Stay or Go'* was sound
- "*Prepare. Act. Survive.*" greater emphasis on leaving early
- Residents are provided with scaled advice, e.g.
  - *"People in the path of the fire will almost certainly die…"*
    Prepare. Act. Survive. Bushfire Survival Plan, p.2.

Bushfire survival options. Poster available from the website, 'Your Bushfire Survival' (www.firecommissioner.vic.gov.au/yourbushfiresurvival/)

INFORMATION REQUIREMENTS

1) Probability that bushfire will threaten people and homes
2) Expected levels of life and home loss
3) Bushfire risk mitigation strategy effectiveness
4) Costs of bushfire risk mitigation strategies

- This information is not readily available!

EFFECTIVENESS AND COSTS OF BUSHFIRE RISK MITIGATION STRATEGIES

LANDSCAPE-SCALE PRESCRIBED FIRE

- Current rates between 0.5% and 1.5% of study area forests and woodlands per annum
- Effective for up to 4 years
  - High rates of fuel accumulation
  - Long-distance ember propagation

HIZ: VEGETATION TREATMENTS

Country Fire Authority and Building Commission (2010, p. 4)

Australian bushfire policy allows retrofitting to be based on

"*individual needs and the level of fire protection desired*"

Mown grass provides separation between garden beds.

EVACUATION: EFFECTIVENESS AT SAVING LIVES

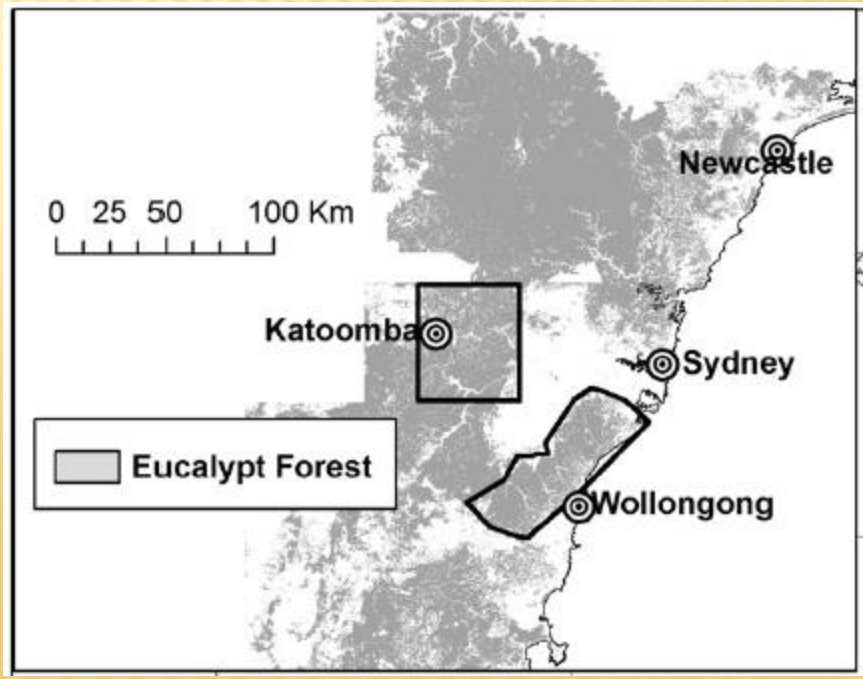
Item	Australia, 1900 to 2009, normalized annual (Crompton et al. 2010)	Australia, Black Saturday 2009 (Parliament of Victoria 2010)	USA annual 2002 to 2006 (Thomas and Butry 2012)
Civilian lives lost	14	172	15
Homes destroyed	301	2298	599
Homes per life lost	21	13	40

- High profile US fires:
  - 2007 southern California fires: >300,000 people evacuated, lost 2223 homes and 7 lives
  - 2011 Bastrap County Complex, Texas, destroyed 1600 homes and killed 2 people.
- Climate, ecological and socio-economic factors responsible for differences between Australia and USA deaths, but policy differences are almost certainly important

INEFFICIENCY OF PRESCRIBED FIRE

- Prescribed fire cited at the WUI may be more efficient; however:
  - Over the last 30 years, an average of 4.1% of forest around Sydney burned annually
  - Halving bushfire risk around Sydney will require burning 100,000 ha/y (5.4% of 1.9 M ha)
  - $23.5 M/y in costs
  - $12 M/y in benefits
  - Higher prescribed fire costs (?)
  - Degrade air quality for residents
  - Many species around Sydney require fire return intervals of 7 to 30 years to persist

(Price and Bradstock 2011)

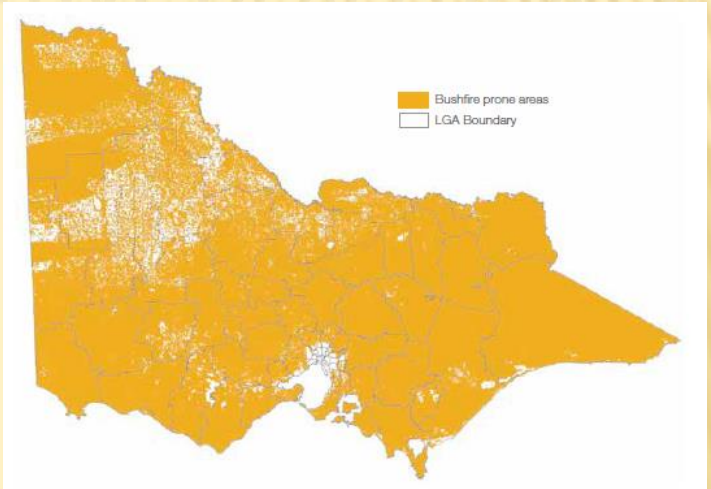


LIMITATIONS

- Results relative to status quo, which is a function of status quo mitigation strategies
- Legal and technical challenges to early evacuation
- Scarce information to support parameter estimates
- Ecological benefits of prescribed fire?
- Climate change?
- Sensitivity analyses do suggest findings are robust

PLANNING FUTURE RESIDENTIAL DEVELOPMENT

- Delineate high-risk bushfire areas like flood plains
- Modify land use policies that allow development close to bushland
- Improve enforcement of existing planning regulations



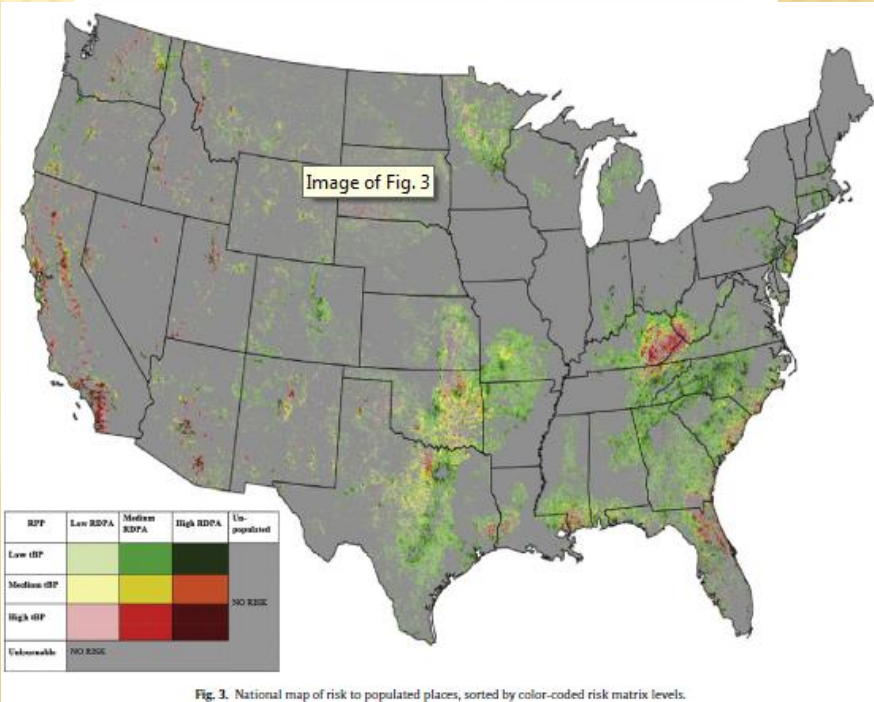


Fig. 3. National map of risk to populated places, sorted by color-coded risk matrix levels.

(Haas et al. 2013)

APPLICATION TO THE USA

- Burn probability in USA lower

- Prescribed fire effectiveness higher
- Economic efficiency of prescribed fire unclear

- HIZ treatment effectiveness similar to Australia
- HIZ treatments economically inefficient