Quantifying the effects of fire regimes on runoff and erosion

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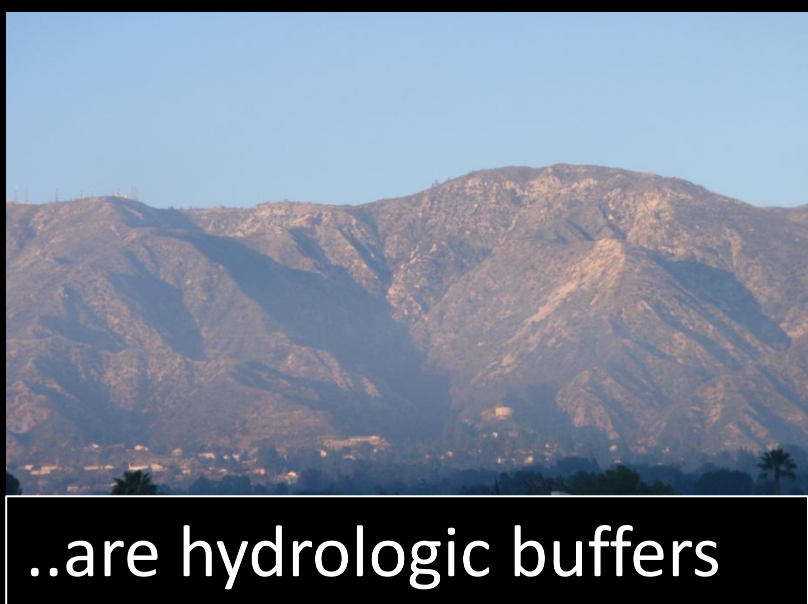
Catchments…

..provide drinking water

…support ecosystems



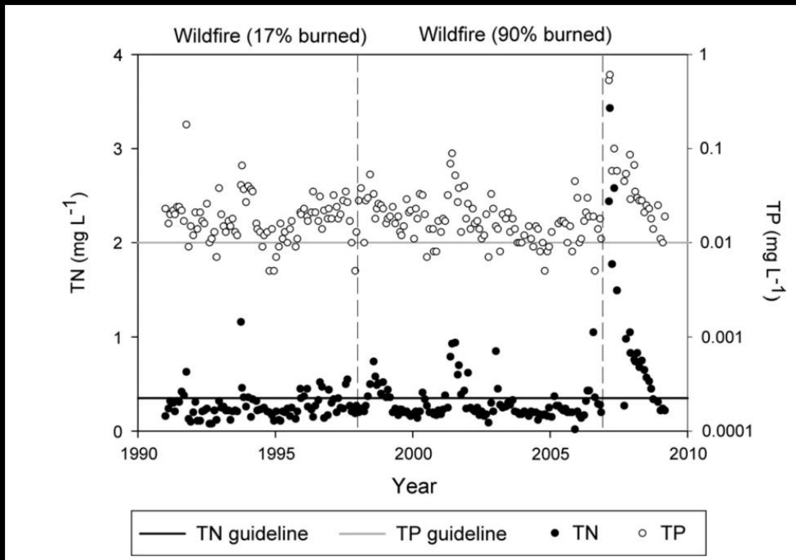
..are hydrologic buffers

Fire impacts on catchment processes

Wellington River, Feb 2007

PHOTO: Adrian Murphy, Melbourne Water

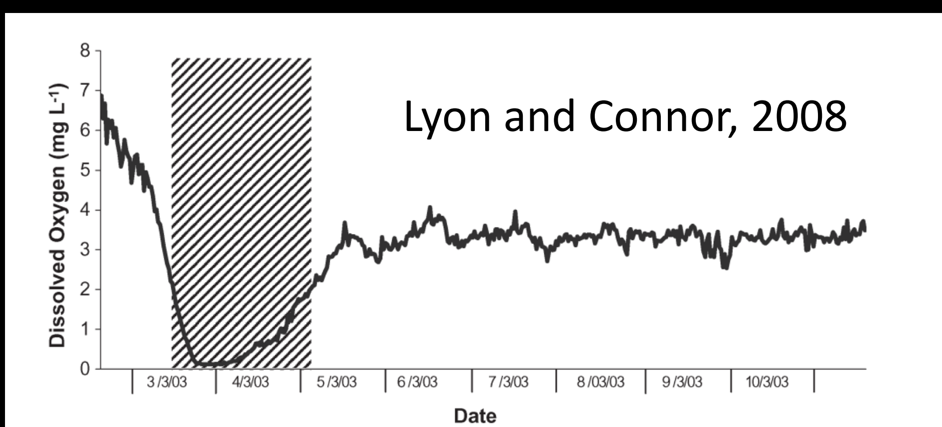
Downstream water quality impacts can be large



e.g. Lake Glenmaggie

Increased nitrogen and phosphorous concentrations

Smith, et al (2011), Wildfire effects on water quality in forest catchments: A review with implications for water supply, *Journal of Hydrology, 396(1-2), 170-192.*



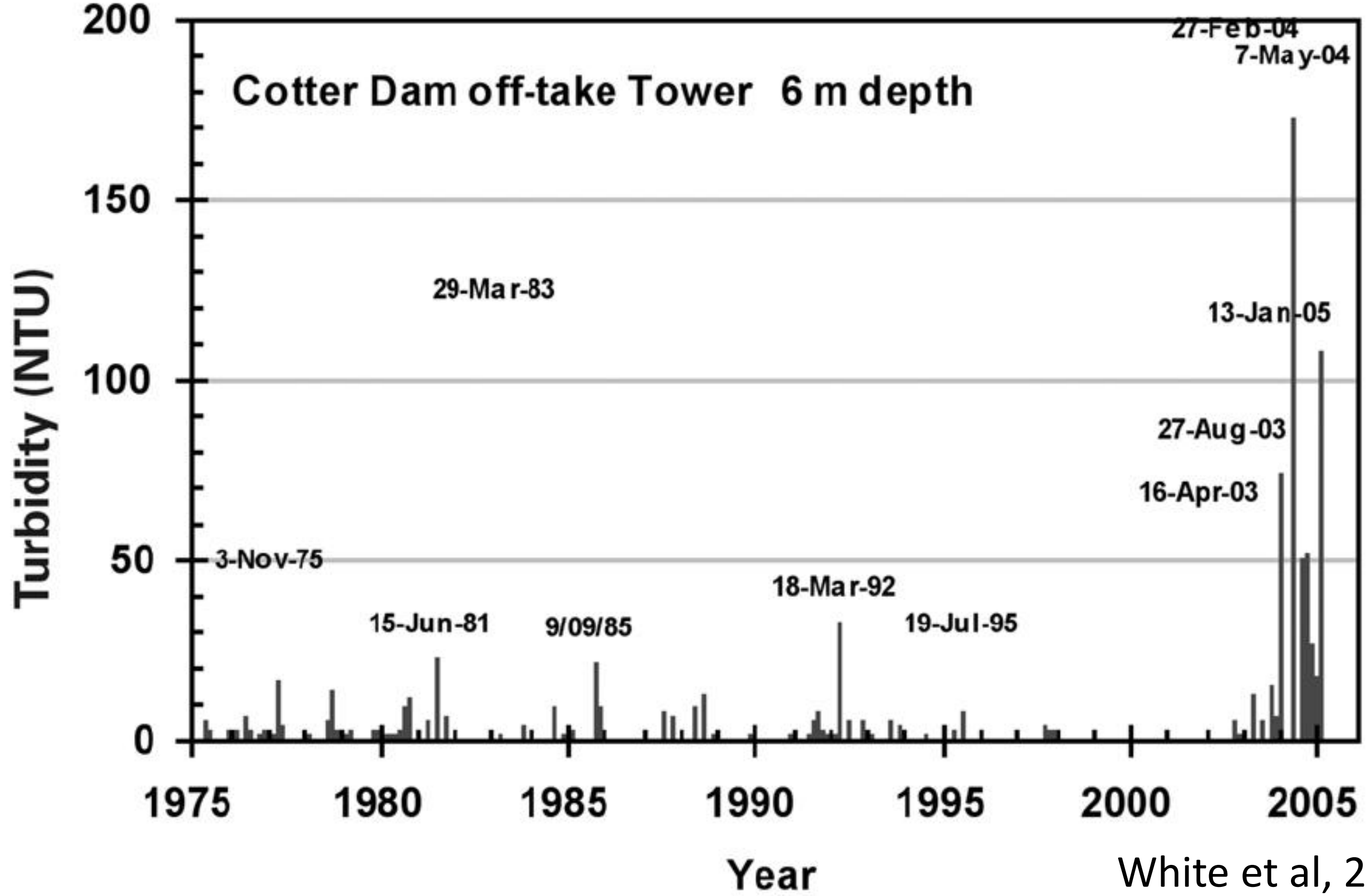
e.g. Ovens River

Dramatic drop in dissolved oxygen

Lyon and O'Connor (2008), Smoke on the water: Can riverine fish populations recover following a catastrophic fire-related sediment slug?, *Austral Ecology, 33(6), 794-806.*

Downstream water quality impacts can be large

e.g. Cotter Dam, *Increased turbidity*



White et al, 2008

White et al (2006) The vulnerability of water supply catchments to bushfires: Impacts of the January 2003 wildfires on the Australian Capital Territory. Australian journal of water resources 10: 1-16.

Direct impacts…

PHOTO: Charlie Showers, DSE

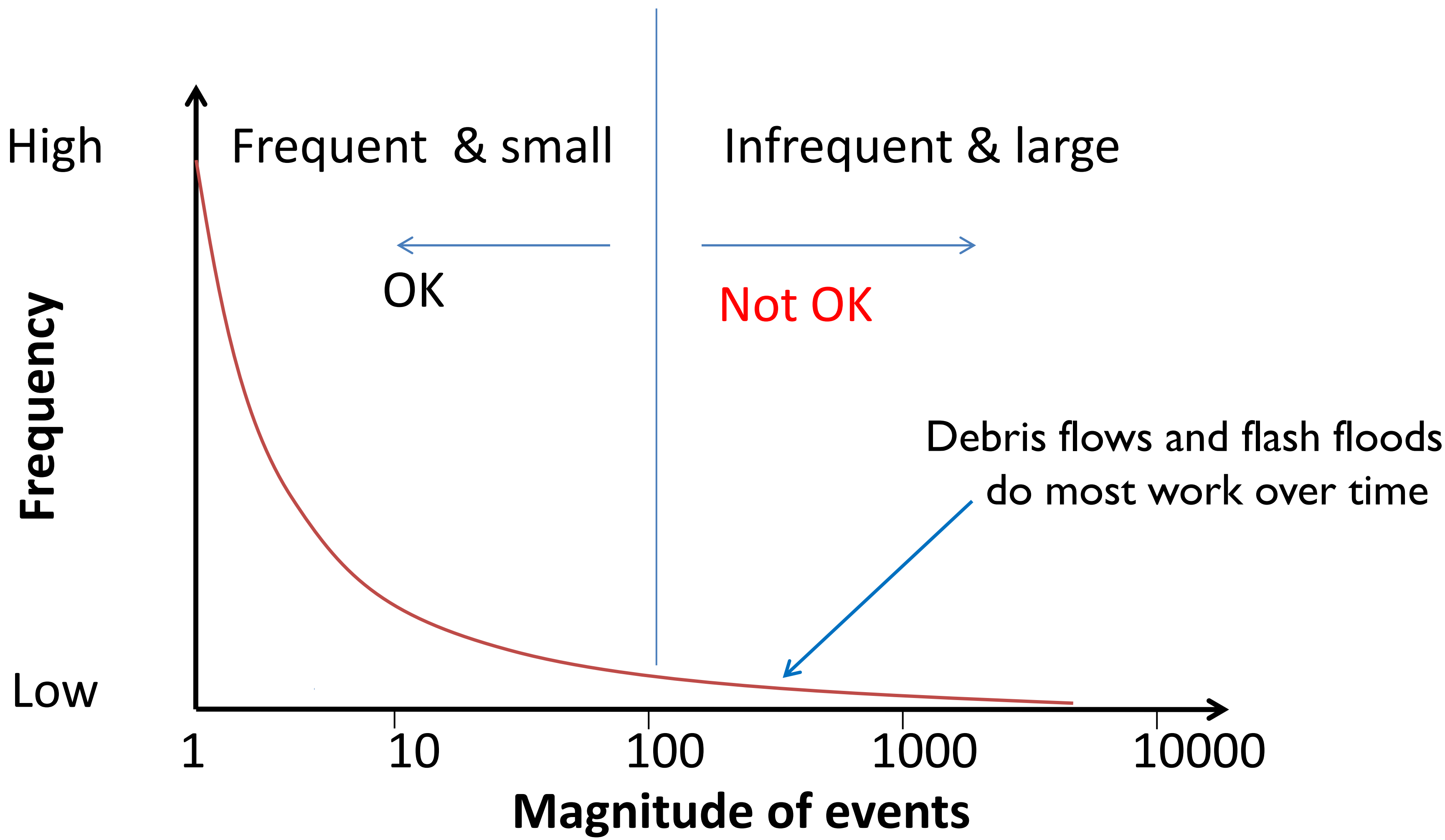
Harrietville, Mar 2013

Direct impacts…

"A severe storm has brought flash flooding to the Gippsland town of Licola, knocking a house off its foundations and damaging seven others, weeks after bushfire" (Houghton, 2007)

"A flash flood swept their 4WD off a bridge into a creek…a fire fighter was washed away in a 2-m wall of water" (Berry and Bradley, 2003)

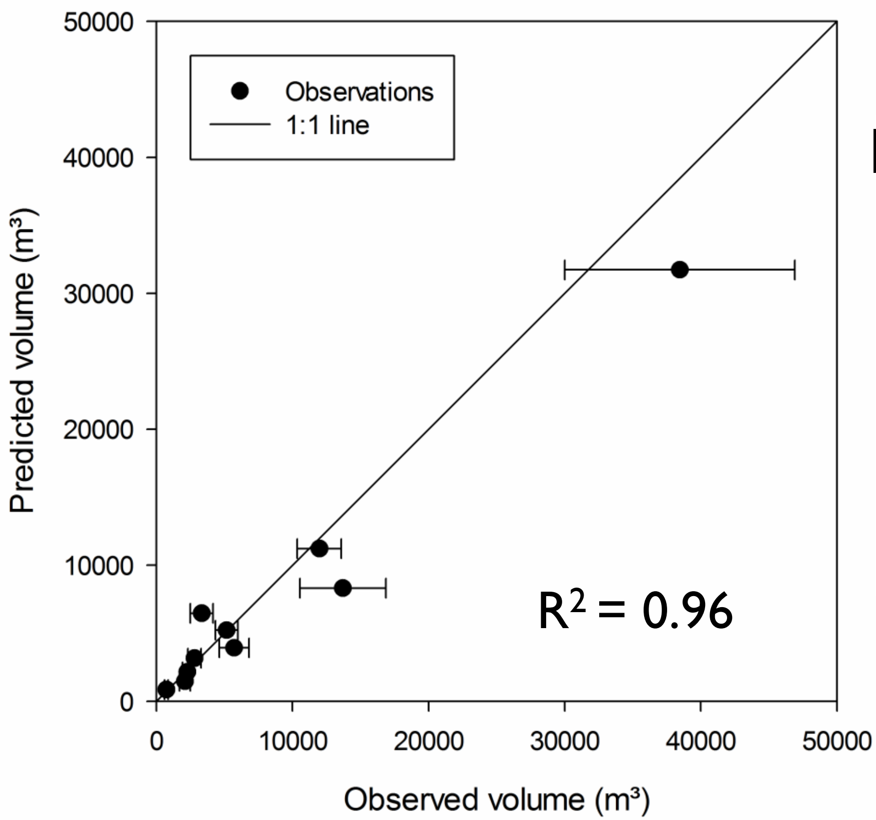
What do we know?
---Large events are most important---



What do we know?
---USGS debris flow model---

USGS Debris flow model works well in southeast Australia!

- Observed vs predicted



$$\ln(V) = 7.2 + 0.6\ln(S_{th}) + 0.7B^{0.5} + 0.2R_{tot}^{0.5}$$

V= volume

S_{th} = area with **slope** > 30%

B = area with **burn severity** > 2

R_{tot} = total storm **rainfall**

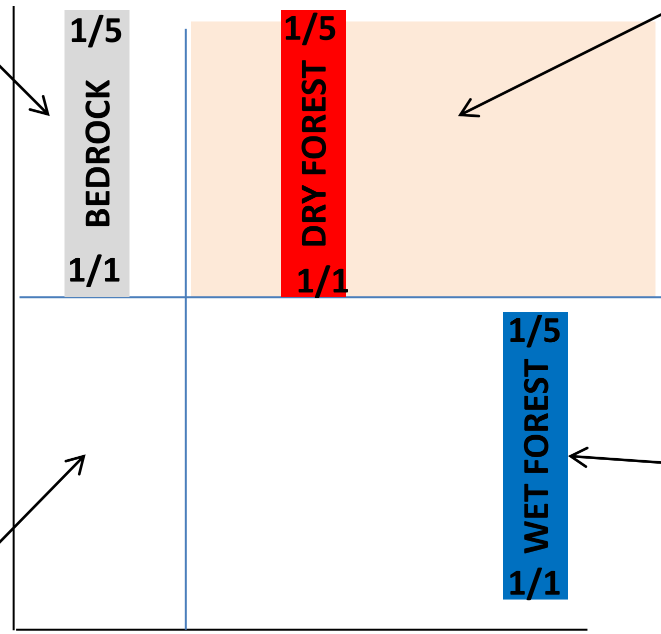
What do we know?
---Landscapes are variable---

Sediment limitation
e.g. Mt Buffalo,
Nyman et al (2011)

High severity fire

DEBRIS FLOW REGION!!!
e.g. Rose River, & Yarrarabula ++,
Nyman et al (2011)

Infiltration excess runoff



Sediment availability

Transport limitation
e.g. East Kiewa,
Lane et al (2006)

Sediment and transport limitation…
e.g. flat rock..
Dinner Plains maybe

BF CRC research priorities

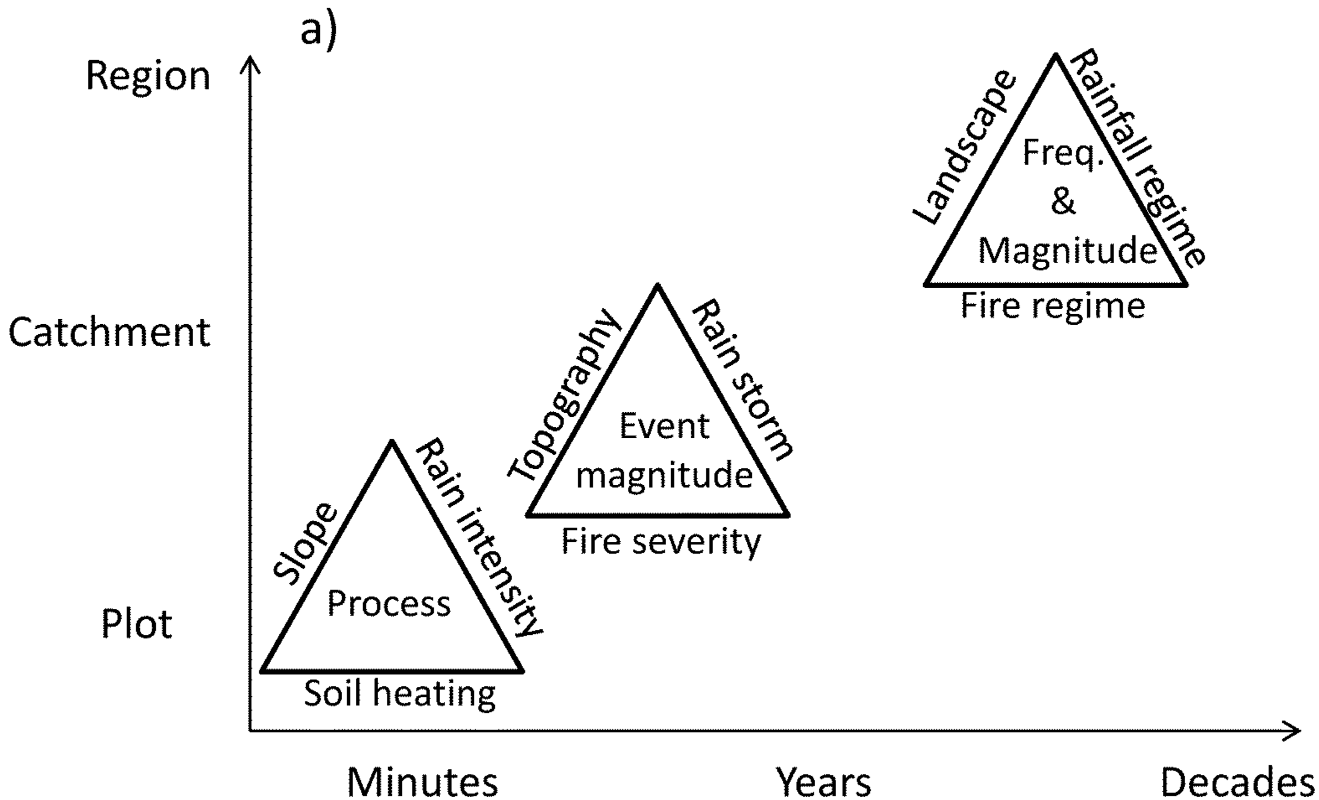
1. Understanding the threat: linking research outputs and management needs.

2. Model disturbance effects of fire-regimes (as opposed to fire events)?

3. Quantify spatial variability in landscape response to fire disturbance?

Three research components
---Review and modeling---

1. Framework for modeling fire-effects on catchment processes.

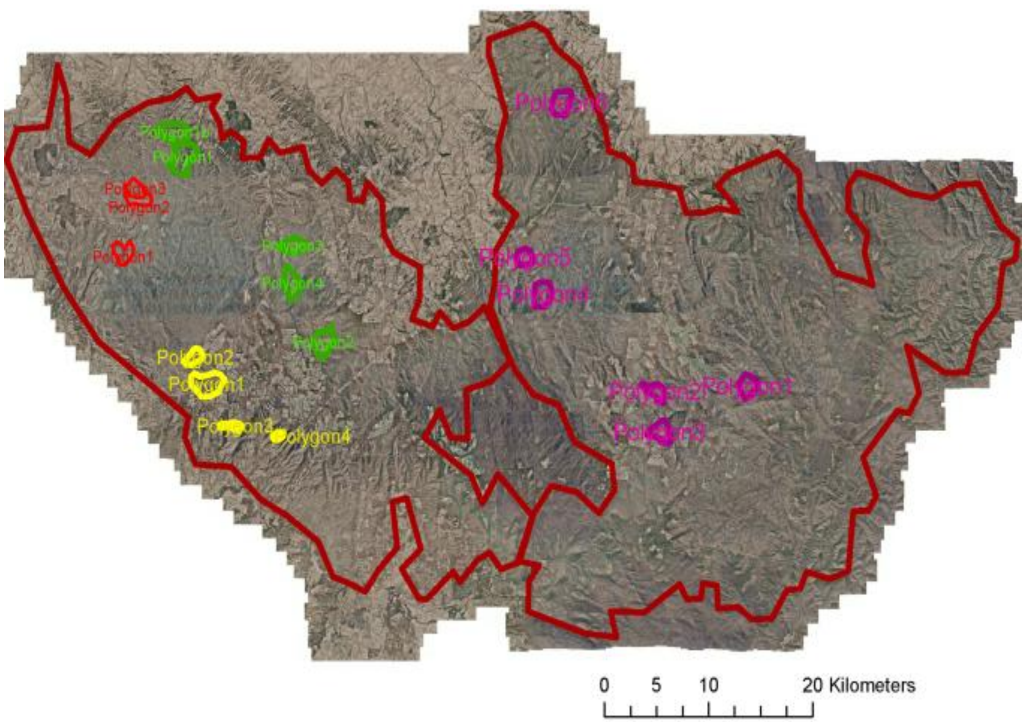


Three research components

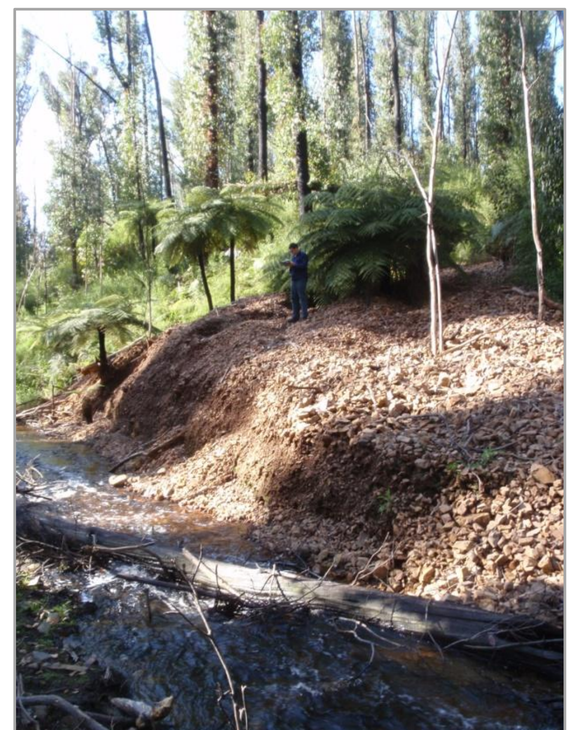
---Debris flow mapping---

2. <u>Aerial images to quantify debris flow response.</u>

Aerial photography (2009 fires)



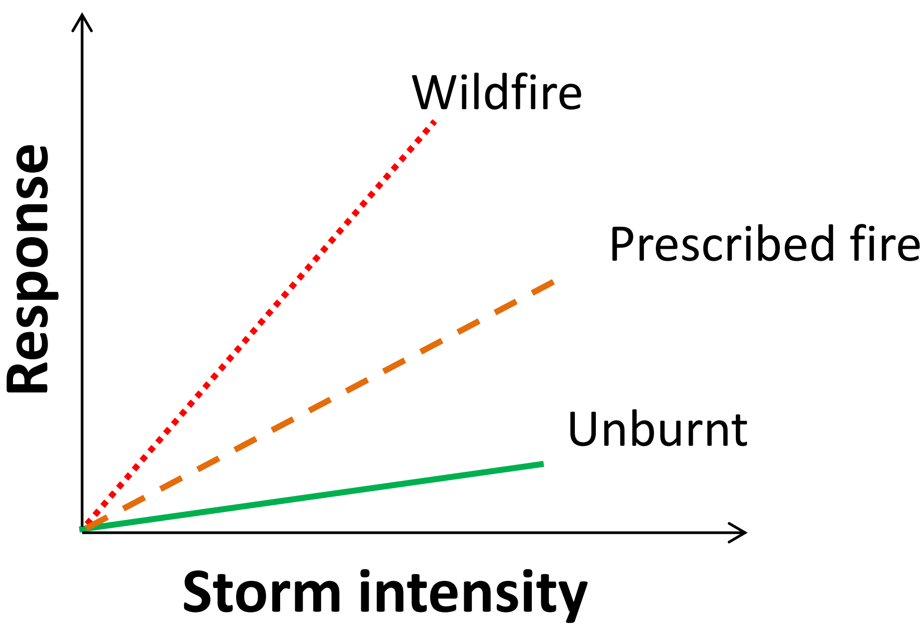
Field surveys



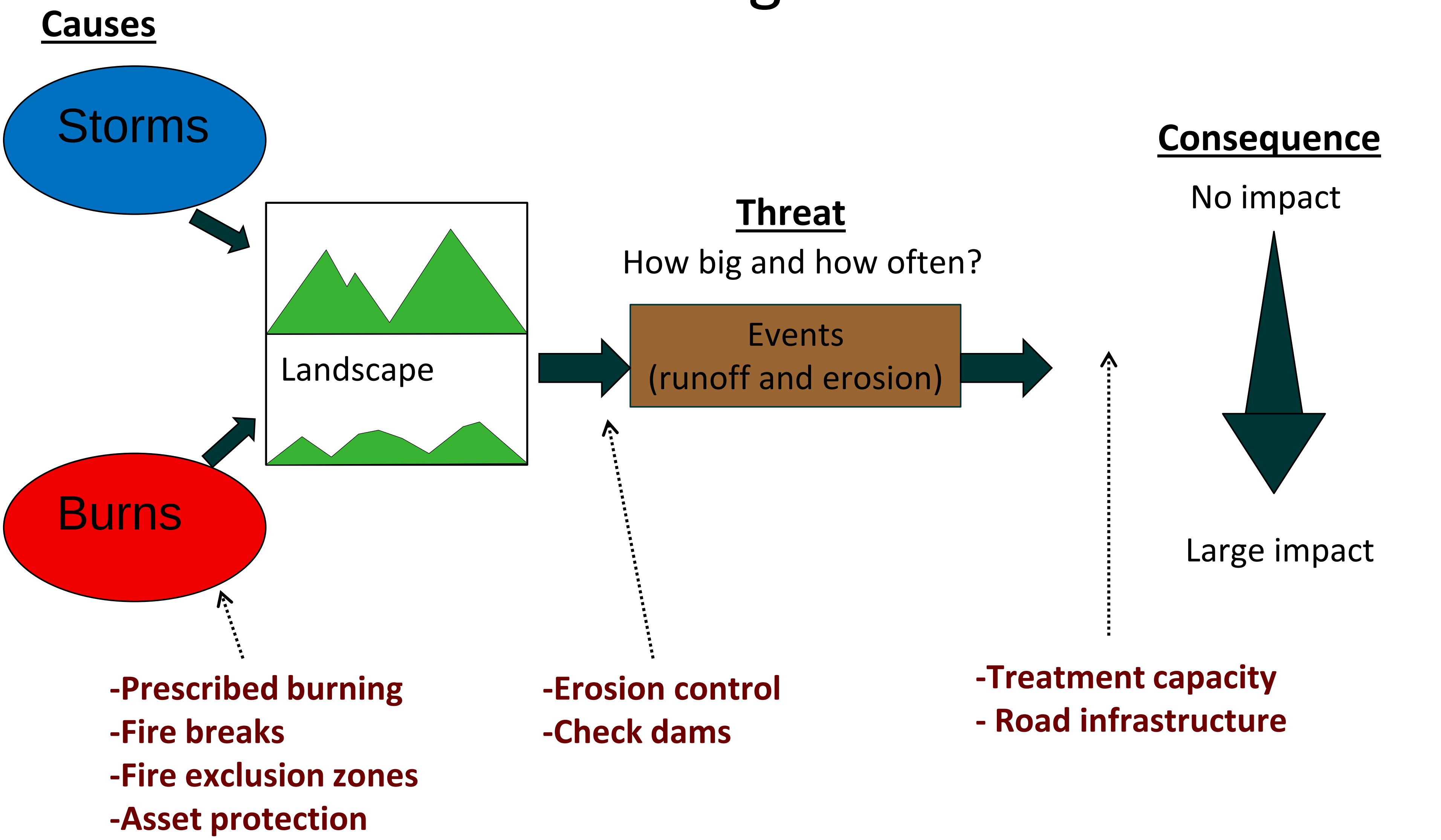
Three research components
---Runoff monitoring---

3. <u>Tipping buckets in small headwaters.</u>

Monitoring runoff and erosion

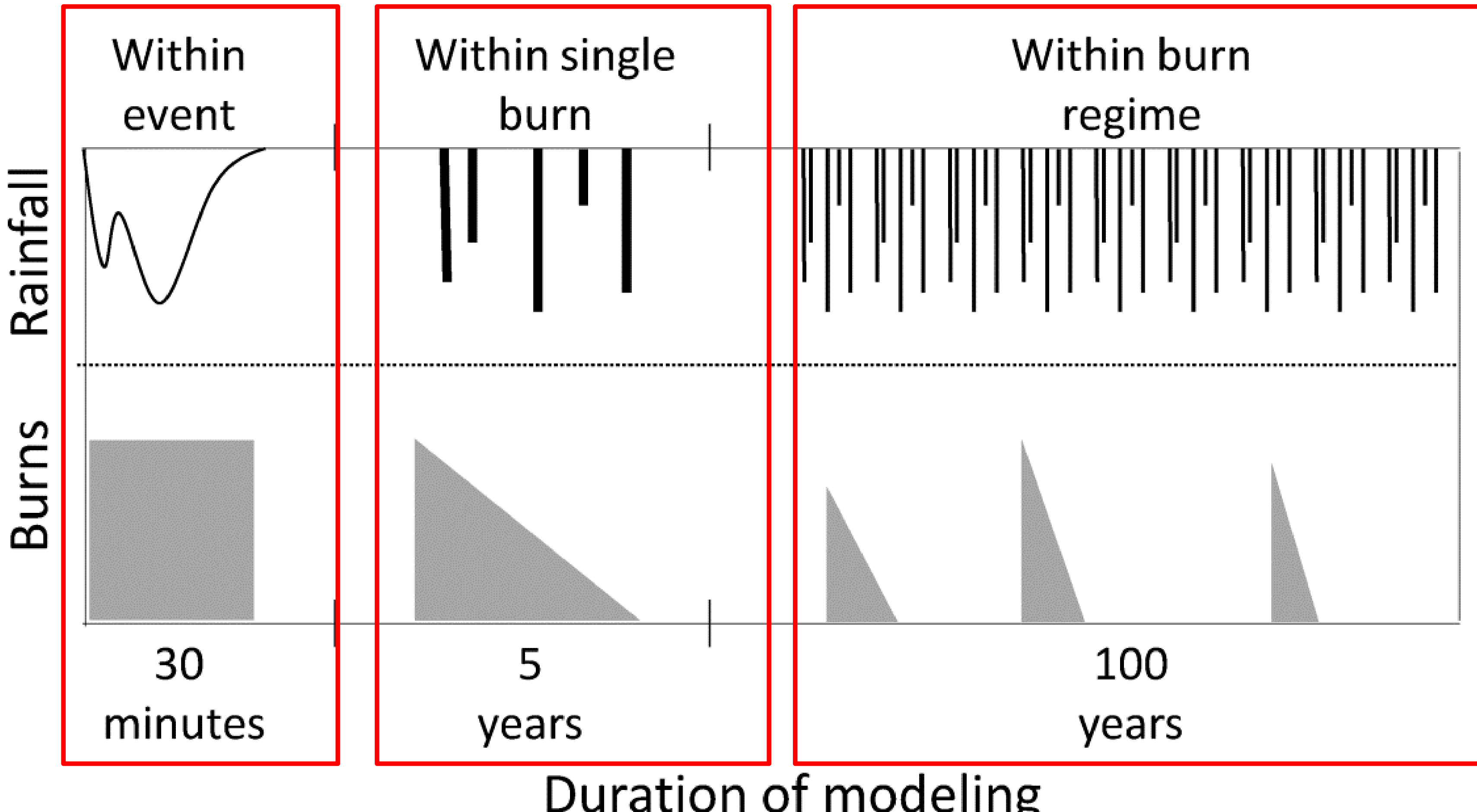


1. The model framework
---Understanding the threat---

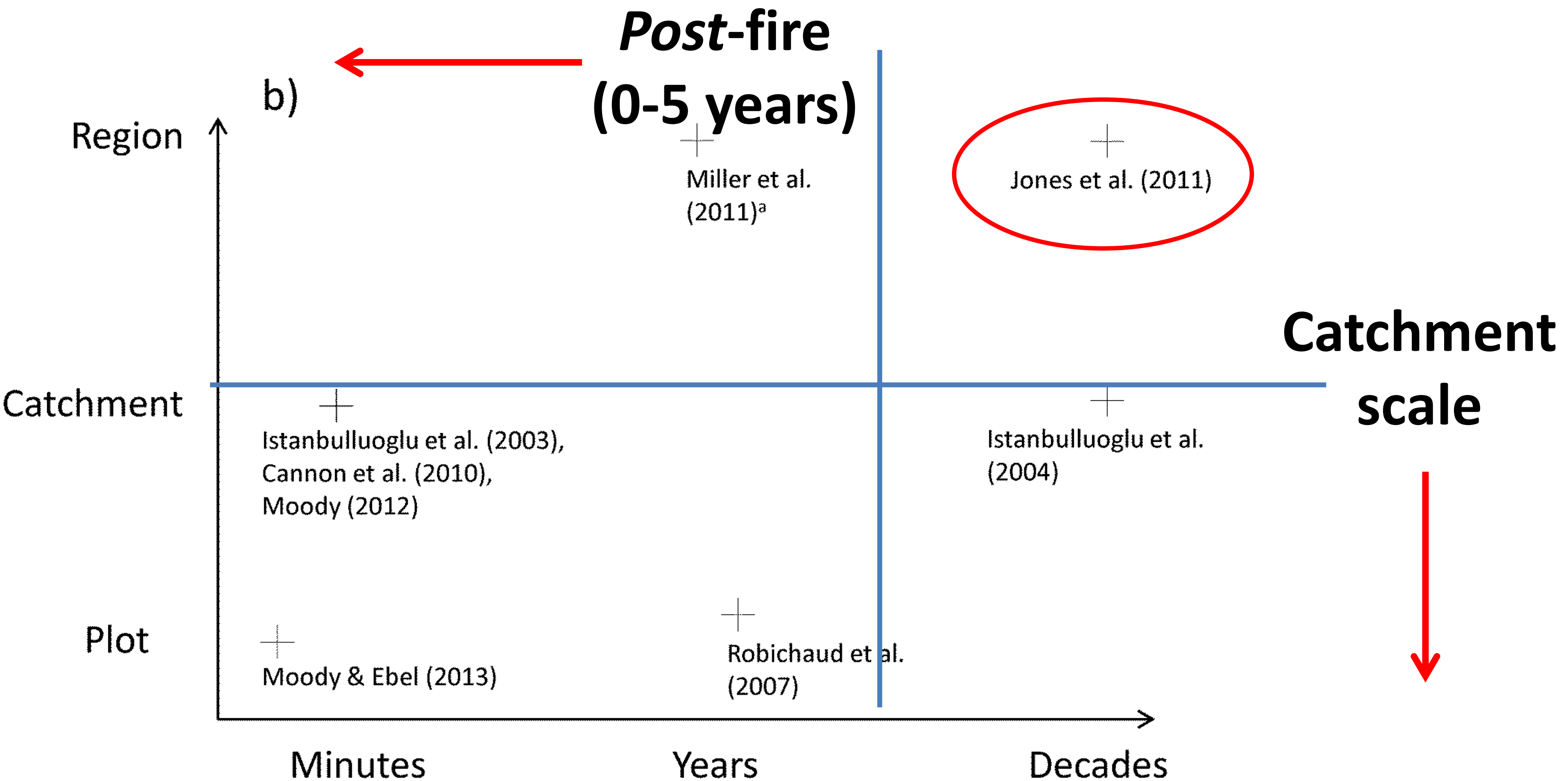


1. The model framework
---Understanding the threat---

Different perspectives on time:



1. The model framework
---Understanding the threat---



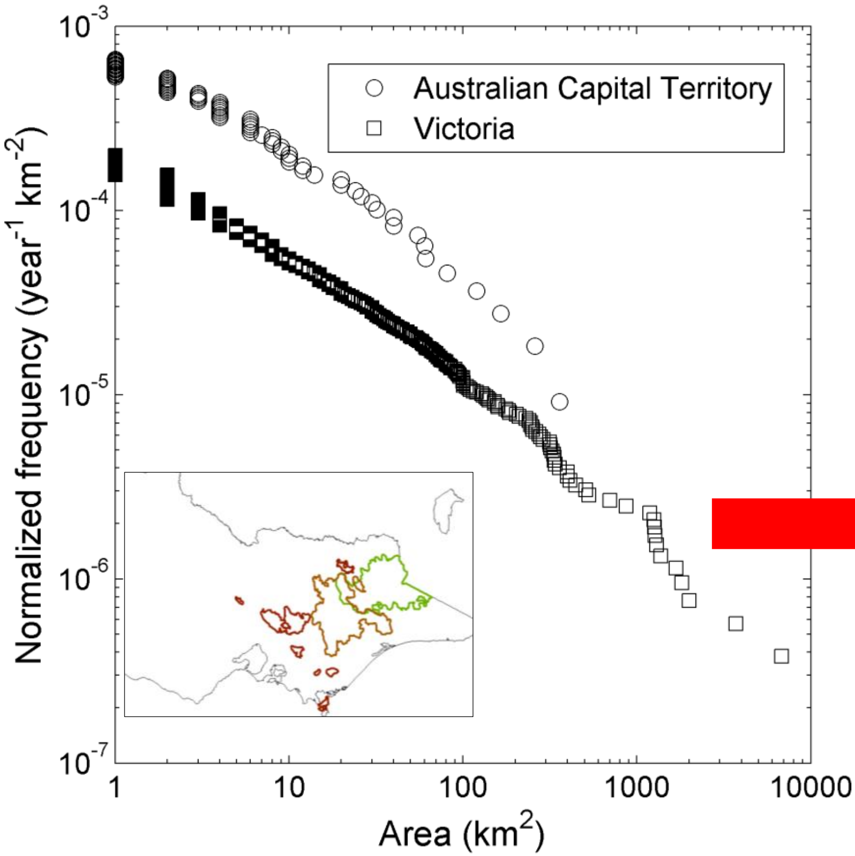
[a] The model predicts hillslope erosion but was applied to hillslopes across regions.

1. The model framework

---Fires in space and time--

DATA

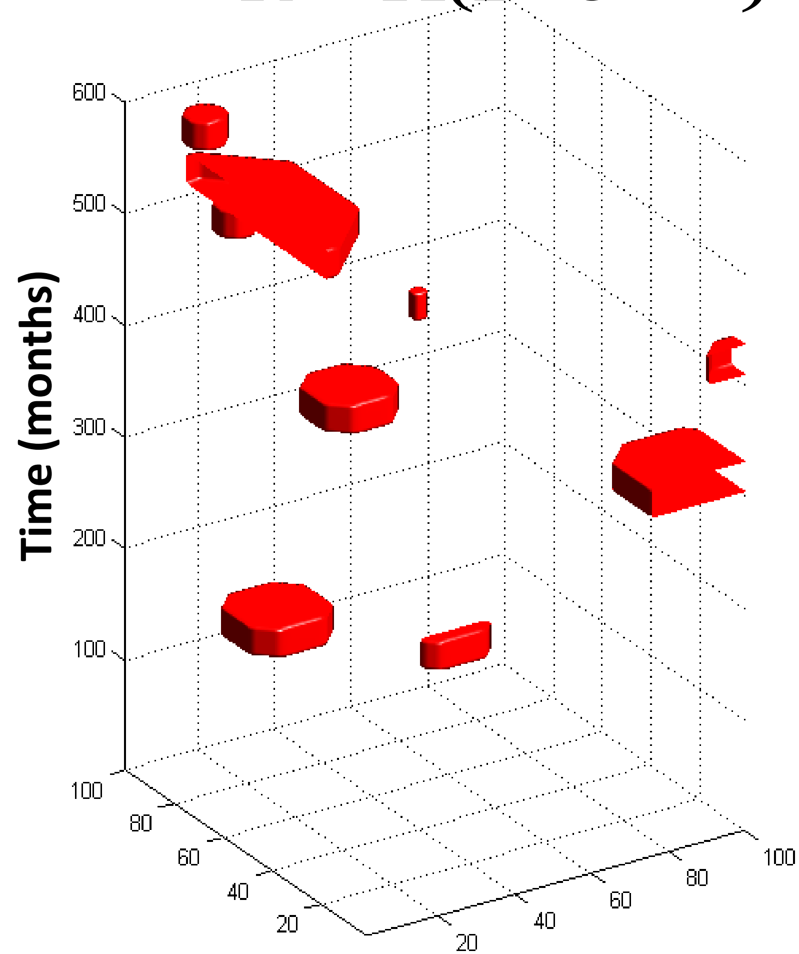
Fire regime



Data from the Department of Sustainability and Environment

MODEL

$$R = \Omega(1 - e^{-\lambda\alpha})$$

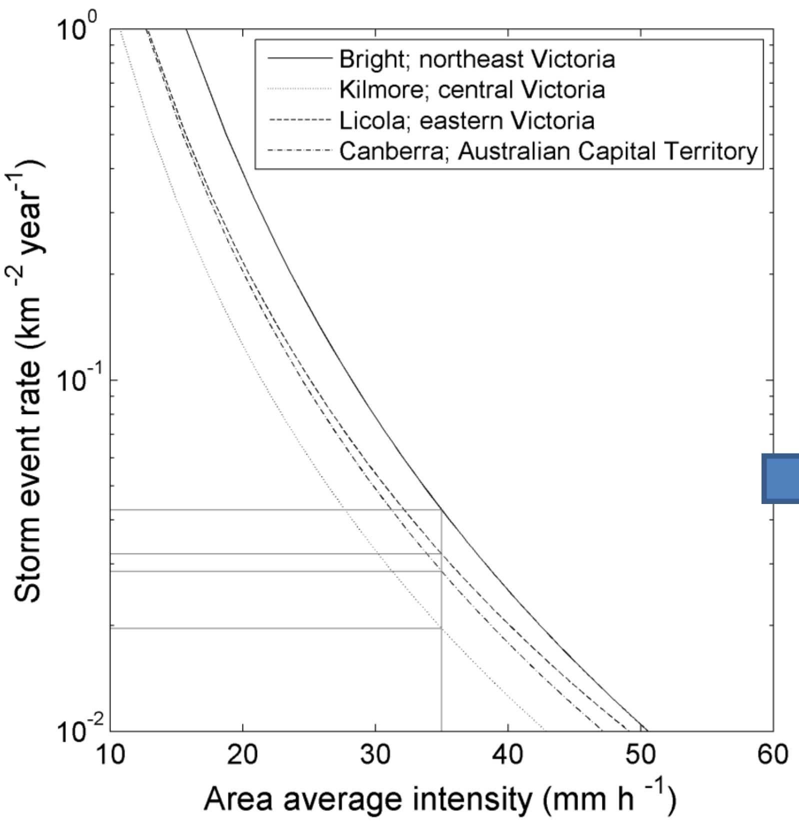


1. The model framework

---Rain storms in space and time---

DATA

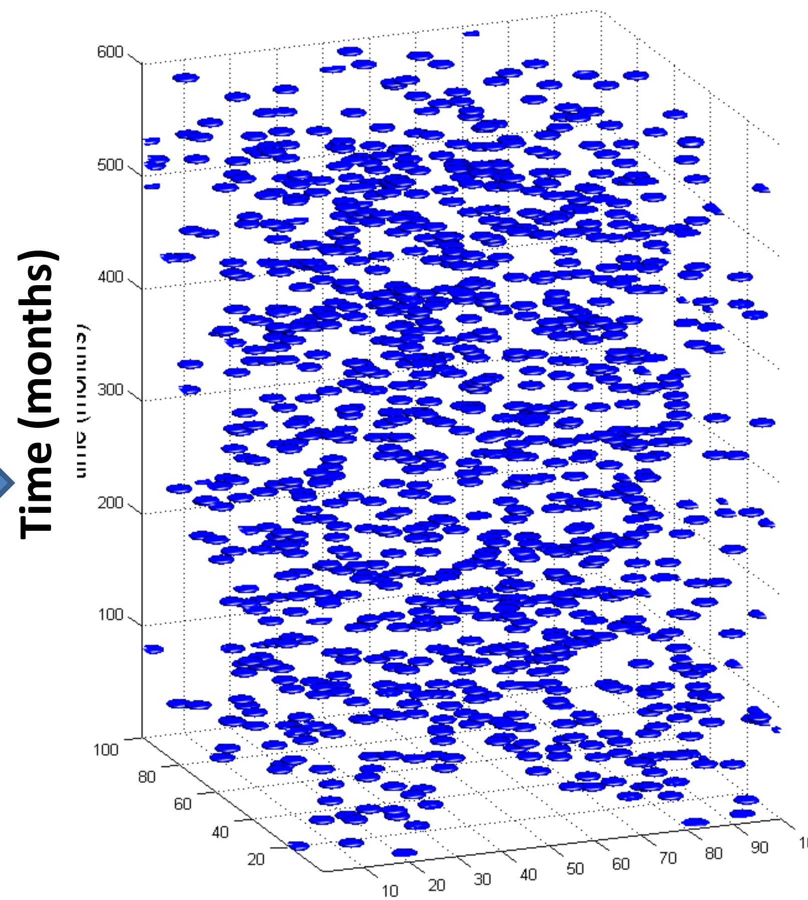
Intensity, frequency, duration



Data from the Bureau of Meteorology

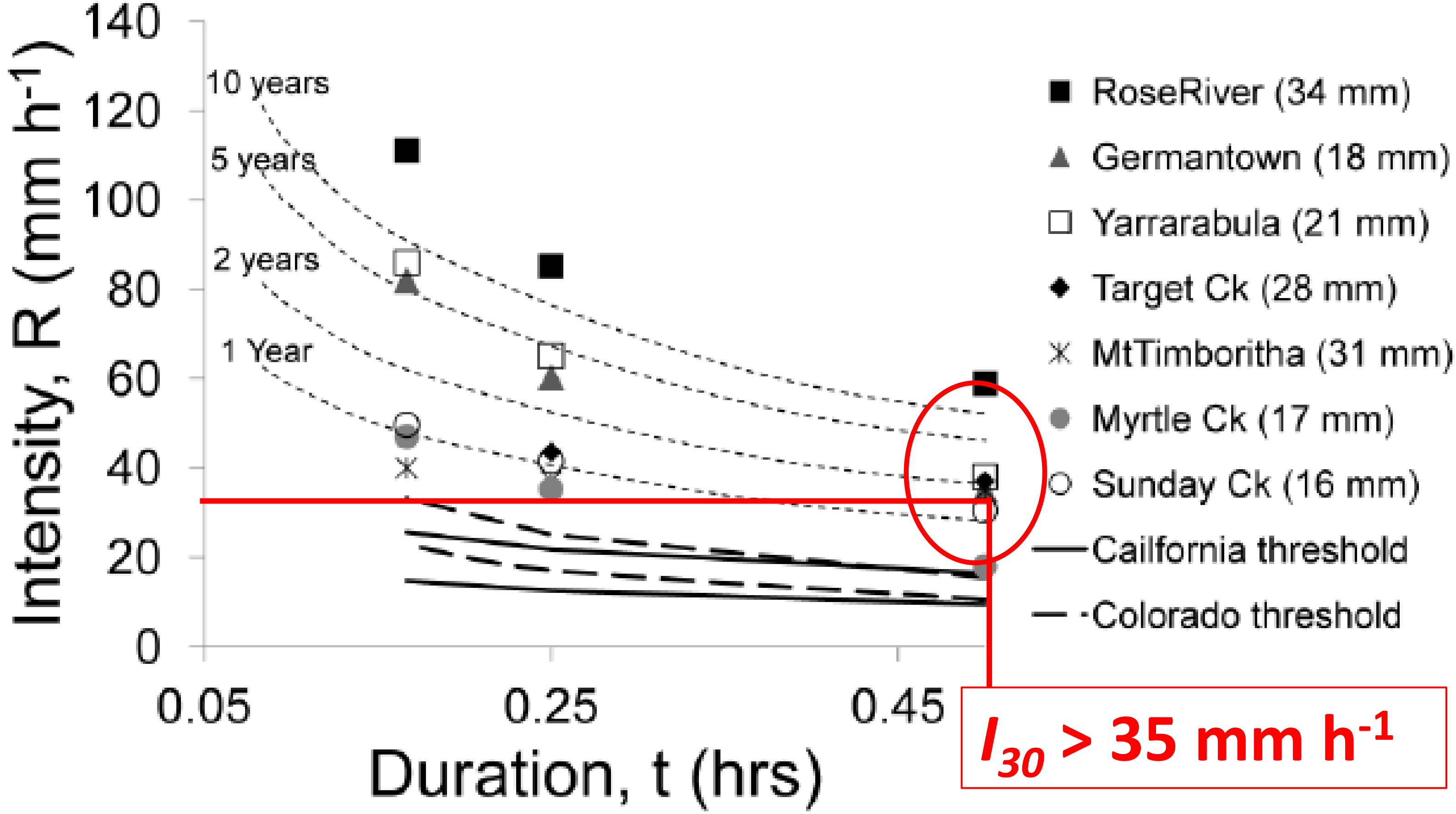
MODEL

$$R = \Omega(1 - e^{-\mu\beta})$$



1. The model framework

---Storms that matter--



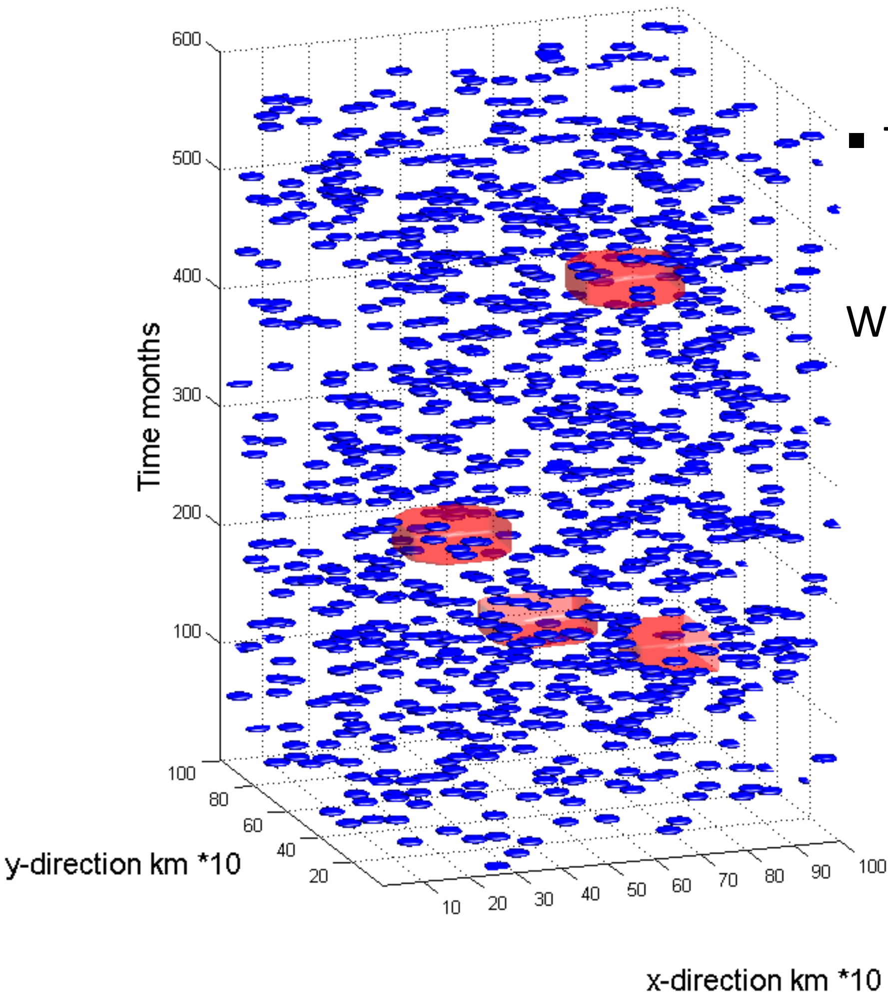
1. The model framework

---Fires and storms in space and time--

Location	Storm event rate [a] $\times 10^{-2}$	Storm size $\times 10^{-4}$	Fire event rate $\times 10^{-4}$	Fire size	Fire event rate with climate change (2050)[b] $\times 10^{-4}$
	μ	β	λ	α	λ_{cc}
	km⁻² year⁻¹ → $km^{-2}\ year^{-1}$	$km^{2}\ {*}year$	$km^{-2}\ year^{-1}$	$km^{2}\ {*}year$	$km^{-2}\ year^{-1}$
		Victoria			
Licola	3.20				
Bright	4.27	5.7	0.941	201	1.13 – 1.74
Kilmore	1.96				
		Australian Capital Territory			
Namadgi NP	2.85	5.7	1.850	67	2.22 – 3.42

b Climate change effects on frequency of fires > 100 ha modeled using data from Bradstock et al , 2009

1. The model framework
---Fires and storms in space and time---



Germ and grain

- The expected annual 'area' of intersection :

$$R = \Omega(1 - e^{-\lambda\alpha})(1 - e^{\mu\beta})$$

Where,

λ = fire event rate (per unit area and unit time)

μ = storm event rate (per unit area and unit time)

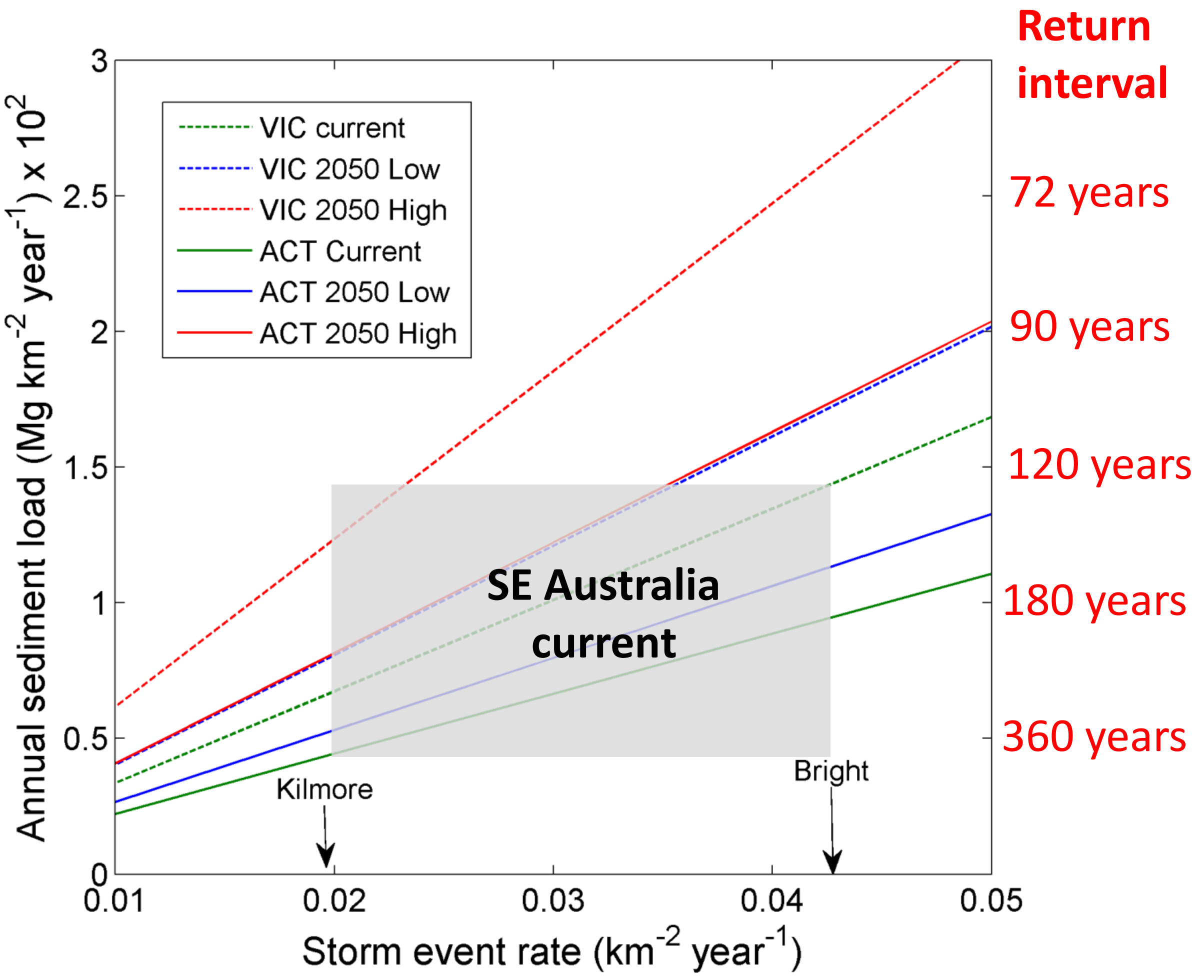
α = E[||fire event||] (in km^2 * years)

β = E[||rainfall event||] (in km^2 * years)

1. The model framework
---Fires and storms in space and time---

Erosion rate from debris flows for catchments in *Dry Eucalypt forest*

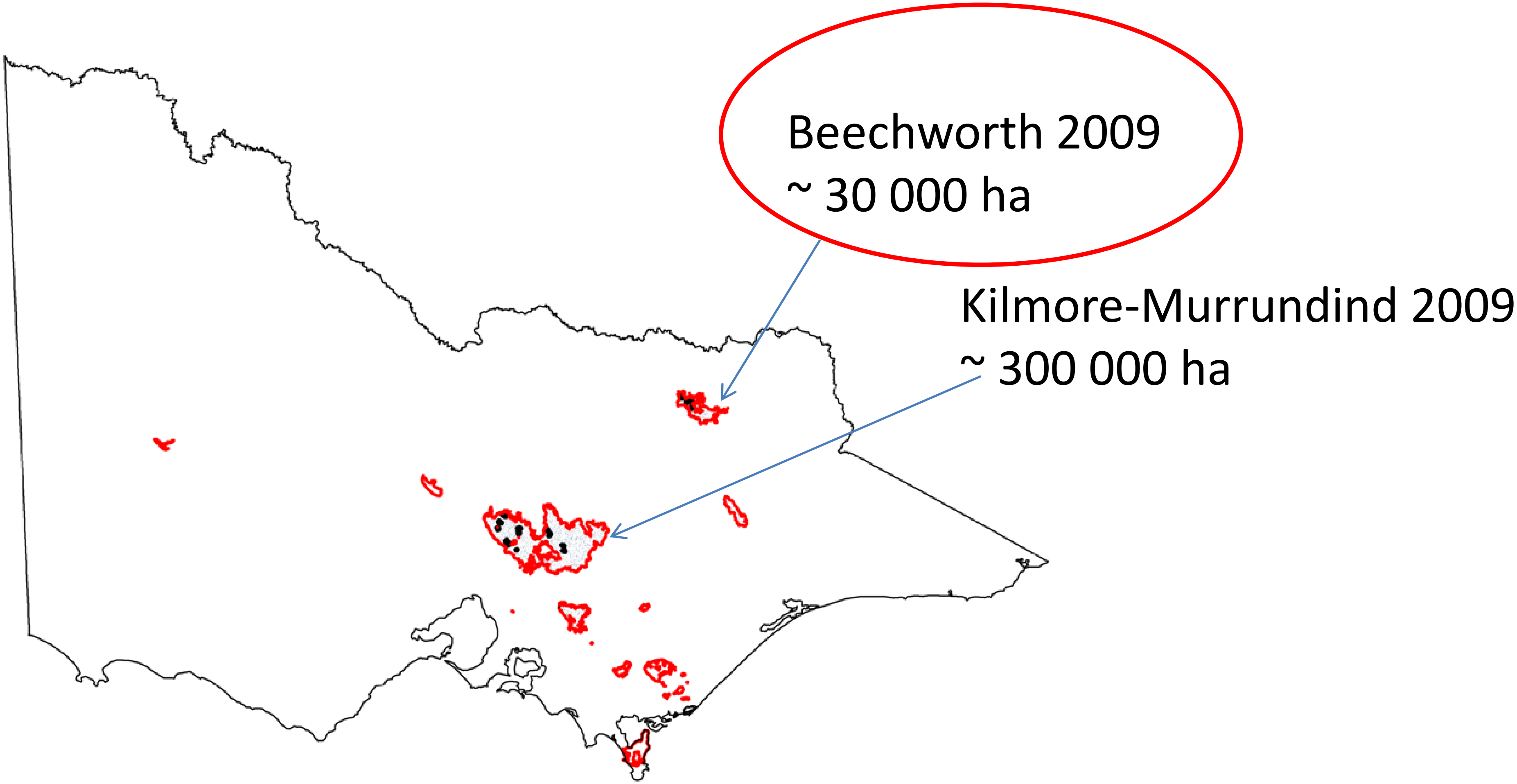
Rainfall threshold: I_{30}> 35 mm/h



Jones OD, Nyman P and Sheridan GJ (in review) Modeling the effects of climate change on extreme erosion events in forests. *Stochastic environmental research and risk assessment*

2. Landscape response to fire

---Response variable: Debris flows---

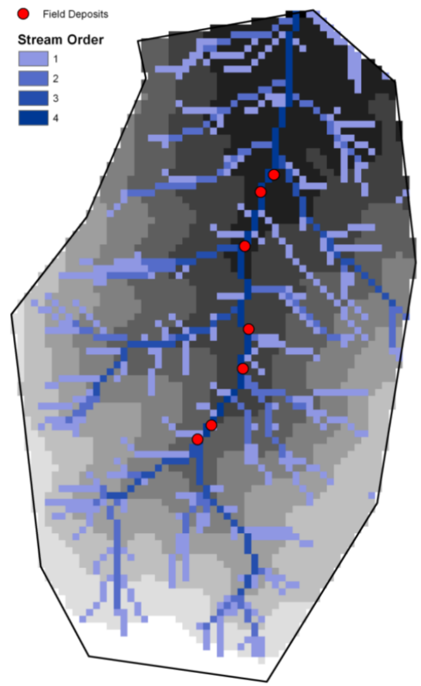


2. Landscape response to fire

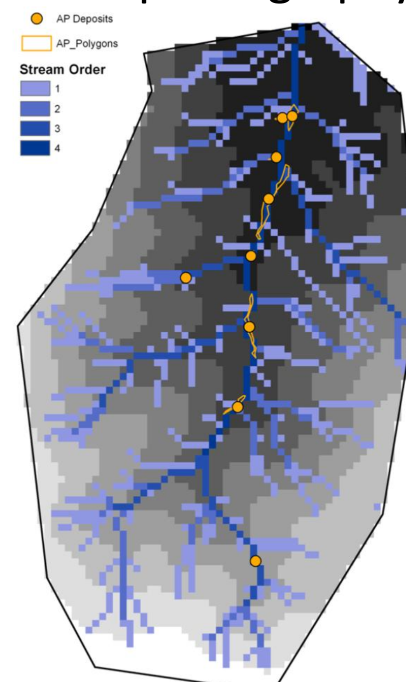
---Response variable: Debris flows---

Stanley– March 2009

Field survey

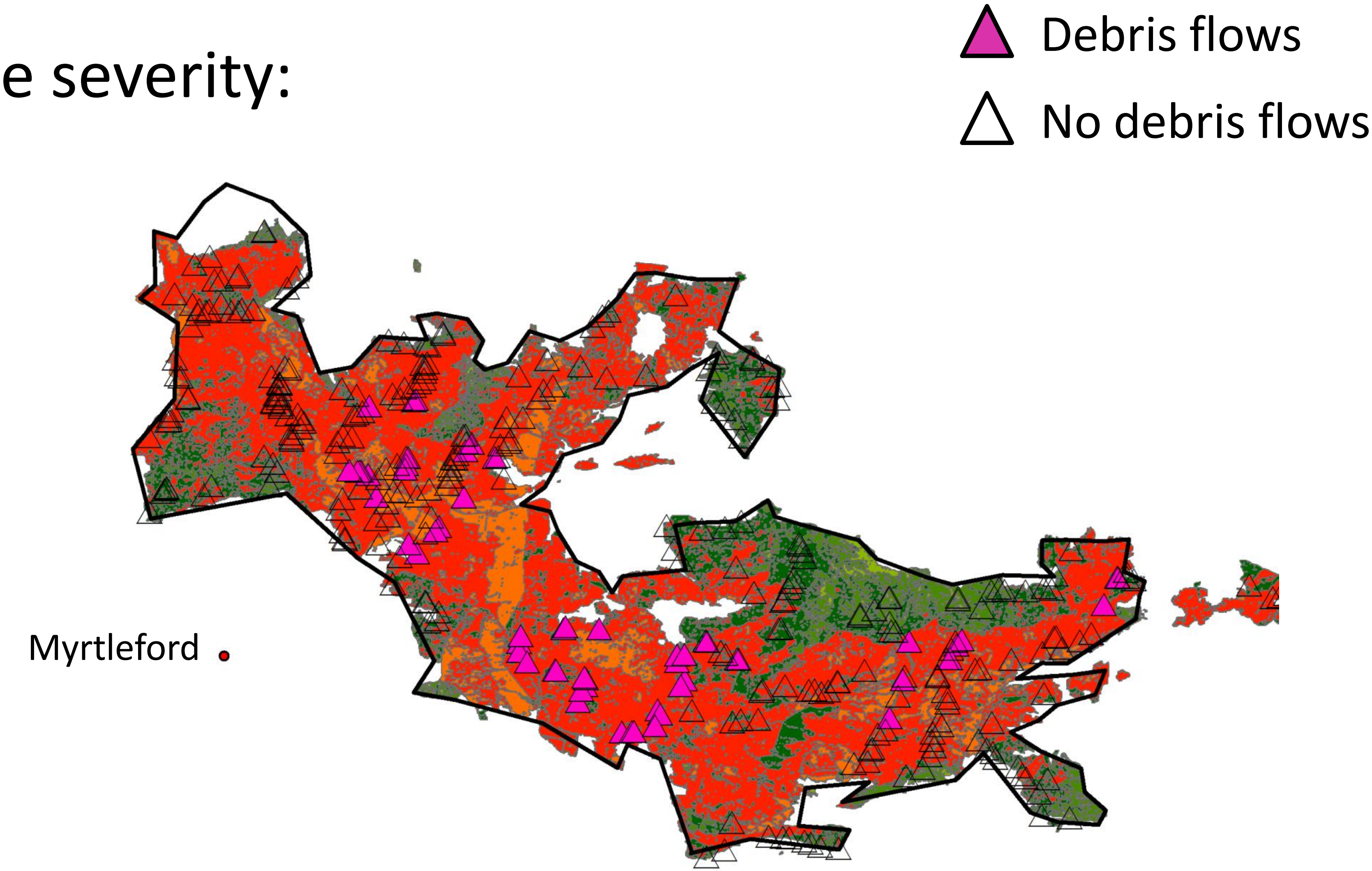


Aerial photography



2. Landscape response to fire
---Predictor: Fire severity--

Fire severity:



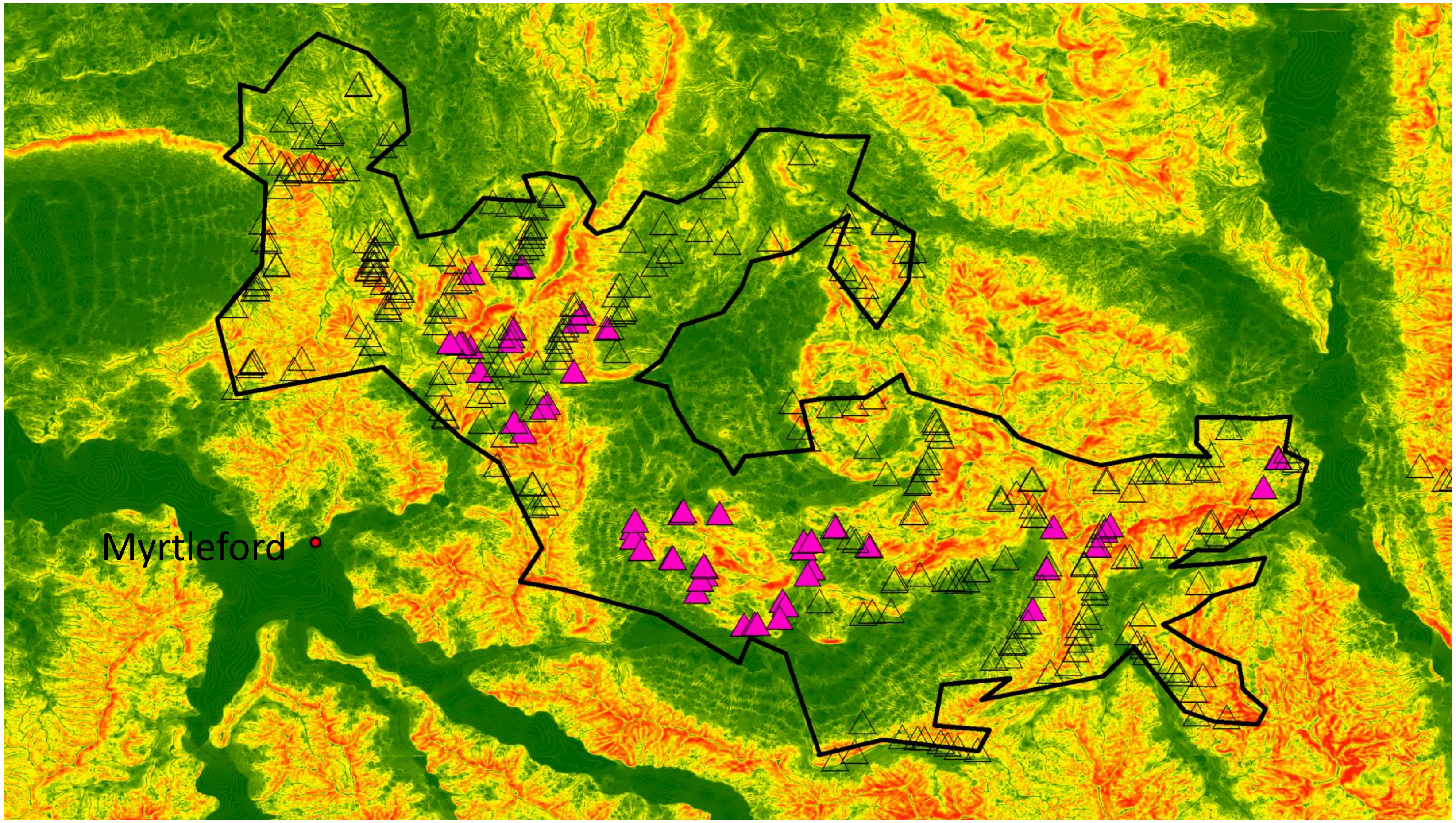
2. Landscape response to fire

---Predictor: Slope---

Debris flows

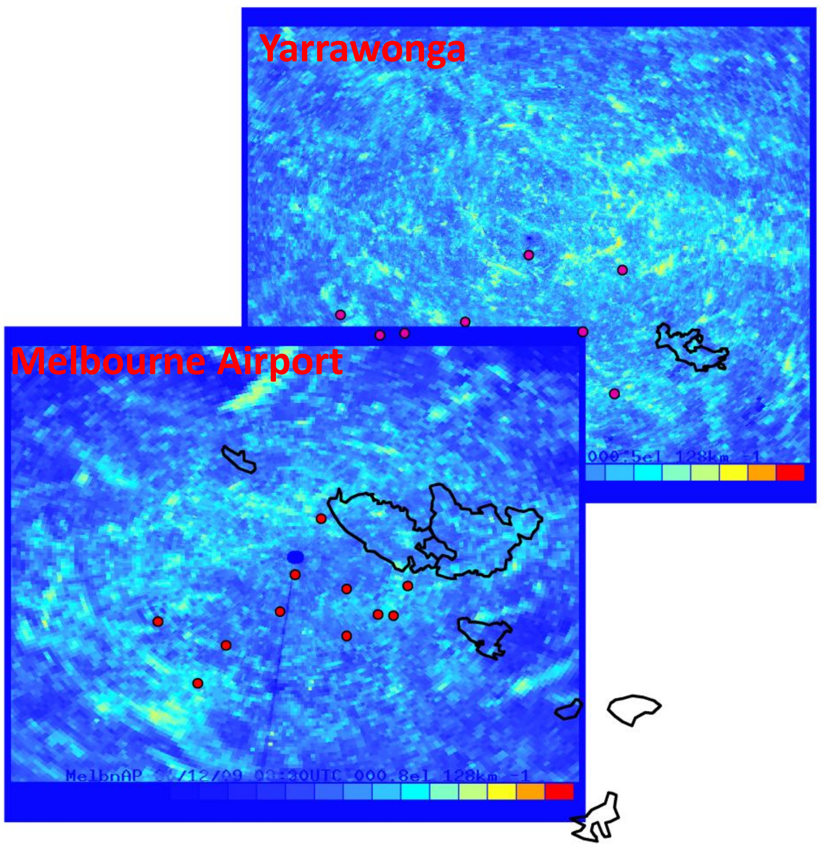
No debris flows

Slope:

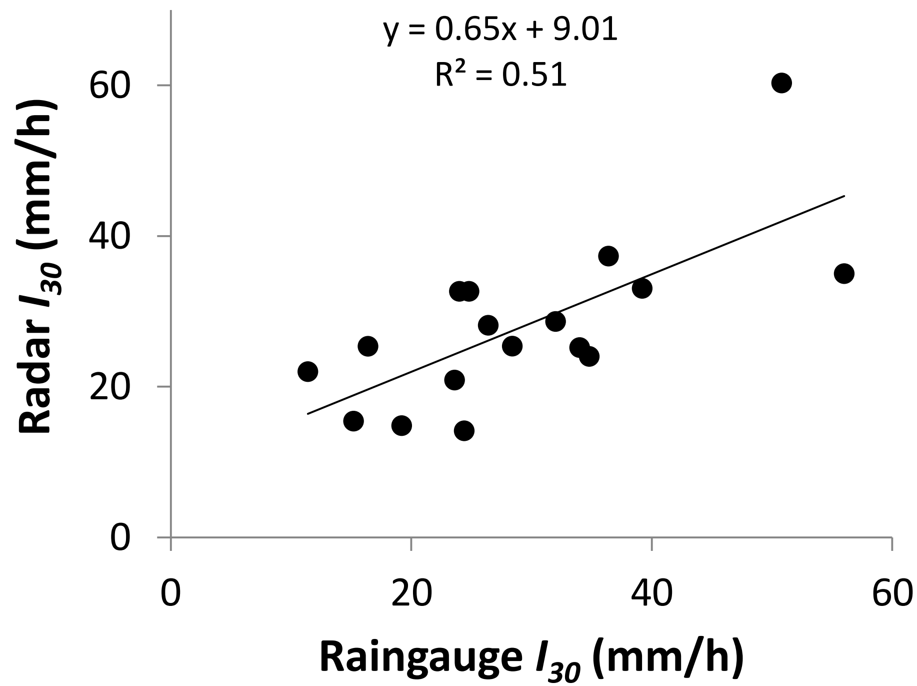


2. Landscape response to fire
---Predictor: Rainfall intensity---

Radar data
Max 30-min intensity in the 1st year after fire effect



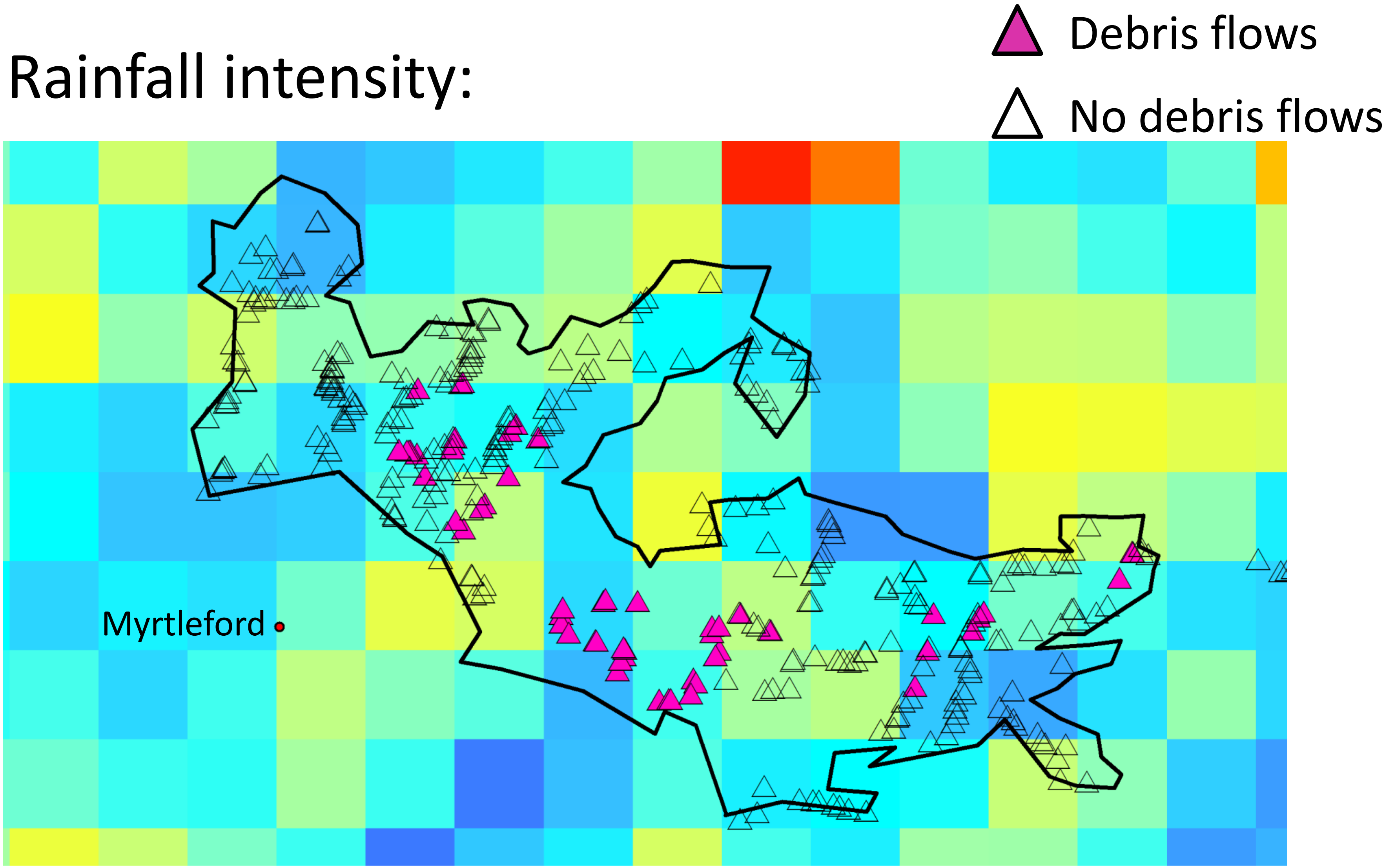
Calibration with measured rainfall
=Large uncertainty



2. Landscape response to fire

---Predictor: Rainfall intensity---

Rainfall intensity:

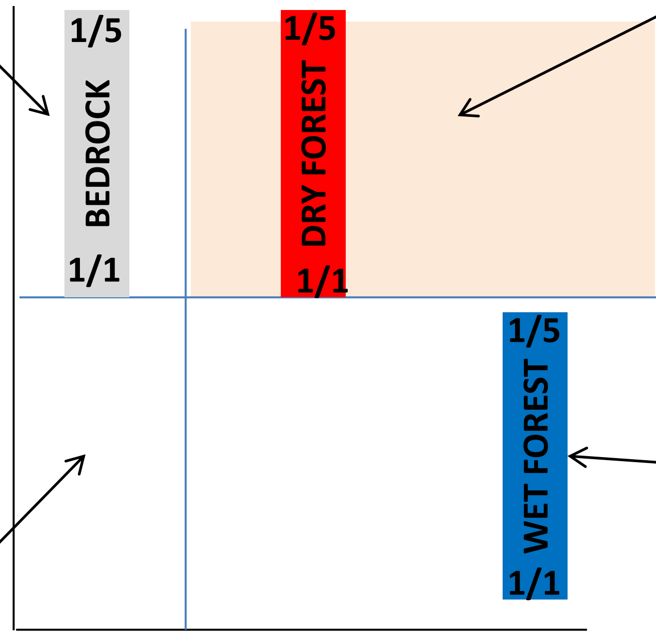


2. Landscape response to fire

---Predictor: Landscape aridity---

Sediment limitation
e.g. Mt Buffalo,
Nyman et al (2011)

High severity fire



Infiltration excess runoff

Sediment availability

DEBRIS FLOW REGION!!!
e.g. Rose River, & Yarrarabula ++,
Nyman et al (2011)

Transport limitation
e.g. East Kiewa,
Lane et al (2006)

Sediment and transport limitation…
e.g. flat rock..
Dinner Plains maybe

2. Landscape response to fire
---Predictor: Landscape aridity---

<u>Climate effects(1-5 km^{2}):</u>

-Cloud cover

-Rainfall

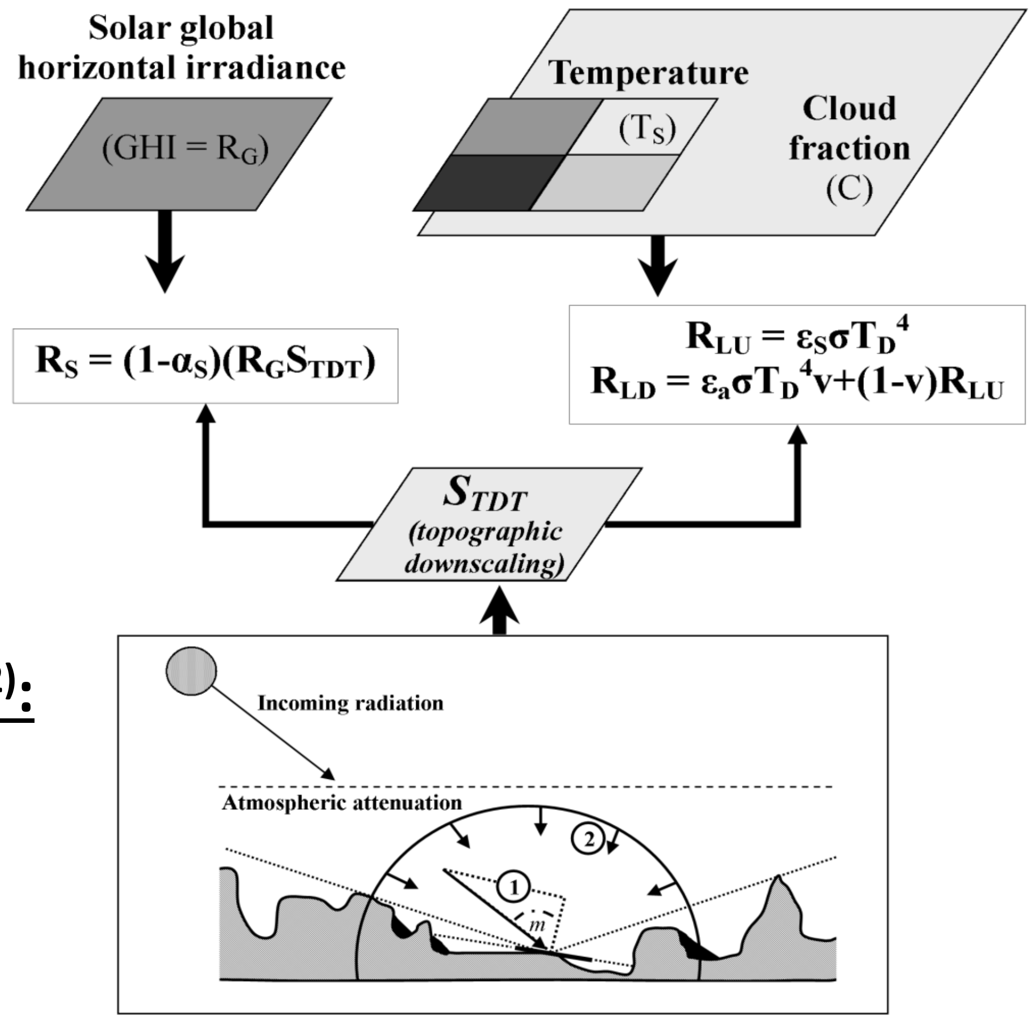
-Incoming radiation

<u>Topographic effects (100 m ^{2}):</u>

-Slope

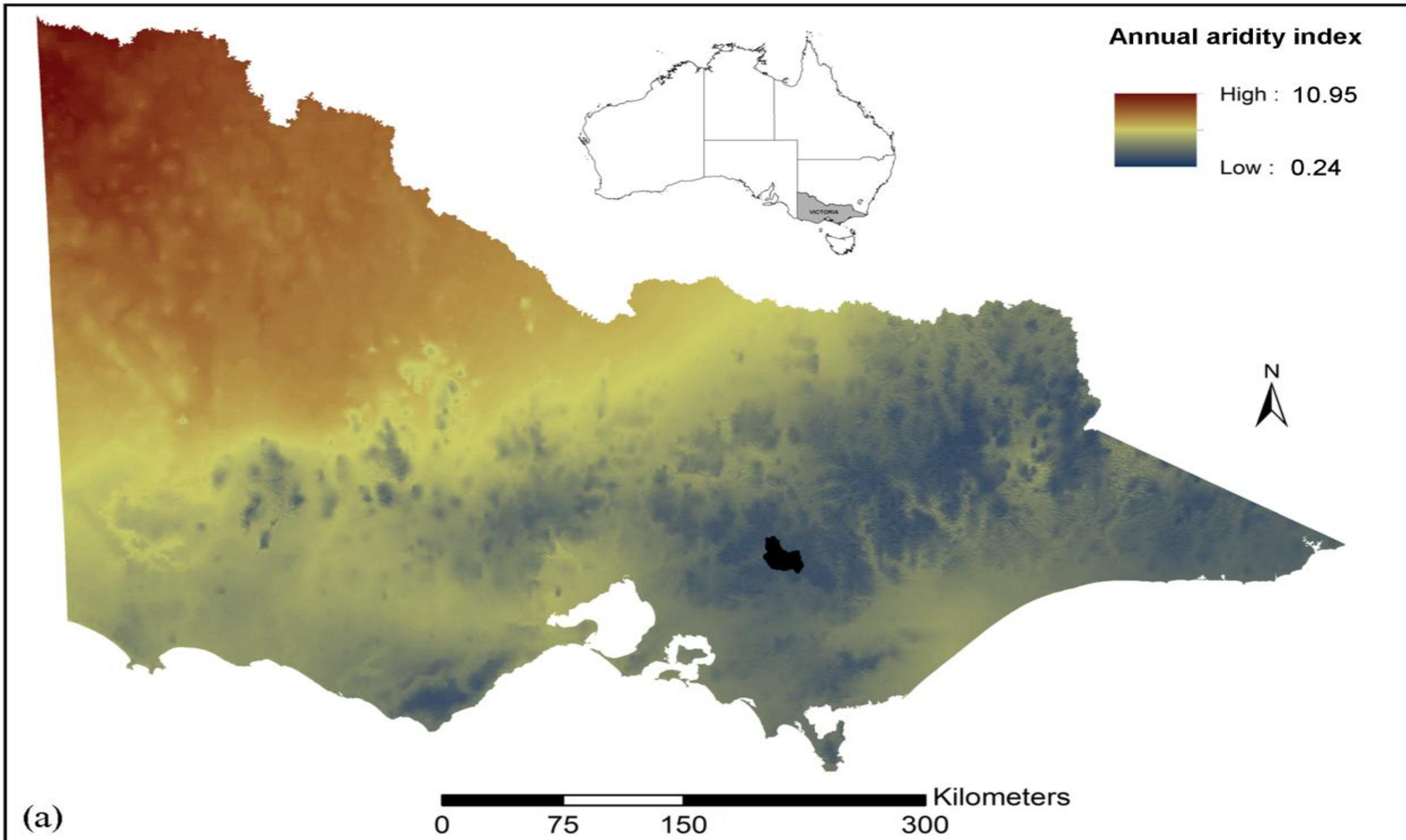
-Aspect

-Shading



2. Landscape response to fire

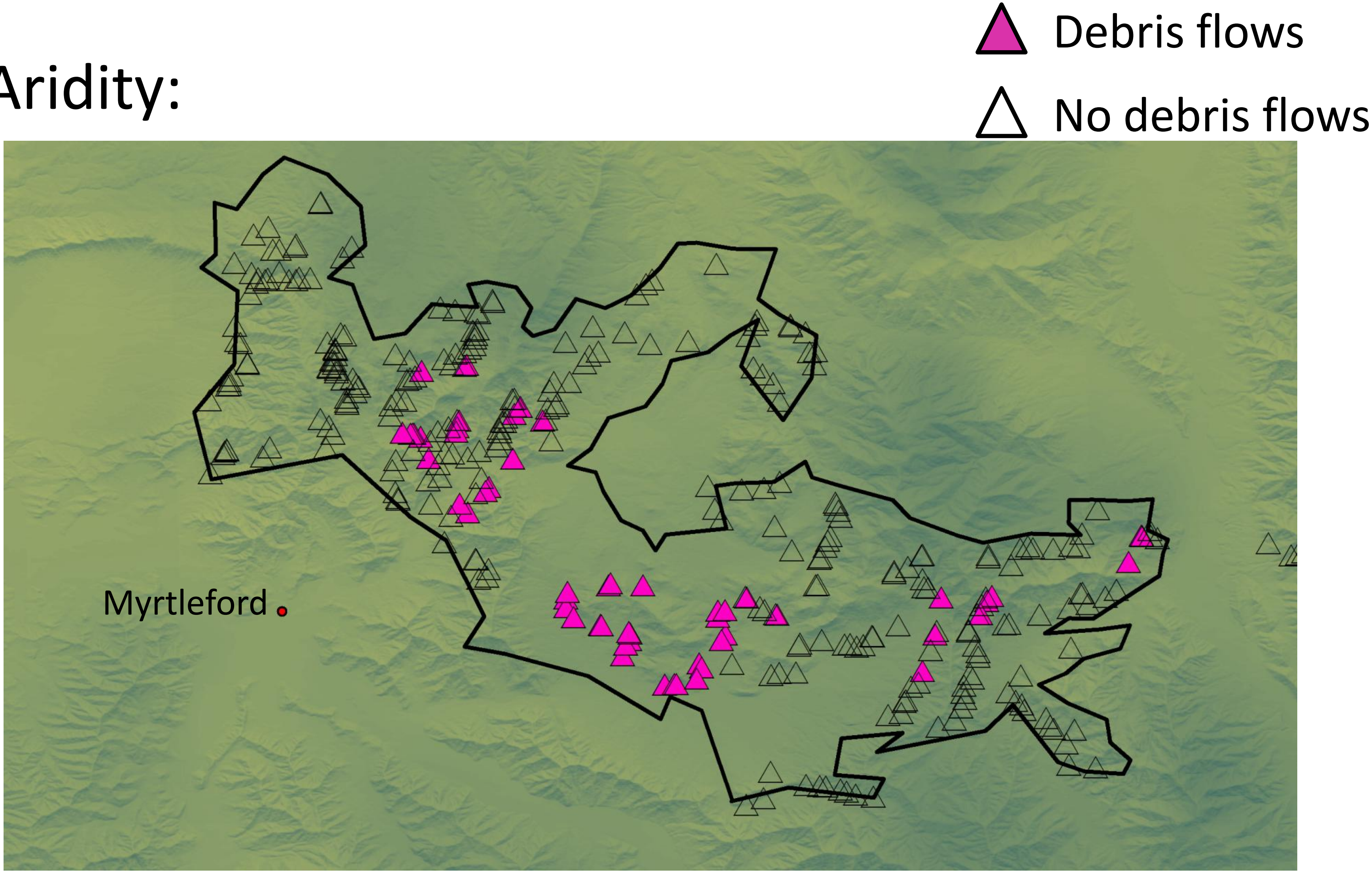
---Predictor: Landscape aridity---



2. Landscape response

---Predictor: Landscape aridity---

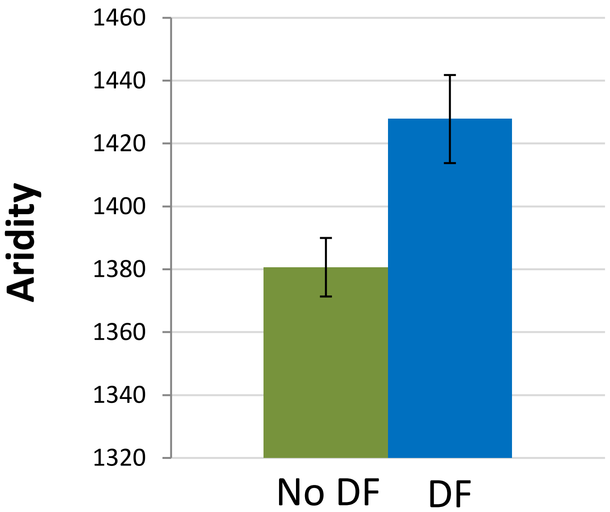
Aridity:



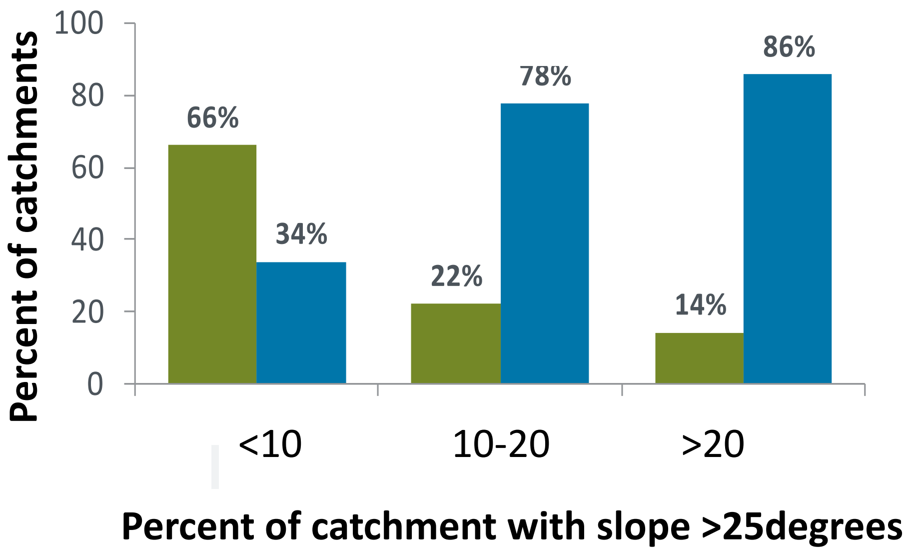
2. Landscape response
---Beechworth fire---

Preliminary results:

Debris flow occur more frequently in catchments that are drier…



And they occur more frequently when the slopes are steep



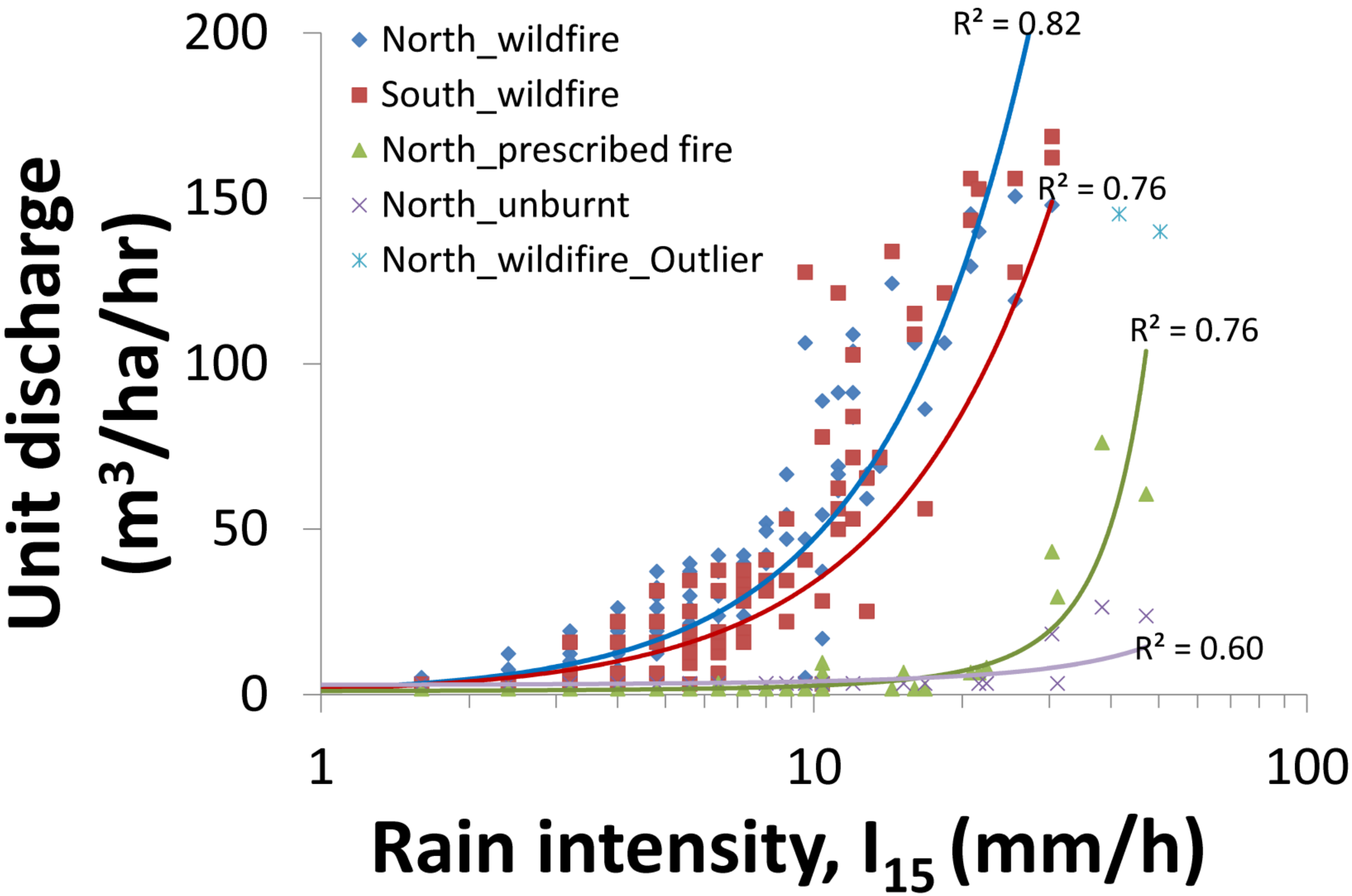
3. Runoff response to fire

---Effects of aridity and fire severity---

	North (dry)	South (less dry)
Wildfire	√	√
Prescribed fire	√	Not yet
Unburnt	√	√

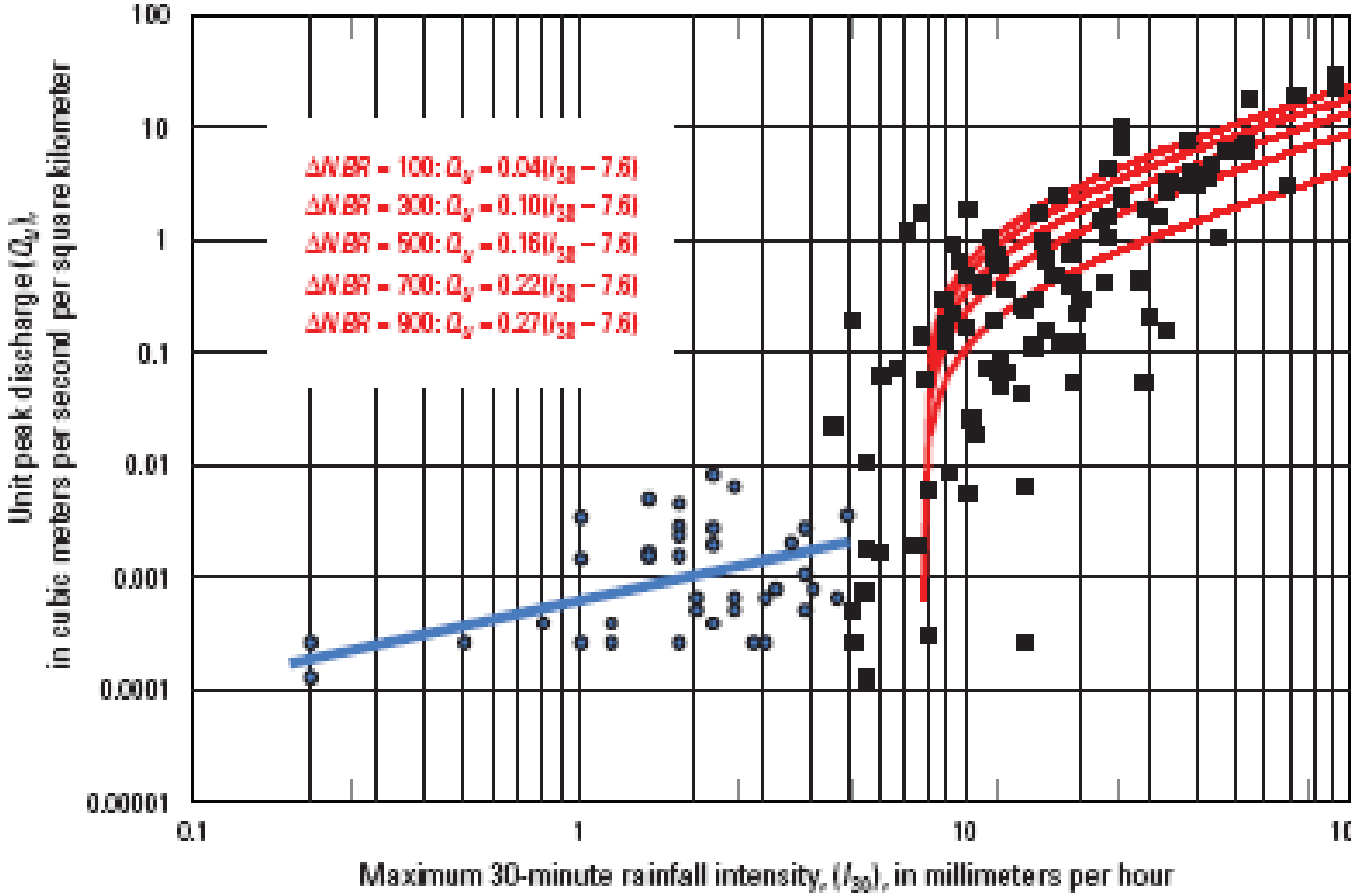
3. Runoff response to fire

---Effects of aridity and fire severity---



3. Runoff response to fire

---Runoff threshold at 10 mm/h---



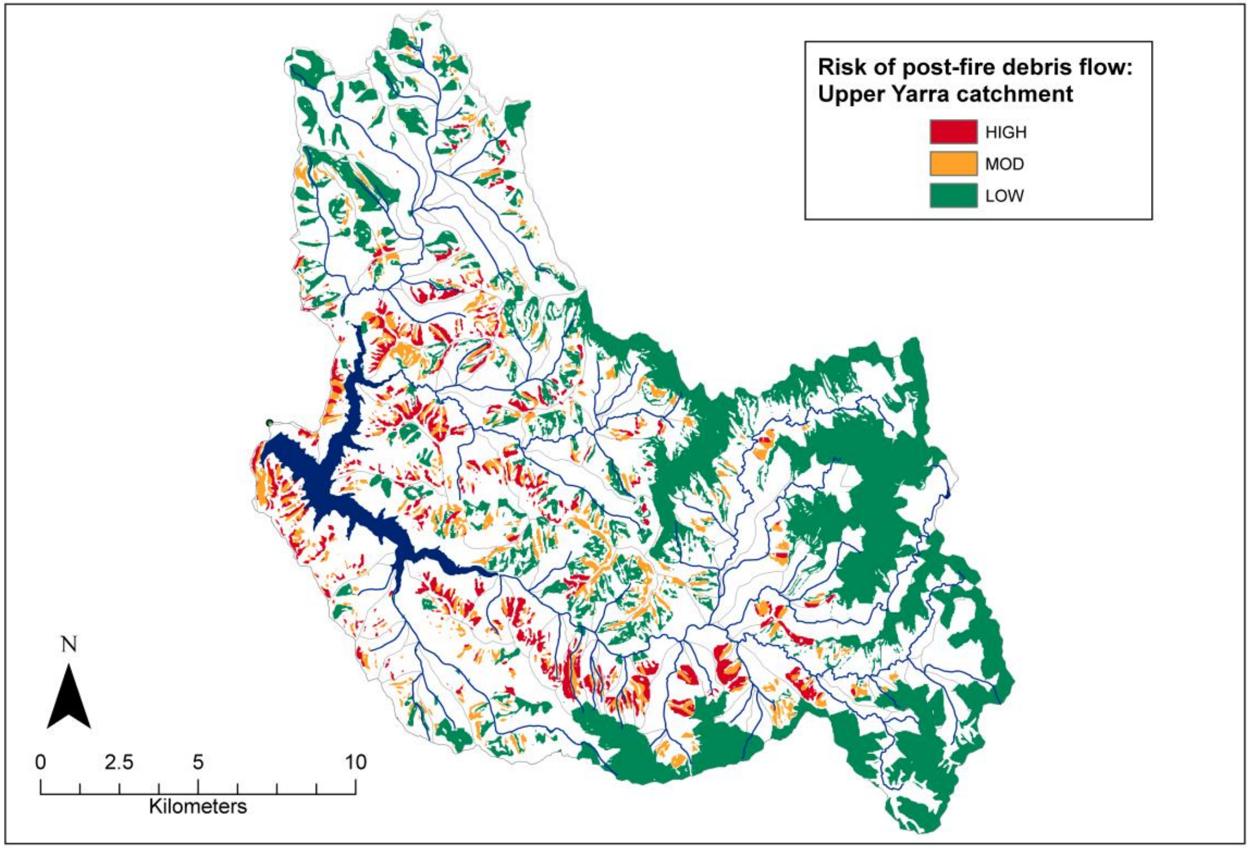
Moody (2012), USGS report

Contribution to knowledge

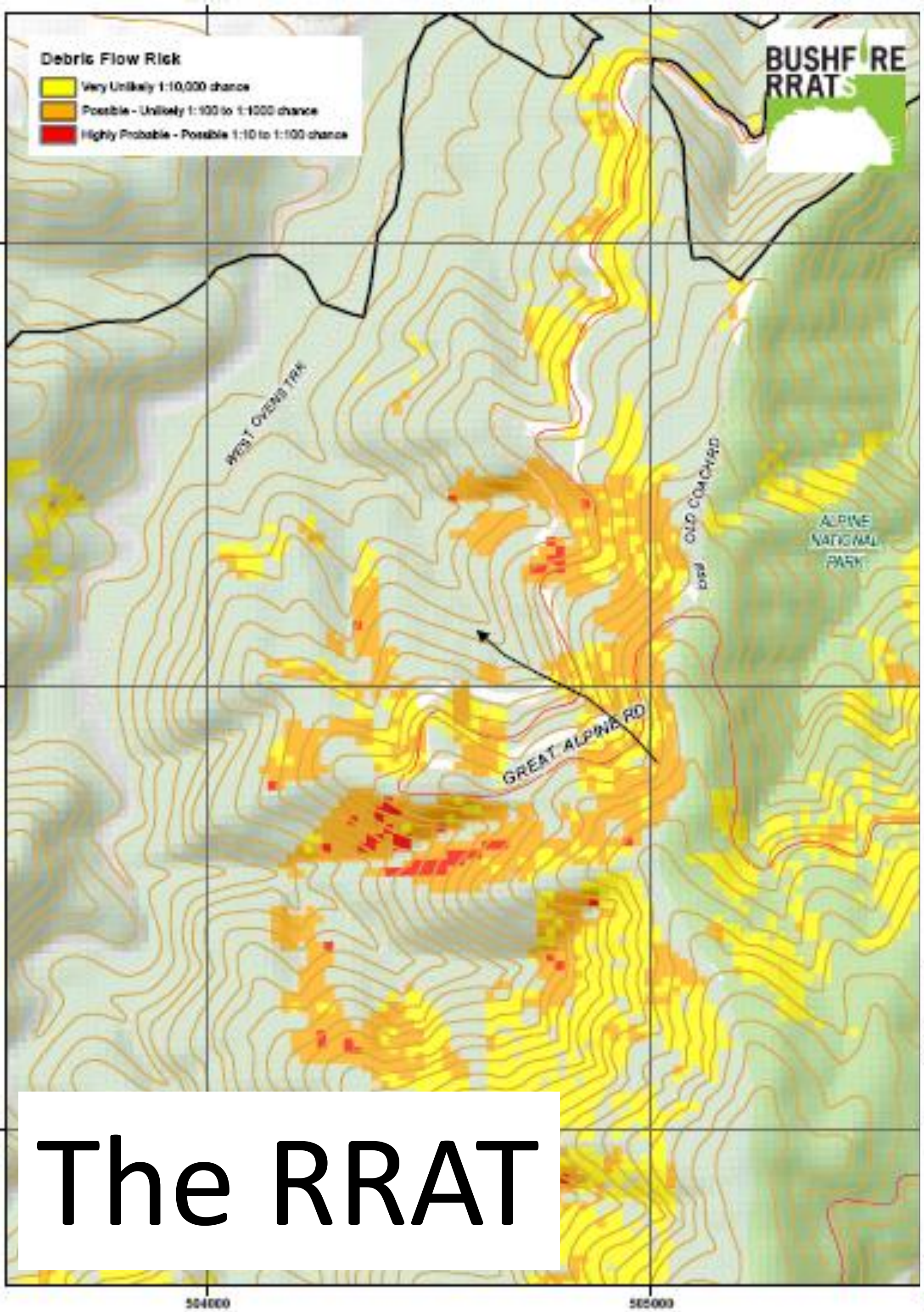
1. Improved capacity to predict landscape scale changes as result of changing fire and rainfall regimes

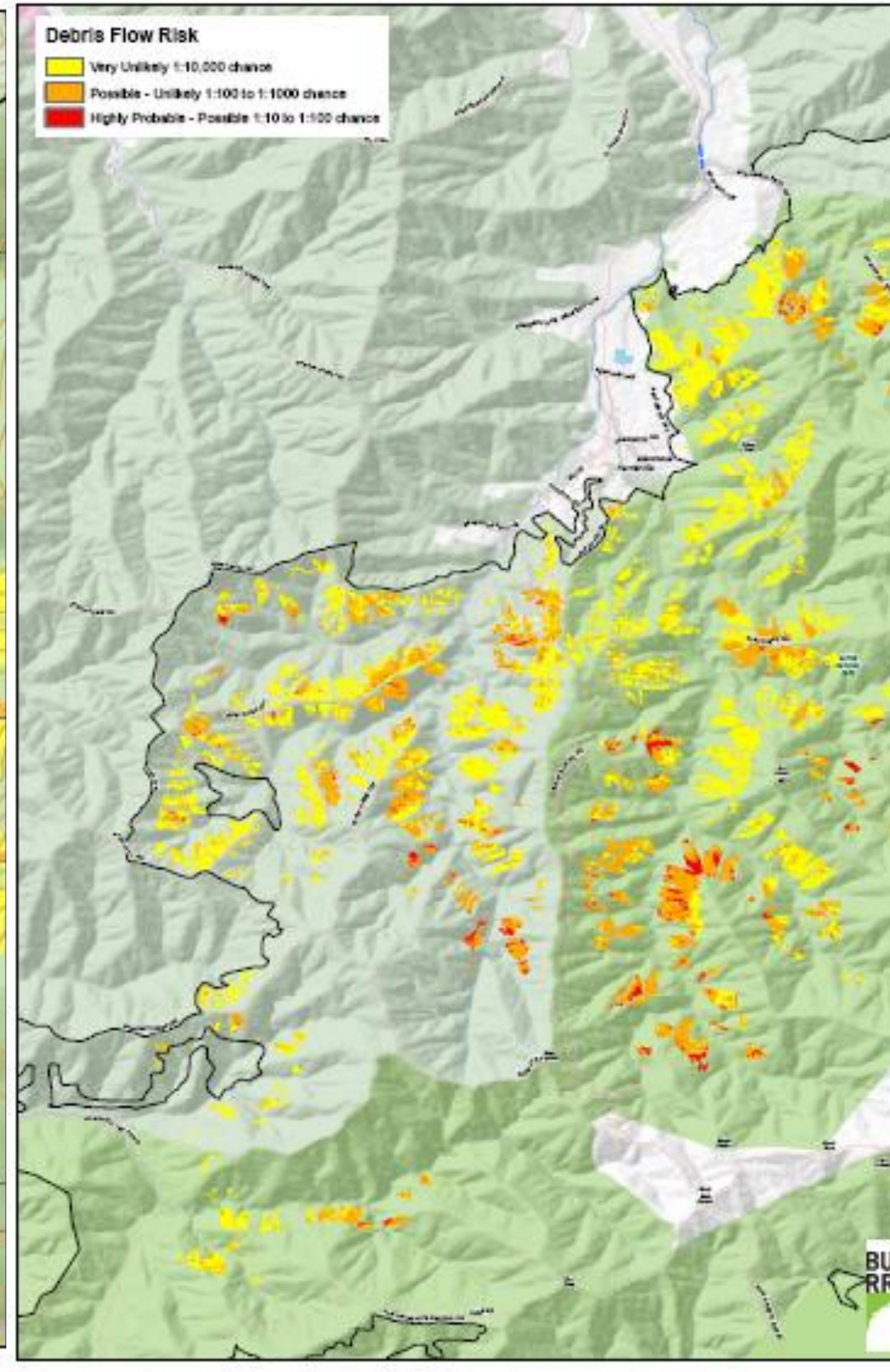
Contribution to knowledge

2. Improved representation of debris flow probability in landscapes with variable soils, rainfall and fire severity.



The RRAT


Debris Flow Risk
Very Unlikely 1:10,000 chance
Possible - Unlikely 1:100 to 1:1000 chance
Highly Probable - Possible 1:10 to 1:100 chance
WEST OVENS TRK
OLD COACH RD
GREAT ALPINE RD
ALPINE NATIONAL PARK
504000
505000


Debris Flow Risk
Very Unlikely 1:10,000 chance
Possible - Unlikely 1:100 to 1:1000 chance
Highly Probable - Possible 1:10 to 1:100 chance

Contribution to knowledge

3. Unique data on runoff processes and peak flows after fire.

Publications

Nyman P, Sheridan GJ and Lane PNJ (accepted 2013) Post-fire response models and their applications in land management. *Progress in physical geography*

Jones OD, Nyman P and Sheridan GJ (in review) Modeling the effects of climate change on extreme erosion events in forests. *Stochastic environmental research and risk assessment*

Sherwin CJ, Nyman P, Langhans C and Sheridan GJ (in prep). Combining satellite measurements and topographic downscaling to model variability in net radiation and aridity index. *Australian Meteorological and Oceanographic Journal*

Nyman P, Sheridan GJ and Sherwin CJ (in prep) Quantifying debris flow frequency in areas burned by large catastrophic wildfires and small patchy prescribed fire. *Geomorphology*

Jones OD, Nyman P and Sheridan GJ (2011) A stochastic coverage model for erosion events caused by the intersection of burnt forest and convective thunderstorms. 19th International Congress on Modelling and Simulation, Perth, Australia, 12–16 December 2011. http://www.mssanz.org.au/modsim2011/E12/jones.pdf

Nyman P, Sheridan GJ, Jones OD, Lane PNJ (2011) Erosion and risk to water resources in the context of fire and rainfall regimes. (Ed. RP Thornton). In 'Proceedings of Bushfire CRC & AFAC 2010 Conference Science Day', 2011, Sydney, Australia

Nyman, P (2012) Erosion risk to water resources in fire and rainfall regimes. Bushfire CRC Fire Note.

Thank you