WATER QUALITY RISK FOLLOWING WILDFIRE: CHARACTERISING THE HYDRO-GEOMORPHIC SENSITIVITY OF LANDSCAPES

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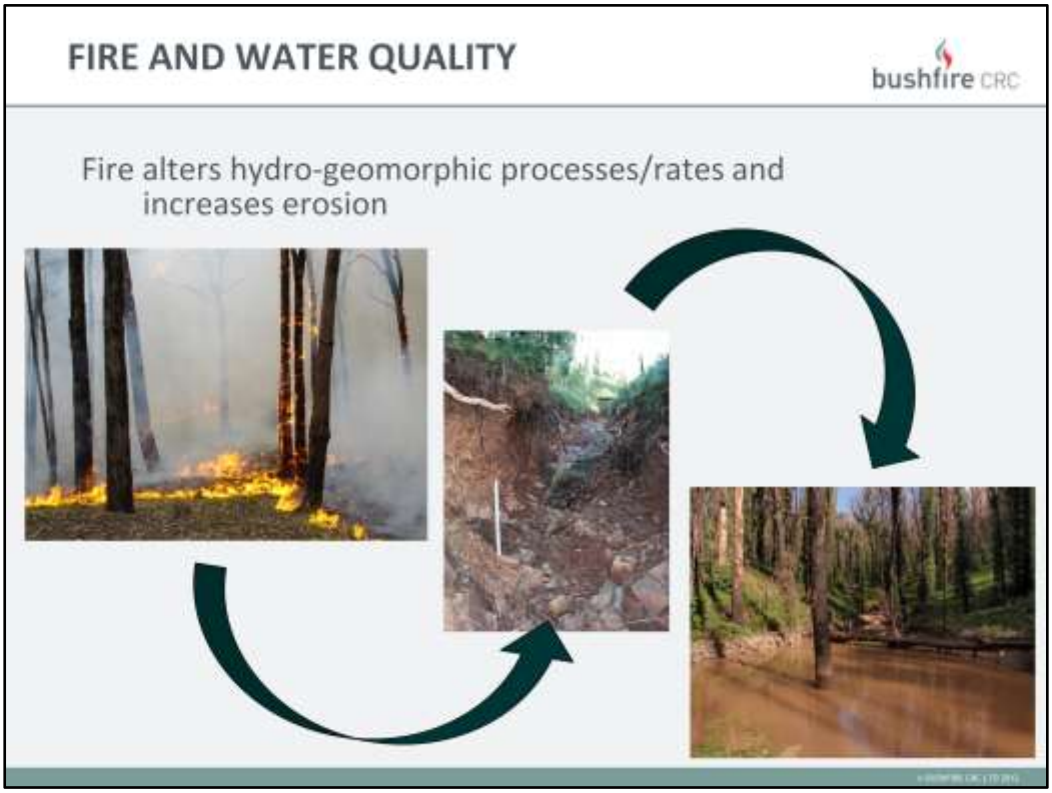
Good afternoon ladies and gentlemen. My name is Rene and I am 10 months into my PhD with the University of Melbourne, funded by the Bushfire CRC. Today I will be taking you through my research. My project is part of the ‘fire in the landscape’ series, more specifically my studies are designed to compliment others in the University of Melbourne working towards ‘quantifying water quality risks following wildfire’.



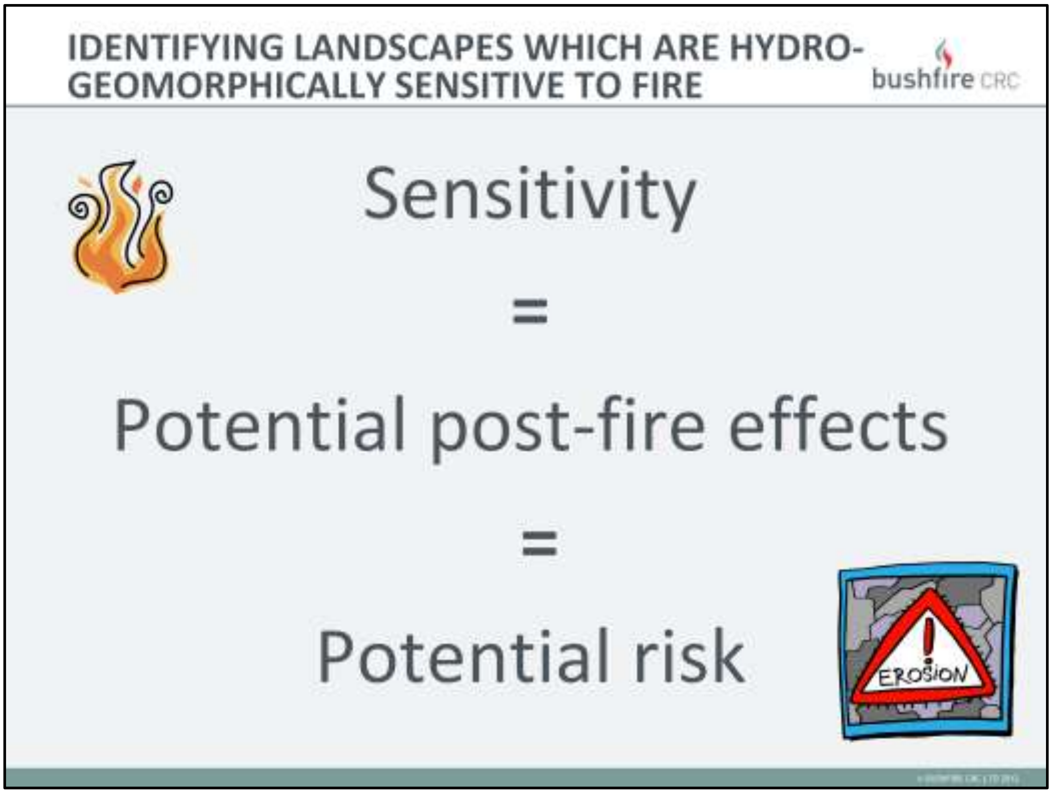
I’m sure you are all familiar with the effect of bushfire but here’s a quick rundown from the water quality perspective.

Fire burns away the vegetation of a forested catchment and alters the soil properties. When it rains, this leads to erosion from the hillslopes and channel, which results in poor water quality.

Sometimes so poor that it is unable to be treated for human use. In addition to the water quality issues, erosion after fire, especially large erosion events such as debris flows, can damage infrastructure and threaten lives.

So, the impact of fire on a forested water catchment can have very serious flow on effects for water supply, and the community. Making these catchments and important asset, requiring careful management and protection.

An important part of that management is knowing what to expect after a fire. I’ve given a basic rundown here but, not all landscapes, catchments or hillslopes will be affected to the same degree by fire.

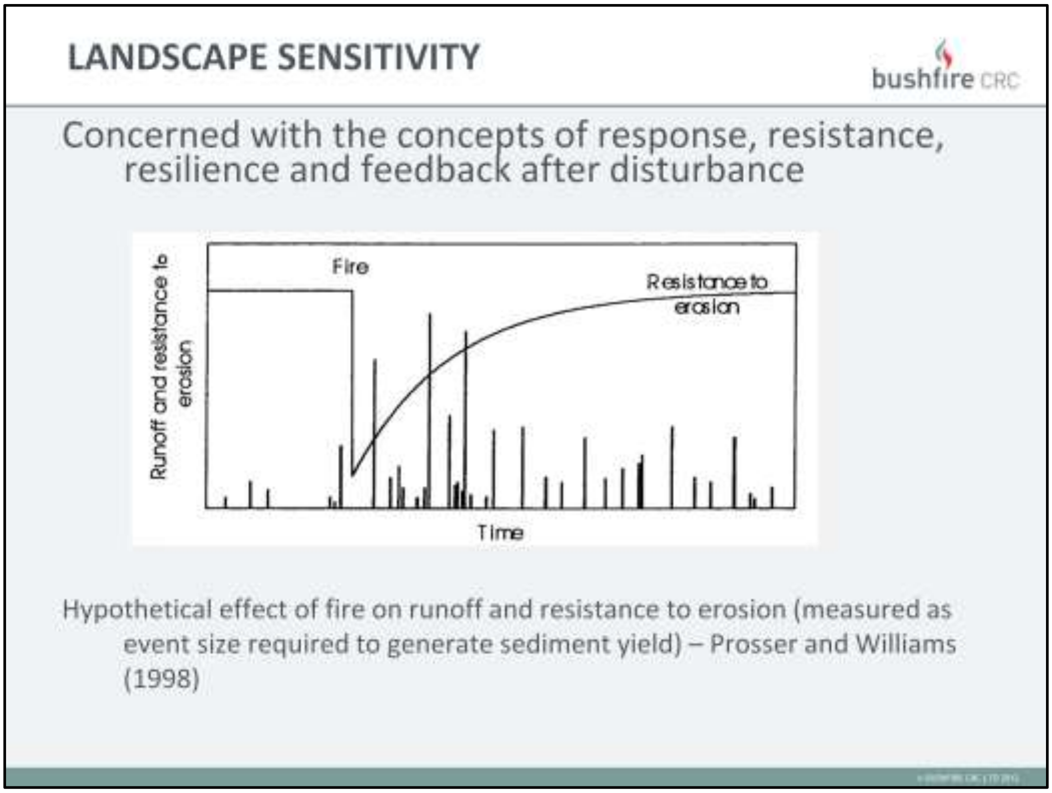


For example, the wildfires in Canberra in 2003 burnt the forests surrounding the cotter river catchment, where approx 60% of Canberra's water supply was sourced. The fire and subsequent storms resulted in such high sediment loads that this water was untreatable. An alternative water source, the Googong dam, was available but it was not capable of meeting peak demand . This situation prompted the city to not take its water for granted and resulted in the building of a 38million dollar new flocculation and filtration plant . An expensive solution.

In contrast with this result. During the black Saturday fires of '09 approximately 30% of the North eastern section of Melbourne water catchment area was burnt, with no real impact on water treatment at all.

So, what can we deduce from this? These observations suggest that some landscapes appear more hydro-geomorphically sensitive to fire than others. Logically it follows that the greater the sensitivity of an area, the greater potential of extreme adverse effects following fire and the greater risk.

The objective of my study is to develop a method for identifying sensitive post-fire landscapes, through studying this hydro-geomorphic sensitivity and investigating its causes.
Why? To aid management decision making
Before a fire: - where is fire mitigation best placed – where should we put resources into fire breaks or fuel reduction
During a fire – we know the value of protecting a particular area – water supply is an asset like any other and we need to know what the danger is to the asset and its value
And after – is remediation (eg. building log dams) needed – where will it be most effective?

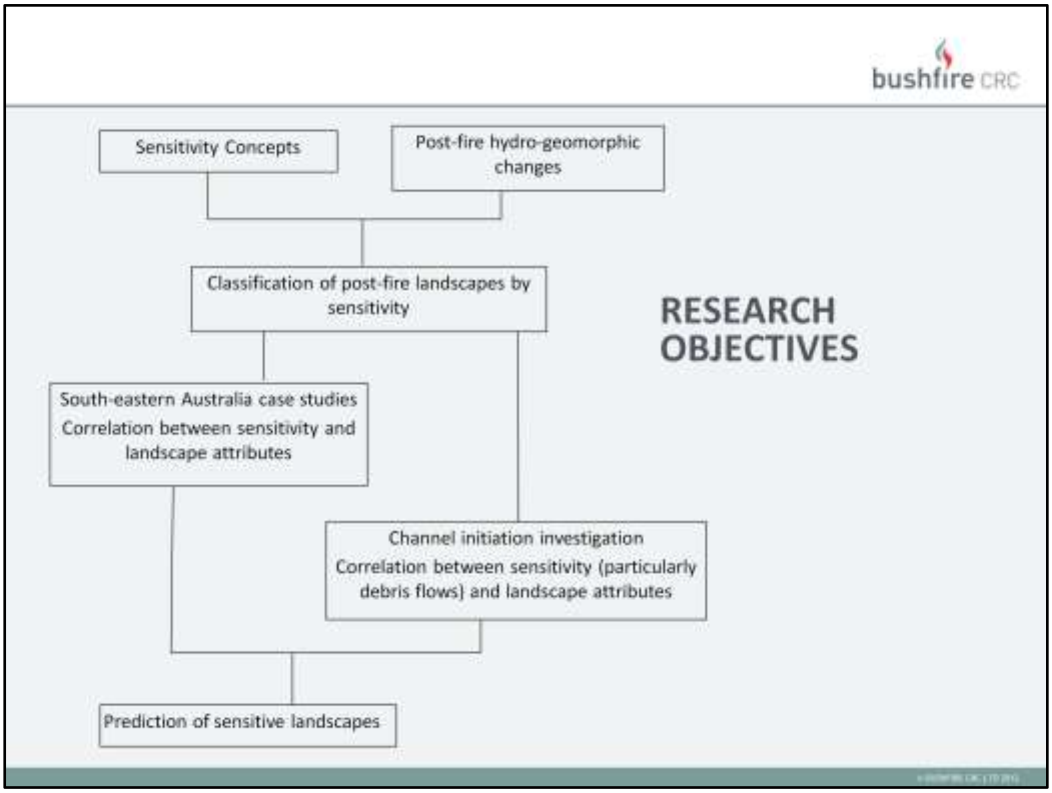


What do I mean when I talk about sensitivity?
Well landscape sensitivity is linked with stability (or instability) and stability is a balance between two major forces: The external force acting on the landscape (in this case fire) and the resistance of the landscape to change. When investigating sensitivity we are also interested in the resilience of the landscape (how quickly and by what path it returns to a pre-fire state) and internal feedback mechanisms which might reduce or enhance the response.

When I talk about hydro-geomorphic sensitivity I'm specifically interested in changes to water and soil movement. And here is an example – this graph shows a hypothetical situation, it shows fire lowering the resistance to erosion threshold and thus increasing runoff erosion. Over time this effect is reduced as the system recovers to a pre-fire state. So, this dip here is the one of interest, as well as this time here. In this theoretical landscape the threshold is lowered this amount, but in another on that is less sensitive it might only be lowered this much – or recovery might take this long.
So, sensitivity is concerned with the change in thresholds or processes, not in the absolute value of eg annual runoff.

The concepts of landscape sensitivity have been used to investigate the impacts of climate change and land use change but have rarely been applied to the area of post fire research (except for this one graph that I have located).

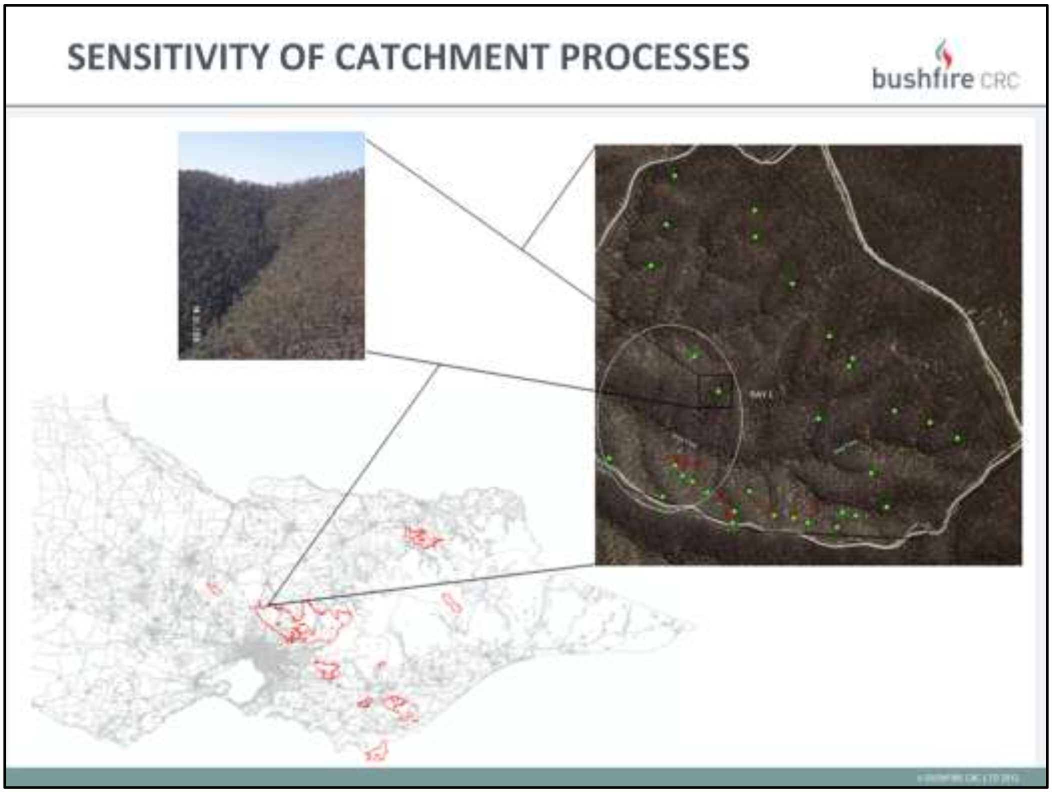
But, They could be applicable in this area and I believe could be developed into an assessment framework, which would allow the comparison of many different post-fire investigations at many different levels. Because, not only are the hydro-geomorphic response of landscapes to fire different, but the ways in which they are measured a different also. Sensitivity (as a unit less set of concepts) could provide an overarching framework to compare studies, even when the units or scales used are different.



In this project I will be using the sensitivity concepts and fire research concepts to create a method of assessing sensitivity at two different levels.

At a large scale I will be investigating sensitivity of South-eastern Australian landscapes. This area is a good place to do my research for several reasons:
-The area is effected by large wildfires, fairly frequently and climate change research suggest this may increase into the future
- SE Aust. Covers a number of unique landscape types which have been observed to have varying responses to fire.
-For example,
-RA Shakesby of the University of Wales and colleagues expected substantial post-fire erosion at their study site in Nattai NP, SW of Sydney, due to the highly erodible nature of the sandy subsoil – yet after the 2011 fires this was not observed.
-By comparison in the dry forests of NE Victoria, Petter Nyman of the University of Melbourne documented extreme erosion, in the form of debris flows, following the 2009 fires
-- Lastly research into post fire hydro-geomorphic effects in south eastern Australia is relatively limited, a case study would bring together the current body of work, increase knowledge in this area and help to identify gaps for future research.

The second part of this project is an investigation of the causes of sensitivity at a small scale...and this is what I'm going to go into a bit more detail on today



My investigation of sensitivity at the smallest scale, starts right at the top of the head water, where the hydro-geomorphic processes switch from passive to active (in sediment transport terms). For this part I am investigating single head water channels.

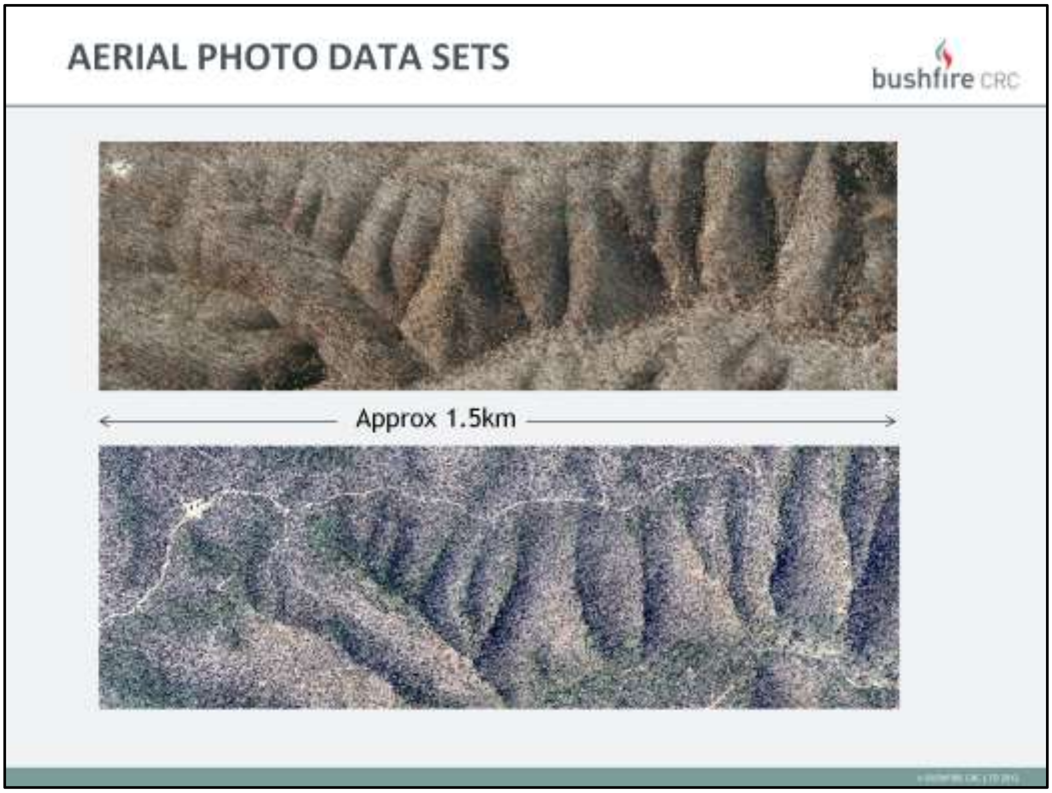
The reason I'm looking in this area is because, this is where it all starts. This is where sediment is activity eroding, where debris flows start. It's where an energy threshold is reached (where the overland flow has enough energy to cut down into the soil – to move it down hill) and thresholds are a great way to investigate sensitivity.

The sorts of things which the literature suggests are likely to effect sensitivity at this scale are:
Soil availability
Dryness (radiation compared with precipitation)
Forest type
Resilience (speed of forest regeneration)

So, this is a great place to look for sensitivity on a small scale. There is just one problem, there is very little data at such a fine scale. Research into single catchments is resource intensive. Especially if they are in remote areas, and even with reasonable access it can take hours to walk to, and take measurements of a single point. Small scale investigations involve lots of field work and so when they are done, they are usually only done in a specific area, they aren't done over a wide range of landscapes.

But I want my study to be applicable in many areas, I want to be able to relate my results back to the SE Aust landscape level I talked about earlier.

So, how can I gather the data I need on sensitivity, over a wide enough area to give meaningful results?

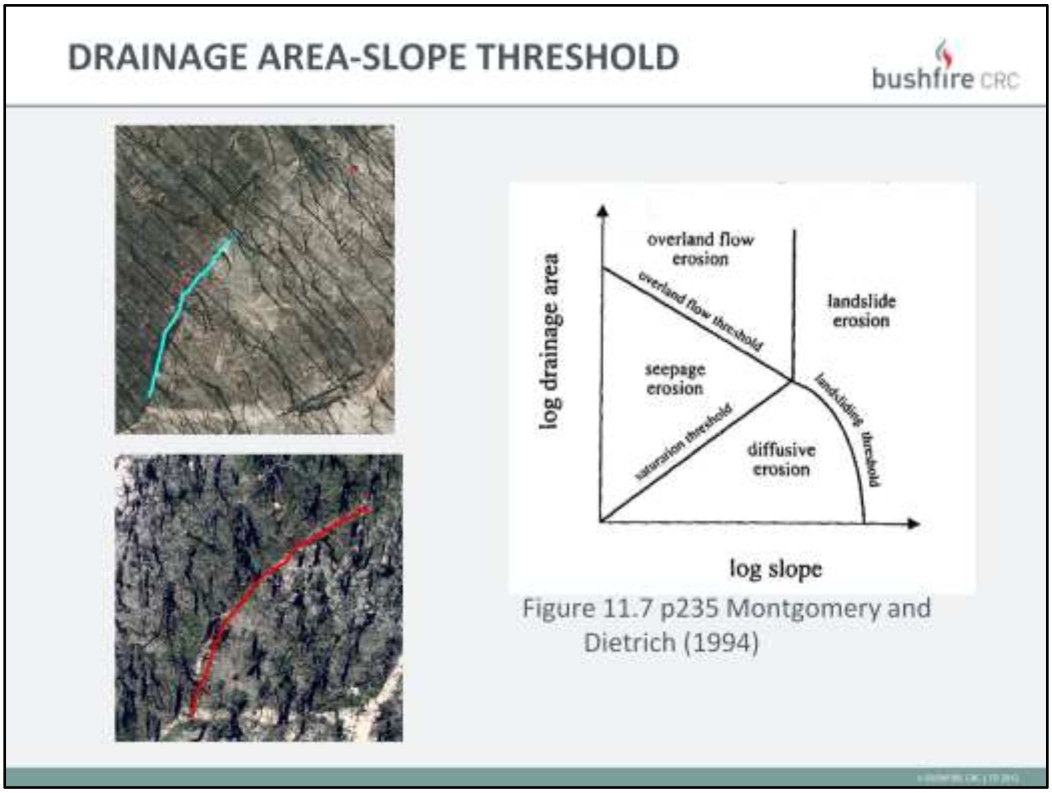


The answer is, remotely.
In this study we are taking advantage of a fairly unique opportunity. We have access to aerial photo datasets taken shortly after the 2009 black Saturday fires occurred in Victoria, and then one about 10 months later of the same area. These photos, therefore, allow us to observe the channels as they were before the fire compared with nearly a year after.

In addition to the timing of the photos, this fire is unique because both the intensity of the fire and the rain storms which occurred the winter following the fire, mean that these areas were exposed to a lot of external forcing, which is not something you always get when studying a natural environment.

This aerial dataset also covers over 300,000 ha , it includes dry, damp and wet forest types, a range of soil types and catchments covering the range of aspects/radiation levels. It also includes parts of the upper Yarra valley water catchment and Beechworth forests where debris flow activity has previously (and is still) being investigated by other members of our group at the University of Melbourne.

So, how can we use this fantastic resource to get a heap of data on erosion at small scales.
Well. We use it by comparing the changes between the first and the second set.
Because the first set is taken so soon after the fire (before any major rains) we can assume that it shows the landscape as it was before the fire, but with the added bonus that there is basically no vegetation in the way, so we can see them! With normal aerial photos you cannot usually identify much visually, which is why LiDAR and other multi spectral information is needed.
Now, these pictures aren’t quiet zoomed in enough, but if they were you could see evidence of post-fire erosion. So we can see it, but how do we translate that into hydrogeomorphic sensitivity? How do we tell what areas were effected the most?



What I’m proposing is to look at the movement of channel initiation points. The reason I’m looking in this is as a proxy for the movement of the sediment movement threshold.

Channels form where sediment transport processes change from diffuse to active transport. Most relevant in this project is where overland flow as measured through contributing drainage area and slope) is great enough to overcome the erosional resistance of the ground surface.

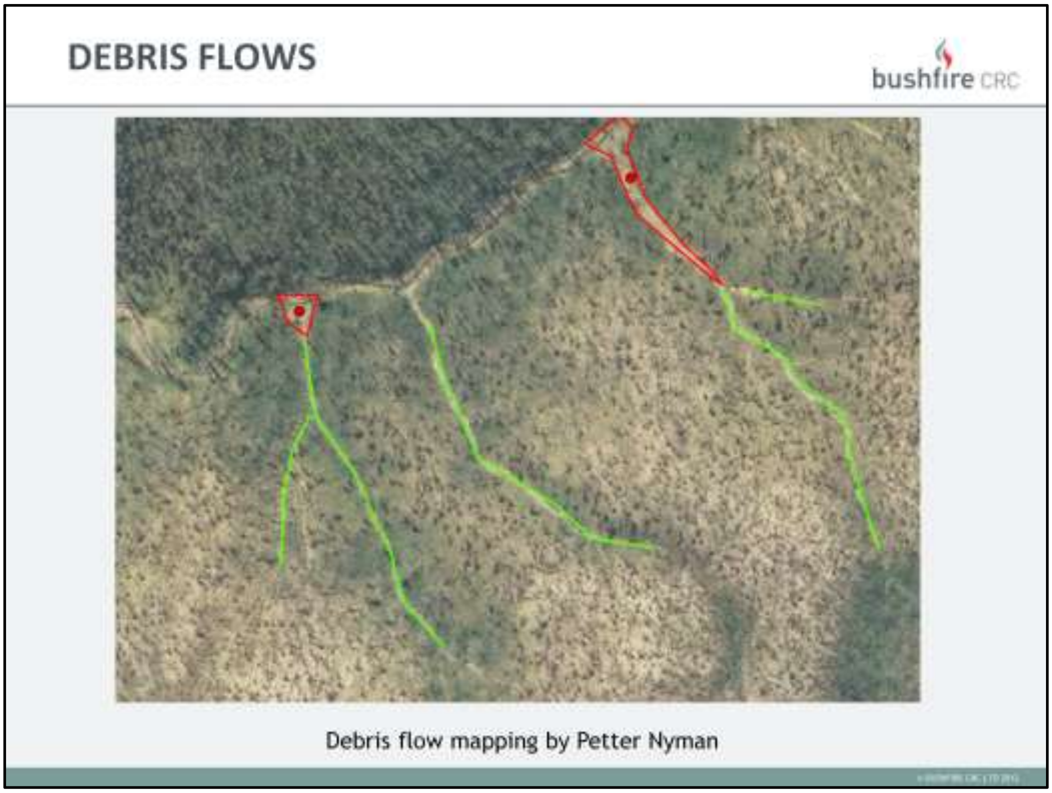
The graph (taken from Montgomery and Dietrich 1994) illustrates the division of landscapes by process regime, according to the contributing drainage area and slope. Catchments below this line are only subject to diffuse erosion and will thus be unchanneled, catchments which fall above the overland flow thresholds will have runoff initiated channels.

This graph is based on studies under normal conditions. However, after fire these thresholds can move, causing the channels to start higher in the catchment.

And the greater the movement, the greater the sensitivity...

Information, gained from the aerial photo dataset, should immediately provide a huge amount of data on the sensitivity of individual channels. This information will then be linked to attributes such as radiation/precipitation balance, aspect, vegetation type, soil type/availability.

But, for this to be able to work, to be able to get this data, first I need to work out if I can pick the channel ignition point (or zone) from the aerial photos. As far as we know, no one has ever used this method before. So I’m out in the field trying to answer this question right now. What is the error involved in picking these points and what kind of method can I use that will minimise this error?
I don’t have answers on this one yet, but I’m excited to find out.
So, I can hear you thinking, what if it doesn’t work?



That’s okay because there are lots of other things we can use as a measure of sensitivity, like which channel produced debris flows compared with which channels didn’t. These extreme erosion events usually take a lot of energy to initiate under ‘normal forested conditions’, only one study in SE Aust, undertaken by Ian Rutherford, then of Monash University and his colleagues documents the occurrence of debris flow unrelated to fire, these occured after record flood (with a 50 year recurrence interval).

The fire and subsequent storms in ’09 produced was an event which lowered initiation thresholds enough to produce debris flows in many catchments across the burnt area. But although some areas had the same burn intensity and the same storm intensity. Not all catchments within them produced debris flows. The deposits from the flows can clearly be seen in the aerial photos.

Here we can see debris flow deposits outlined in red and the channels indicated in green. The middle channel did not produce a debris flow while the two either side did. Suggesting that the middle channel was not as hydro-geomorphically sensitive. Why? That is what we need to know if we want to be able to predict sensitivity to aid management...

Binary vs continuous data set

SENSITIVITY AND DRYNESS

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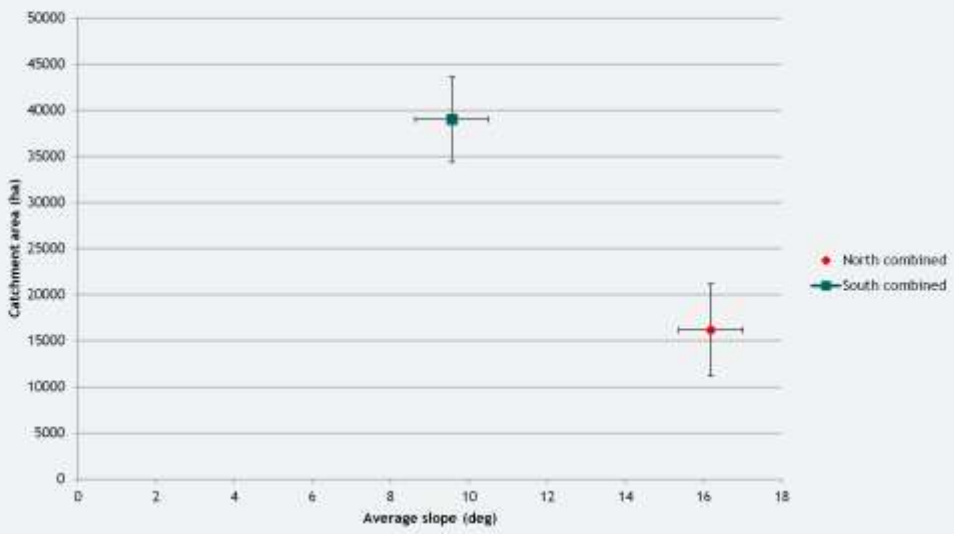

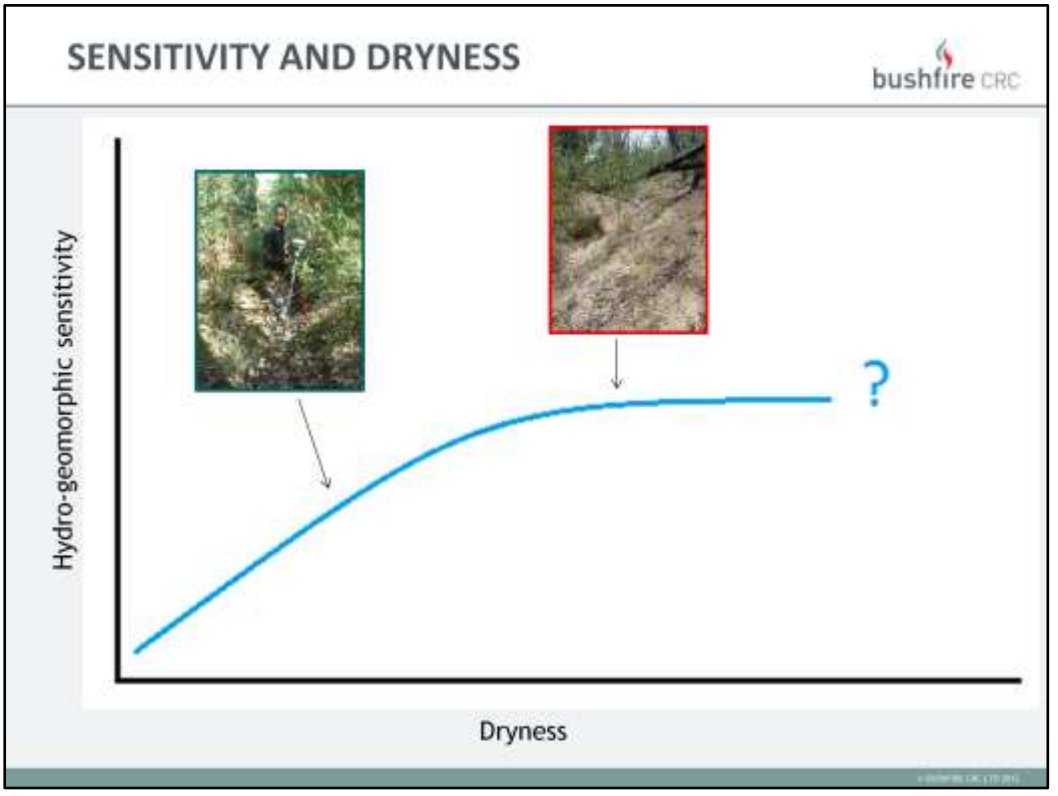

And there is also a lot of other great information provided by this dataset.

For example, something we immediately noticed in the field was the difference between north facing and south facing catchments, even right next to each other. These graphs show the difference between the contributing catchment area and average slope (that is the area above the channel initiation point, or contributing to the channel initiation).

This correlates with a difference between the solar radiation sites are exposed to as well, as the site are so close together, some paired catchments, it's likely the precipitation in all is simular. However, as you can see average radiation is higher in the north facing catchments (no huge surprise there), causing them to be dryer.

This reflects what we observed in the field, south facing slopes (wetter), where better vegetated, with larger catchment areas and lower slopes. While north facing catchments had smaller catchment areas with steeper slopes. [Very steep in some cases] I hypothesise that these differences will have a big effect on a channels sensitivity to fire.
For example, we have observed that the south facing slopes are highly vegetated (3 years after the fire) while dryer north facing slopes show a lot less recovery. This has also been observed by others in our group, Phil Norske currently has equipment measuring the difference in runoff and erosion by aspect.

Aspect appears to have an important role in resilience, which will have an effect on the duration of the response to fire (and thus the overall magnitude of the response). Thus affecting the sensitivity of a channel to the effects of fire.

Summary – these results are showing a distinction in the potential sensitivity of channels based on their aspect, So, the question now is, which channels are most sensitive? This is what we are continuing to investigating with the photo dataset. The data set has the potential to provide a wealth of information easily and quickly about sensitivity on a small scale.

This data can then be used to analyse what makes them so sensitive – is aspect or dryness index a strong predictor everywhere – what other attributes is this linked with, e.g. vegetation recovery, soil availability.

And finally, how can these results be used to link sensitivity with catchment attributes...with landscape attributes...in order to predict the potential response, or at risk areas to fire... this can be used by management to determine which areas most require fire mitigation...for example water catchments are an asset, how much do they need to be protected...

The results of this study will be applicable before, during an after a fire to guide management decisions around mitigation and resource deployment to protect our communities...

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REFERENCES

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Prosser, I. P., & Williams, L. (1998). The effect of wildfire on runoff and erosion in native Eucalyptus forest. *Hydrological Processes, 12(2), 251-265.*

Montgomery, D. R., & Dietrich, W. E. (1994). Landscape Dissection and Drainage Area-Slope Thresholds. In M. J. Kirkby (Ed.), *Process models and theoretical geomorphology (pp. 221-246). Chichester ; New York: John Wiley & Sons Ltd.*