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Title: **Pyrogenic Panic or Perceptive Planning for a New Fire World? Fire and Water Quality.**

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Pyrogenic Panic or Perceptive Planning for a New Fire World? Fire and Water Quality.

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Abstract. The changes projected for the occurrence and intensity of fires have considerable implications for the management of water catchments in south-eastern Australia. Should response to change be based on expedience or on a rational basis, such as adaptive management? Experience following the 2003 fires, and previously, have shown that water quality, in particular, can decline rapidly after catchment-wide fires. If such fires were to become more frequent and intense (*i.e*. fire regimes change), then episodes of soil erosion would increase and water quality would decline. As a response to this, catchment managers in forested areas may choose to increase prescribed burning to reduce the chances of catchment-wide, intense, fires or upgrade suppression operations. While the effectiveness of these measures can be tested in an adaptive management system, the prescribed-burning alternatives, in particular, are so numerous, and the time between catchment-wide fires so extended, that attention to experiences in other catchments and a strong and appropriate research agenda are needed to supplement it.

Introduction

In contemporary science, much has been made of predictions for more frequent, higher intensity, fires under conditions of global warming. Indirect evidence for the former is the landscape model for fires in the Australian Capital Territory developed by Cary (2002) while support for the latter is the output of global models predicting higher forest fire danger indices (Lucas *et al*. 2007). Such predictions of change have led to: (i) a proposal to create a new category of fire danger above the traditional 'worst possible' limit (Lucas *et al*. 2007); (ii) increasing reference to the occurrence of 'megafires' (e.g. Esplin 2007); and, (iii) increasing pressure on some landscape managers to increase their prescribed burning activities. What would a rational response to such changes be compared with what may be seen as an expedient (panic?) response?

Fire authorities may wish to reduce fuels to a minium using low intensity prescribed fires so that they can maximise the probability of controlling any unplanned fire when it occurs. However, the soil-covering fuels of fires are also the main soil-cover for catchments, reducing potential soil erosion (e.g. Siepel *et al.* 2002) and therefore deterioration of water quality. In the management of fire-prone catchments then, there are relationships between fires and fuels, between prescribed and unplanned fires, and between soil erosion and cover.

Here, we address the issues concerning fire in mountain water catchments of the Australian Capital Territory (ACT) in relation to recent research on the relationships between fire occurrence and water quality. This research program seeks to develop a framework for the fire management of water catchments (Gill *et al.* 2008) in view of predicted changes to fire regimes, precipitation, and increasing demand for water due to population increases.

The Catchments

The catchments of focus here are the mountain catchments for the water supply of Canberra, ACT. These are the catchments of the Cotter River and occur across an altitudinal range from 480m to 1912m. The relatively undisturbed cover of the upper Cotter Catchment is largely of eucalypt forests and subalpine woodlands while understoreys vary from herbaceous to shrubby. The lower parts of the catchment have had a long history of utilization for timber and grazing (Wade *et al*. 2008). Average annual rainfall across the catchment has been estimated to be just over 1000mm (T. Xu, personal communication). In 2003, a major fire swept across the entire Cotter Catchment presaging widespread erosion and a rapid decline in water quality.

For understanding and for informed management, monitoring is imperative, e.g. the interactions between fires, water supply and water quality. The importance of fire maps is being increasingly appreciated but, while satellite imagery has facilitated this to some extent, accurate mapping of any prescribed fire is still difficult. Mapping fire intensity is in its infancy worldwide but mapping of fire severity is increasing. For water, the record is also patchy. Stream monitoring for turbidity, suspended solids and water flow is irregular, in many places at least. ACT catchments are relatively well sampled for precipitation. Calendar-based monitoring of water storages for turbidity is routine in the ACT. Lacking is any formal system for the measurement of erosion and sedimentation on slopes.

Fire Events and Fire Regimes affect Water Quality

Fire regimes, the history of fires and their characteristics, affect the long-term yield of sediments leaving the catchment. The fire regime, designed around the effects of fires on plant species, has been considered to consist of the components of *intensity*, between-fire *interval* (or frequency), *season* of occurrence and *type* of fire (whether burning above or in peat or other highly organic materials below ground) (Gill 1975). The importance of spatial matters to the concept of the fire regime has been controversial but potentially has great importance for catchments. There appear to have been no studies on the effects of fire <u>regimes</u> on water quality.

The effect of the *interval* between catchment-wide fires across the catchment for determining the amount of sediment leaving a catchment and the longer term impact of fires on water quality apparently can be made readily, albeit with provisos. If catchment-wide fires occurred every ten years and each event was unaffected by the next, simple arithmetic would suggest the effects of multiple fires. However, events could interact such that sediment was less available with each subsequent event or the type of cover could change with time.

High *intensity* fire potentially could remove all of the cover of a catchment, including tree canopies but low intensity fires, including broad-area prescribed fires, may remove mainly litter and herbaceous material, perhaps in a relatively fine-grained patchy manner.

The *season* of fire occurrence potentially affects water-quality outcomes not just from any links of seasonality with fire intensity. If burning is late in the season for fires and storms, then the greatest chance of restoration of cover before the next storm season occurs.

The *type* of fire in forested catchments is normally above ground but below ground fires can occur in peaty bogs that have a role in buffering water flow in streams. While bogs are usually very wet, they can dry considerably during extended droughts, then burn in unplanned fires.

The question of *area* burnt within a catchment and its effect on water quality has not been formally explored. However, if an entire catchment is denuded of cover by fire or other means, then its chances of eroding are greatest because there is no vegetation to slow overland flow; if only a small part is denuded of cover, even if erosion occurs on the denuded part, any sediment produced is caught up in intact vegetation, does not reach a stream, and hence does not affect water quality. Burning small patches then, is appealing from a water quality point of view. From a fire point of view, burning small patches may be difficult in terms of fire containment (minimum fuel breaks) and increase the chances of re-ignition; determining the optimum size and dispersion of patches is a matter for research.

Prescribed burning in small patches raises new questions for managers who may be concerned with issues other than water, such as biodiversity conservation. Prescribed fires in mountain catchments will not burn all sites because of the variety of fuel moistures and the need to burn under relatively mild conditions. If 100% of the catchment can burn under extreme weather conditions but only 50% can be burnt using prescribed fire, then parts of the catchment will be burnt twice as often under prescription and some not at all if the same average interval between fires is to be maintained. Furthermore, if the prescribed burning is carried out to the same extent every year, then overlap of patches burnt will be common; some patches will likely be burnt many times, others few and some not at all. There are many alternative scenarios from these considerations, let alone in regions across a range of rainfall zones.

Adaptive management: perceptive planning?

From the considerations of future change mentioned above, it may be evident that there are many questions that remain unanswered regarding the effects of fire events and regimes on water quantity and quality. Changes to fire regimes depend on ignitions, climate, fuels and suppression. Changes in fuels to due to increasing concentrations of carbon dioxide are unknown but increased accumulations are possible. Trends in weather variables have been noted but quantitative prediction of each of them for any one area is difficult. Trends do suggest, however, more extreme fire weather in mainland south-eastern Australia (Lucas *et al.* 2007).

Four main responses to the predictions of a more fire-prone, and higher fire-intensity, future may be foreshadowed: (i) do nothing; (ii) increase the use of prescribed fire for fuel reduction; (iii) increase suppression capacity; and, (iv) manage human-caused ignitions. The first of these appears to be the cheapest option but may lead to further major episodes of soil erosion and loss of water quality if the scenarios become reality. The last three of these may be examined within an effective adaptive-management system. Adaptive management systems follow change and adjust to it; this sounds like an ideal way to proceed but appears to be rarely adopted. What is an effective adaptive management framework?

In this context, the aim of management is to provide a high quality water supply. With this aim, identification of the main components of the catchment system and their measurement follows so that an appropriate monitoring system can be established. This system provides the core data to evaluate the management of the catchment. The main drivers – the precipitation regime and the fire regime (including infrastructure to support it) – and the main output variables need to be measured; these variables have been touched upon above. Locations for the measurement of precipitation and stream, slope or storage variables can be established while fires can be mapped across the catchment. Methods of analysis, storage and dissemination of data can be devised, the means of assessment of data determined and the implications of the data analyses forwarded to decision makers for adjustments in policy to be made. That is, an adaptive process occurs.

After rare, catchment-wide fires, various measures may be set in place to counter their re-occurrence but because of their rarity, the test of the adopted measures may not be evaluated within a human lifetime, or more, at any one place. While the test of a system may be partly evaluated by experiences in other catchments, the sheer number of possible alternative responses to widespread fires means that experiences elsewhere are likely to be limited to some extent in their applicability. Assessment of the place of prescribed fires in catchments in relation to water and other issues using the principles of adaptive management seems appropriate in the current climate of uncertainty but adaptive management may need to be backed by a suitable suite of research investigations and comparative case histories for maximum benefit.

Conclusion

An adaptive management system that includes a strong monitoring component can be used to assess any change made to landscape management as a result of current predictions for changed fire regimes. Possible limitations to such a system are the many possible response alternatives and the long times currently experienced between high intensity catchment wide fires in south-eastern Australia. Careful assessment of current knowledge and the encouragement of process-based research are considered to be necessary as parallel activities to any adaptive management system for catchments.

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