Background briefings on emerging issues for fire managers from AFAC and Bushfire CRC.

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FIRE NOTE

TOPICS IN THIS EDITION
- NATURAL ENVIRONMENT
- RISK

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FIRE IN THE LANDSCAPE – ASSESSING THE IMPACT

SUMMARY

Fire, like rain, snow, heat, drought and human activity, has long been a contributor to the nature of the Australian landscape. Fire can be destructive and it can be beneficial. In all ecosystems, too much, too little or the wrong kind of fire can have profound effects.

▲ Quantifying fire-related carbon loss and redistribution.

Fire and its effect on the landscape has been a key component of the Bushfire CRC's research program since 2003, when the national research body was formed.

Over the past four years (2010-2014), researchers from the University of Melbourne and the University of Sydney conducted four research projects on the effects of fire on water quality and quantity, and the changing nature of above and below ground carbon stores after fire. Two of the projects focused on the maintenance of water quality and quantity from forested catchments, which is one of the key challenges facing land managers. The other two projects concentrated on the quantification of carbon losses during fire, a key issue emerging from climate change and increasing greenhouse gases within our atmosphere.

The results from the two water-related projects suggest, in the absence of further information, well-managed low-intensity hazard reduction burning in mixed-species eucalypt forests is unlikely to impact greatly on water yield or quality. The carbon-related research showed that current methods for carbon accounting needed to be revised, and approaches for a better estimation of carbon emission from forest fires in south eastern Australia have been developed.

A detailed report on these projects can be found at: http://www.bushfirecrc.com/category/projectgroup/9-fire-landscape

This *Fire Note* provides an overview of the research in two parts. Part one summarises the two water-related research projects while part two sets out the carbon loss-related research projects.

ABOUT THIS PROJECT

This *Fire Note* summarises four research projects in the *Fire in the Landscape* program, positioned within the *Managing the Threat* research stream of the Bushfire Cooperative Research Centre (CRC). The projects commenced in 2010.

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PART 1: WATER QUALITY AND QUANTITY IN FORESTED CATCHMENTS

The two water-related projects were concerned with the role and impact of planned and unplanned fire on water quality and quantity from catchment forests in south-eastern Australia. The broad management questions considered by these two projects focused on the volume of water used by trees after fire, the quantity of water that goes into catchments, and water quality fitness for use in towns and cities. One of the water-based projects focused on determining the hydrology (water balance) of mixed-species forests by collecting empirical data and modelling the water balance in regenerating eucalyptus forests following bushfire. The second project quantified and modelled the risks to the water supply of catchments burnt by bushfire and used this information to predict the reduction to these risks of planned fire should fire be introduced into catchments.

PROJECT 1 - *FIRES AND HYDROLOGY OF SOUTH-EASTERN AUSTRALIAN MIXED-SPECIES FORESTS*

CONTEXT

Mixed-species forests constitute a considerable percentage of the catchment estate in south-eastern Australia. They are often found on foothills, immediately adjacent to farms and settlements. To date, most research into water use by eucalypts in south-eastern Australia has concentrated on the tall open forests dominated by *Eucalyptus regnans*. These forests regenerate by seed after fire, whereas mixed-species forests predominately regenerate vegetatively. As the eucalypts that dominate mixed-species forests differ in life history to *E. regnans* we cannot assume that the severity or longevity of reductions in catchment yield following fire will be the same.

BACKGROUND

Quantification approaches to ascertain overstorey tree water use in relation to soils and climate have been in development for some time. Similarly, models now also exist that allow for the extrapolation of annual time scales and sub-catchment geographic scales. However, there was a need to investigate forests further regrowing after fire – whether post bushfire or planned fire. Key questions for further investigation related to how re-sprouting eucalypts differed from those that regenerated from seed (for example, Ash-type eucalypts). In particular, little was known about the water use of resprouting eucalypts and how it was affected by leaf anatomy and phenology (the study of regularly recurring biological phenomena).

The study sites were selected from areas burnt in the 2009 Victorian bushfires and formed part of an important forest catchment for the supply of water to Melbourne. This project was designed to fill an important gap in knowledge for modelling of tree water use in catchments in fire-prone forests.

BUSHFIRE CRC RESEARCH

The broad aim was to examine the eco-hydrology of mixed-species eucalypt forests as they regenerated after fires that completely removed the crowns of trees. The primary questions were: do mixed-species forests follow the same trend as Ash-type forests and have a lengthy period of reduced catchment yield following crown-removing fire; or do mixed-species forests have a shorter period of reduced catchment yield following crown-removing fire?

The secondary aim was to extrapolate the findings from the particular study sites to other forested areas, and to do this required an understanding of leaf physiological (functioning) processes.

RESEARCH OUTCOMES

It was found that after the crown-removing fires in 2009, the water-use of burnt trees was similar to nearby unburnt trees. Within the four-year timeframe of this project, the regenerating canopy developed from many small branches distributed evenly along the stem, to fewer and larger branches which would eventually form a full (recovered) canopy. It was also found that as the leaf form and canopy structure slowly changed after fire, tree water-use did not change.

HOW IS THE RESEARCH BEING USED?

These results can be used by catchment managers and water supply authorities to determine optimal strategies for simultaneously managing fire risk and ensuring continuity of water supply. A model designed for use by agencies that will greatly simplify the process of estimating tree water-use is being finalised. The results from this project are directly applicable to mixed-species catchments in south-eastern Australia. Outside of this area, catchment managers and water supply authorities may be able to adapt this research by validating tree water-use models for new vegetation types. There is also the potential for this research to be used at a strategic level to inform water policy.

▲ Understanding the impact of fire on soil.

PROJECT 2 - *QUANTIFYING RISK OF WATER QUALITY IMPACTS FROM BURNED AREAS*

CONTEXT

Fire poses an immediate threat to the water supplies of towns and cities because water treatment facilities in south-eastern Australia are designed to treat relatively clean water from unburnt forested catchments. For example, following the 2003 fires, Bendora Reservoir, an important water supply for Canberra, experienced turbidity (sedimentation) values 30 times the previously recorded maximum, forcing water restrictions on the Australian Capital Territory. Melbourne's water supply is also at risk, with approximately 80 per cent of the city's water sourced from the Upper Yarra and Thomson forest catchments, the city having minimal treatment capacity.

BACKGROUND

Existing catchment modelling tools are concerned primarily with predicting event magnitude *after* a fire has occurred (for example, the catchment conditions and the fire event are 'given'). The challenge is to understand the impact of fire on soil and being able to model the connectivity between hill slopes and drainage networks for different fire severities. With this temporal scale of modelling there is a 'window of risk' for several years within which severe erosion events may occur, depending on whether a storm of sufficient magnitude overlaps with the burnt area. However, both fire and rainfall regimes vary spatially and are sensitive to changing climate, while fire regimes can be modified directly through fuel management and fire suppression.

BUSHFIRE CRC RESEARCH

This project addressed the following questions:

1. What was the first-order effect of the spatial-temporal (time and space) overlap between fires and storms on erosion?
2. How did this first-order effect translate to erosion response in landscapes with variable topography, soils and burn properties?

RESEARCH OUTCOMES

An understanding of the relationships between fire severity, peak flows and sediment transport from headwaters has been developed. Slope and vegetation are important predictors of the occurrence of debris flow, but there are many interactive processes occurring. A model representing water quality risk as a function of rainfall and fire regimes within a particular catchment has been developed and tested to extrapolate process-based (site-specific)

responses to landscape-scale catchments. This model has been tested under scenarios of climate change and will be tested further in other catchments to understand potential patterns.

PART 2. INCREASING GREENHOUSE GASES – QUANTIFYING CARBON LOSSES DURING FIRE

Fire has a direct impact on the carbon balance of forests. This occurs through emissions of carbon dioxide, volatile organic compounds and other greenhouse gases formed during the combustion of vegetation and litter. Plant biomass is also converted to various forms of carbon-containing ash and charcoal that may stay on-site and be incorporated into the soil or removed from the site. These two carbon-related projects investigated the fate of carbon after fire, using complementary laboratory and field-based studies.

PROJECT 3 - *ENVIRONMENTAL IMPACTS OF PRESCRIBED FIRE AND BUSHFIRE – EMISSIONS MANAGEMENT*

CONTEXT

Planned fires over large forest areas are essential to reduce the risk of large-scale bushfires, particularly in forests near population centres and important forest assets such as water catchments and commercial plantations. However, planned fires release emissions and reduce the forest carbon stock. It is widely recognised that planned fires reduce surface fuels (i.e. dead partly decomposed organic material on the forest floor). However, the impact of fire on other major carbon pools, such as overstorey trees, shrubs, ground cover, coarse woody debris and soil organic matter, is not well documented for south-eastern Australian forests.

BACKGROUND

Fire modifies forest organic matter to produce a wide range of charred and partially oxidised materials. The addition of burnt organic matter to the soil surface has not been clearly accounted for. A holistic approach for measuring fire-related carbon loss and redistribution among pools for south-eastern Australian forests was lacking. As there was no data available for carbon distribution among carbon pools there was no clear understanding of how burning practices could be modified to minimise carbon losses and emissions.

BUSHFIRE CRC RESEARCH

Over the three years of research, 61 study plots were established in long unburnt eucalyptus forests across five states of south-eastern Australia. Forest types measured included dry sclerophyll, lowland, open, shrubby dry and coastal forests. Experimental design included the establishment of circular sampling plots of 45 metres in diameter at each study site and measurements of four major carbon pools:

- Above ground alive (live overstorey trees, understorey vegetation, elevated fuels).
- Deadwood (stump, dead standing trees, coarse woody debris).
- Litter (dead leaves, bark, twigs and branches on the forest floor with diameter <2.5 cm).
- Soil to 30 cm depth, including organic matter.

Using standard inventory techniques, forest carbon pools were measured before and immediately after fire.

RESEARCH OUTCOMES

Preliminary results indicated that planned burns three months prior to a bushfire significantly reduced the severity of that bushfire, affecting only forest floor carbon (litter and coarse woody debris). Charring of overstorey trees in fuel-treated sites did not exceed two metres, which contrasted to complete crown scorch in long unburnt forests. Combined carbon emissions from planned burns and bushfire in fuel-treated forests were half that compared to emissions during bushfire in long unburnt forests.

HOW IS THE RESEARCH BEING USED?

The knowledge of forest carbon balances has improved drastically by quantifying the impact of fire on forest carbon stocks and providing more reliable estimates of the magnitude of emissions produced during planned and unplanned fire. It was found that planned fire released only a minor fraction of the carbon stored in forests (two to three per cent) and that emissions from planned burns and bushfire in fuel-treated forests was half that compared to emissions from bushfire in long unburnt forests. It was also established that two per cent of the carbon that was previously considered to have been lost to the atmosphere in gaseous and particulate form remained in the forest through redistribution.

END USER STATEMENT

The new knowledge and understanding that has been developed from the *Fire in the Landscape* projects has been transferred to agencies in a variety of ways. Field and laboratory site visits were found to be particularly useful for delivering information to end users. This allowed for people to take up information in different ways. Importantly, the field demonstrations of the water-based projects have assisted in bridging the gap between research and operational delivery.

The *Fire in the Landscape* program will significantly improve our understanding of the consequences of using planned fire in managed ecosystems. This type of land management activity needs to be continually supported by good management decisions and sound scientific research.

– Neil Cooper, ACT Parks and Conservation Service

PROJECT 4 - *GREENHOUSE GAS EMISSION FROM FIRE – ENVIRONMENTAL IMPACT*

CONTEXT

Reliable estimates of carbon emissions from planned and unplanned fire are required to assess the impact of smoke on the atmosphere. Gaseous emissions from fire can be estimated if variables including the area burnt, mass of fuel burnt, combustion completeness and emission factors for trace gases are known.

BACKGROUND

Vegetation fires inevitably lead to the production of smoke. Smoke from bushfires and planned burning affects the atmosphere through the production of trace gases (defined as a gas that makes up less than one per cent by volume of the atmosphere of the Earth) and aerosols (a suspension of fine solid particles or liquid droplets in a gas). Trace gases and aerosols have enormous consequences for regional air quality, pollution and climate.

Until recently, smoke composition research had largely concentrated on emissions from fire in savanna in Australia, with few studies available for temperate forests in south-east Australia.

BUSHFIRE CRC RESEARCH

Four studies including one modelling exercise were undertaken during this project. The three experiments were laboratory-based to allow for repeatable, highly controlled measurements. The research program was designed to determine the role of one of the most important components of fire behaviour – fuel moisture content – on smoke emissions and fuel flammability.

To validate the results obtained in the first two experiments using trees grown under controlled conditions, fuels from forested sites in south-eastern Victoria were collected and combusted under similar conditions. The results were used for modelling of greenhouse emissions using a range of different calculation methods.

RESEARCH OUTCOMES

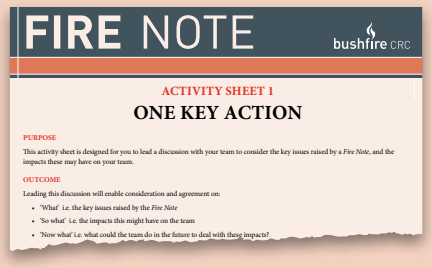
From the research done during this project it is clear that emissions of CO_2 and CO are

▲ Assessing the role and impact of planned and unplanned fire on water quality and quantity.

dependent on the moisture content of the fuel, but not necessarily the type of fuel. Testing of several species of eucalyptus showed limited differences in flammability attributes or carbon emissions among species. This allowed for the identification of general relationships covering these variables and fuel moisture content. However, greater differences in flammability attributes and carbon emissions were detected among tropical and savanna grasses, providing some limits to the level of generalisation that can be made.

NOW WHAT?

What three things stand out for you about the research covered in this *Fire Note*? What information can you actively use, and how? Tools are available at www.bushfirecrc.com/firenotes to help, along with activities you can run within your team.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ACTIVITY SHEET 1

ONE KEY ACTION

PURPOSE

This activity sheet is designed for you to lead a discussion with your team to consider the key issues raised by a *Fire Note*, and the impacts these may have on your team.

OUTCOME

Leading this discussion will enable consideration and agreement on:

- 'What' i.e. the key issues raised by the *Fire Note*
- 'So what' i.e. the impacts this might have on the team
- 'Now what' i.e. what could the team do in the future to deal with these impacts?

HOW IS THE RESEARCH BEING USED?

More accurate emission factors can be used by Australian and international jurisdictions to help manage greenhouse gases in the atmosphere. The identification of variable flammability within Australian fuels could potentially become an early warning indicator for fire managers, for example, in jurisdictions with introduced weeds. Recognition of potential differences in flammability between co-located fuels also introduces a new factor that may need to be accounted for in fire behaviour models.

FUTURE DIRECTIONS SUMMARY

As the research undertaken in these four projects comes to an end, data will continue to be developed for use in peer-reviewed publications and research reports as appropriate. Researchers and postgraduate students will continue to present their research findings at national and international conferences. Surveys have identified that there is strong support for the research presented in the *Fire in the Landscape* projects. There was also a categorical call for the water- and carbon-related research to continue in the future.

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AFAC is the peak body for Australasian fire, land management and emergency services, creating synergy across the industry. AFAC was established in 1993.