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

bushfire CRC afac

FIRE NOTE

ISSUE 56 MARCH 2010

Figure 1a: The Rapid Deployment Greenhouse Gas Laboratory (RDGG-Lab) setup at the Snowy Plains research sites, NSW.

MOBILE LAB FILLS GREENHOUSE-GAS KNOWLEDGE GAP

SUMMARY

This research project resulted in the design and construction of a groundbreaking Rapid Deployment Greenhouse Gas Laboratory (RDGG-Lab) for use in remote locations, which is capable of working independently and continuously for several days, measuring multiple gases simultaneously. The RDGG-Lab has been deployed in alpine, sub-alpine and montane ecosystems in Victoria and New South Wales (NSW) over the past three years, measuring fluxes of carbon dioxide, methane and nitrogen dioxide in burnt and unburnt study sites, resulting in highly significant insights that will be invaluable for future modelling scenarios, and for general knowledge of the impact of fire on greenhouse gases in soils. In this *Fire Note*, the discussion of results is limited to methane fluxes to and from soils under snowgum (*Eucalyptus pauciflora spp. niphophylla*) woodland on the Snowy Plains in NSW. The research there is focused on a grazing x fire interaction study, set up with additional funding from the Federal Government to the Bushfire CRC.

ABOUT THIS PROJECT

This *Fire Note* is an update of ongoing research and is one of five sub-projects of the HighFire Fuels and Ecosystem Functions (HFEF) project. It is part of HighFire Program B5.1: Ecosystem Processes.

The authors: all are at the University of Sydney, where Professor Mark Adams is Dean of the Faculty of Agriculture, Food and Natural Resources; Dr Robert Simpson is a Postdoctoral Research Fellow; and Mike Kemp is a Technical Officer.

CONTEXT

Carbon-rich soils in alpine ecosystems are one of the most important sinks for greenhouse gases and fire could have a major impact on the storage and release of these gases to the atmosphere. By designing and constructing a unique analytical system, this research is addressing a major gap in our understanding of the inter-relationships among alpine soils, vegetations and fluxes of greenhouse gases. This research is contributing key data to the global accounting of greenhouse gas sources and sinks.

BACKGROUND

Natural, undisturbed ecosystems are a source and sink of greenhouse gases and, on a global scale, generally result in only trace emissions. That is, the production of gases by plants and microorganisms (biological respiration) is largely balanced by their consumption (photosynthesis by plants and oxidation by microorganisms). Since the industrial era (1750) there has been a significant increase in emissions due to human activities, including industrial processes, changes in land use (e.g. land clearing and agriculture), fossil fuel use and biomass burning.

Greenhouse gases contribute to increasing temperatures by preventing reflected radiation from leaving the earth's atmosphere. The

◄ **Figure 1b:** The Genset, used to keep battery bank voltage above set-point.

▼ **Figure 2:** An open sampling chamber at a Snowy Plains research site.

DEFINITIONS

Enteric fermentation: takes place in the digestive systems of ruminant animals.

Greenhouse gases: atmospheric gases that absorb and emit radiation, a process responsible for the greenhouse effect. The main greenhouse gases are water vapor, carbon dioxide, methane, nitrous oxide, and ozone.

Methanotrophic bacteria: able to metabolise methane as one of their primary sources of carbon and energy.

Montane: forested zone between the subalpine zone and lower elevation woodlands.

Subalpine zone: immediately below the alpine zone, consisting primarily of Snow Gum woodlands with an understorey and/or patches (in the presence of cold-air drainage) of grassland, herbfield or heathland.

Alpine zone: above the treeline, including herbfields, grasslands, bogs, fens and heathlands.

major greenhouse gases include carbon dioxide (CO_2), methane (CH_4), ozone (O_3) and nitrogen dioxide (N_2O) contributing approximately 60%, 20%, 10% and 6% respectively to global warming.

Quantification of rates of emission of CO_2, N_2O and CH_4 gases from soils provides a direct and sensitive method for quantifying changes in the functioning of soil as a result of fire. All three of these gases are directly modulated by microbial/fungal communities (Conrad, 1996). Hence, changes to the functioning of ecosystems by factors such as fire alter the microbial/fungal populations and the emission of trace gases.

Alpine soils are an important sink for greenhouse gases and an understanding of how fire affects soil conditions and gas fluxes is critical to modelling how fire will alter alpine landscapes (in terms of biomass and flammability) and have impacts on fire management and global warming.

The aim of this research is to determine the effect of fire on large, catchment-scale areas including mountain slopes, forests and other remote areas. However, the methods available are only capable of measuring single gases and require intensive manual operation. A fully automated system within a secure and mobile housing, capable of continuous operation unattended for long periods (several days to weeks), in remote locations is required.

BUSHFIRE CRC RESEARCH

The ideas behind our Rapid Deployment, Greenhouse Gas Laboratory (RDGG-Lab) are based on designs for analytical systems developed in Germany and extensively tested at many field sites around the world (e.g. Kiese and Butterbach-Bahl 2002; Kiese, Hewett et al. 2003). Contained within a 4WD and trailer (Figures 1a and 1b), the RDGG-Lab is a mobile system capable of being deployed in most environments. The RDGG-Lab has sophisticated analytical equipment which is underpinned by purpose-designed support systems. The analytical components include chambers, a gas chromatograph, a computerised system for valve switching and management of pneumatic and sample air streams.

The RDGG-Lab can analyse up to 10 continuously sampling chambers in varying configurations (Figure 2) as programmed by the data acquisition software. In its current configuration, we run nine chambers in three clusters of three chambers each (i.e. only three chambers are closed at any one time). While our current configuration works well, variations to this configuration can lead to problems that include inaccurate flux estimates, a reduced ability to resolve temporal variation, and an inability to detect the immediate effects of random events such as rainfall.

To ensure that rainfall affects all clusters equally, the system is designed to automatically open all chambers for a specific time when rainfall is above a specified threshold. The system automatically re-starts after the rainfall event.

Concentrations of CH_4 and N_2O in the sample stream are determined using an SRI Gas Chromatograph (Figure 3). The sample then flows to a flame ionisation detector for analysis of CH_4 and an electron capture detector for analysis of N_2O.

CO_2 is measured using an infra-red gas analyser.

Over the past three years, the RDGG-Lab has been deployed in Alpine ash (*Eucalyptus delegatensis*) forest at Howmans Gap in Victoria and in subalpine grassland and high elevation, snowgum (*Eucalyptus pauciflora spp. niphophylla*) woodland on the Snowy Plains in NSW. The RDGG-Lab is deployed to each of the long-term experimental sites for two nine-day periods each year to measure net soil fluxes of CO_2, CH_4 and N_2O. Automatic chambers are used to continuously quantify fluxes from paired burnt (n=6 chambers) and unburnt (n=3 chambers) plots.

Figure 3: A Gas chromatograph (on the right with red casing, used to analyse N_2O and CH_4) and an InfraRed Gas Analyser (to the left, used to analyse CO_2) are housed in the back of the 4WD of the RDGG Lab.

RESEARCH OUTCOMES

This project has successfully achieved its main objectives, which were to:

1. design and engineer a fully automated laboratory, capable of being deployed rapidly to remote locations to continuously measure CO_2, CH_4 and N_2O simultaneously for extended periods without manual operation
2. deploy an RDGG-lab at long-term experimental sites to measure greenhouse gas emissions
3. build an evidence base of data derived from the RDGG-lab measurements, to be used to model likely future scenarios of interrelationships among fire, fire management, soil conditions, greenhouse gas fluxes and global warming
4. address gaps in knowledge on the potential capacity of Australian alpine soils for storing greenhouse gases, and
5. address gaps in knowledge on the influence of fire on greenhouse gas fluxes in alpine ecosystems.

The evidence base derived from the deployment of the RDGG-Lab over the past three years is shedding light on the significance of dryland alpine ecosystems as a major sink of greenhouse gases.

END USER STATEMENT

"It is no longer sufficient to assume that any given part of the landscape should or should not be grazed or burnt. The research team has shown that the RDGG-Lab is a great addition to the arsenal of techniques available to land and fire managers who will be increasingly asked to account for their greenhouse gas emissions."

– Mr Barry Aitchison
Operations Officer
Berridale Fire Control Centre
NSW Rural Fire Service

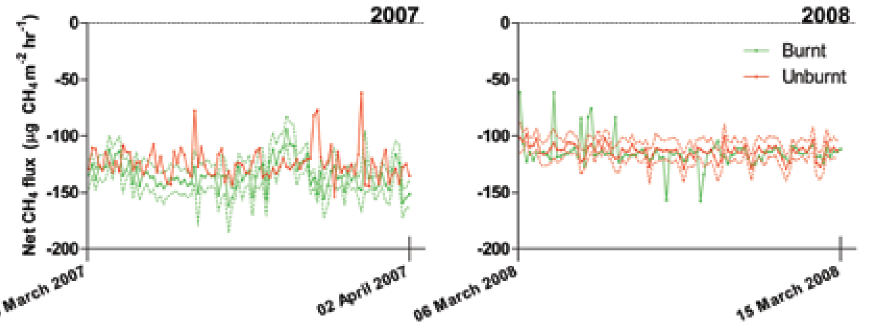
Soils of snowgum (*Eucalyptus pauciflora spp. niphophylla*) woodland on the Snowy Plains in NSW are a significant sink for methane (CH_4; Figure 4) with an average rate of -124 µg CH_4 m^{-2} h^{-1} for atmospheric methane (CH_4) uptake in unburnt plots in 2007. While there have been few studies in other alpine ecosystems in Australia and elsewhere, the rates measured in the Snowy Plains are larger than for *Eucalyptus delegatensis* forest in NSW (Livesley *et al.* 2009), alpine dryland meadows in Austria (e.g. Koch *et al.* 2007) and alpine tundra (cited in Koch *et al.* 2007). Rates for the Snowy Plains are also within the range of several Australian temperate woodlands and forests (ranging from 2 to -445 µg CH_4 m^{-2} h^{-1}).

The effect of fire on atmospheric methane uptake of soils from the Snowy Plains was minimal and short-lived. Although average rates of atmospheric CH_4 uptake immediately post fire were greater in burnt plots (-135 µg CH_4 m^{-2} h^{-1}) than in unburnt plots (-124 µg CH_4 m^{-2} h^{-1}), there was no statistically significant treatment effect. This is an important result highlighting the resilience of these ecosystems to disturbance by fire. Despite a moderate to hot fire, the biological diversity of methanotrophic bacteria (see 'Definitions' box on page 2) does not appear to have been adversely affected.

Interestingly, the uptake capacity of sub-alpine soils in this region of the Snowy Plains (estimated at 43,200 g CH_4 per day) was more than twice the estimated amount of methane emitted via enteric fermentation by 100 cattle grazed on the property each year for short periods (~15,000 g CH_4 per day).

HOW THE RESEARCH IS BEING USED

The limited data available on the emission of greenhouse gases from soil, and particularly from carbon-rich alpine soils, is a major gap not only in our knowledge but in the global accounting of sources and sinks. Moreover, the advent of global warming and increased frequency and intensity of fire adds to the



▲ **Figure 4:** *In situ* measurements of net methane (CH_4) flux (µg CH_4 m^{-2} hr^{-1}) from burnt and unburnt soil at snowgum (*Eucalyptus pauciflora spp. niphophylla*) woodland sites on the Snowy Plains in NSW.

▲ **Figure 5:** A Bushfire CRC Industry Forum at Howmans Gap research sites in Victoria.

significance for greater understanding of how sources and sinks of greenhouse gases are being affected now and under likely future scenarios.

This research will make an important contribution by helping to educate and inform land managers, industry, governments and the public. A greater knowledge of how significant these undisturbed, natural environments are to mitigating global warming – particularly via the soil component and alpine ecosystems – is critical. Some of the major environmental consequences of global warming include major changes in landscape patterns and processes leading to major alterations to greenhouse gas sources, sinks and emissions, in addition to landscape flammability. Incorporating the role of soil into the greenhouse gas accounting should have major implications for future strategies used to manage landscapes, including the threat of fire.

The research outcomes of this project are being shared via community forums, *Fire Notes*, peer-reviewed publications, engagement with industry, and the provision of a modelling tool for predicting future alterations in atmospheric trace gases and the likely impact of climate, landscape properties and land management.

On 5 June 2007, this research team hosted an 'open day' at Howmans Gap for about 40 Bushfire CRC research partners. An update of the research was provided, as well as a field visit to see the RDGG-Lab in operation (Figure 5). Additional public forums are currently being organised.

FUTURE DIRECTIONS

Much is being learnt from data collected from the RDGG-Lab. However, a comprehensive understanding of the impact of fire on trace gas emissions from soil will require a long-term commitment over several decades. The RDGG-Lab will continue to be deployed in long-term research sites in Victoria and NSW.

Already, there are many requests for the deployment of the RDGG-Lab on other sites and other land uses. The Bushfire CRC has the opportunity to engage with a much wider group of stakeholders, as a result.

FURTHER READING

Conrad, R. (1996). "Soil microorganisms as controllers of atmospheric trace gases (H_2, CO, CH_4, OCS, N_2O, and NO)". *Microbiological Rev.* **60**, 609-640

Kiese, R. and K. Butterbach-Bahl (2002). "N_2O and CO_2 emissions from three different tropical forest sites in the wet tropics of Queensland, Australia." *Soil Biology and Biochemistry* **34**(7): 975-987.

Kiese, R., B. Hewett, et al. (2003). "Seasonal variability of N_2O emissions and CH_4 uptake by tropical rainforest soils of Queensland, Australia." *Global Biogeochemical Cycles* **17**(2): 1043.

Koch, O. et al. (2007) "Seasonal and Diurnal Net Methane Emissions from Organic Soils of the Eastern Alps, Austria: Effects of Soil Temperature, Water Balance, and Plant Biomass. *Arctic, Antarctic and Alpine Research* **39**: 438–448.

Livesley, S.J., Kiese, R., et al. (2009) "Soil-atmosphere exchange of greenhouse gases in a Eucalyptus marginata woodland, a clover-grass pasture and Pinus radiata and Eucalyptus globulus plantations." *Global Change Biology* **15**: 425-440.

Fire Note is published jointly by the Bushfire Cooperative Research Centre (Bushfire CRC) and the Australasian Fire and Emergency Service Authorities Council (AFAC).

Bushfire Cooperative Research Centre
Level 5/340 Albert Street
East Melbourne VIC 3002
Telephone: 03 9412 9600
www.bushfirecrc.com
Bushfire CRC is a national research centre in the Cooperative Research Centre (CRC) program, formed in partnership with fire and land management agencies in 2003 to undertake end-user focused research.
Bushfire CRC Limited ABN: 71 103 943 755

Australasian Fire and Emergency Service Authorities Council
Level 5/340 Albert Street
East Melbourne VIC 3002
Telephone: 03 9418 2388
www.afac.com.au
AFAC is the peak representative body for fire, emergency services and land management agencies in the Australasia region. It was established in 1993 and has 26 full and 10 affiliate members.