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# MAPPING BUSHFIRE HAZARD AND IMPACTS

## Annual project report 2014-2015

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The Australian National University
Bushfire and Natural Hazards CRC

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Cover: A prescribed burn in the ACT.

Photo by Marta Yebra.

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# EXECUTIVE SUMARY

This annual report is an output from the Bushfire and National Hazards CRC Project 'Mapping Bushfire Hazard and Impacts'. It summarises the project objectives, introduces the team members as well as documents the project progress and outcomes during the finantial year 2014/2015.

The project team has made great progress this year as demonstrated by

1) Developing a model framework, the **High-resolution Fire Risk and Impact (HiFRI) framework**, to provide best possible estimates on forest fuel load and moisture content and fire impacts on landscape values such as water resource generation and carbon storage.
2) Developing and tested a new software tool based in MATLAB to **automatically derive detailed vegetation structure information** from ground-based LiDAR
3) Successfully obtaining **two student top-up scholarships from BNHCRC**, what will have further positive impacts on the quality of our research.
4) Maintaining a **healthy and engaging relationship with end users**. The strongest connections have been with ACT Parks and Conservation, with whom the team collaborate closely and hands-on. However, the expectations are that once the project team have been able to demonstrate the practical value of research in the ACT, additional end users will find it easier to see how they can concretely engage in the research.
5) Publishing **1 journal paper, 4 conference abstracts and 2 milestone reports.** In addition another manuscript is currently under review with Remote Sensing of Environment, top-ranked in the category of remote sensing.
6) Communicating progress on the research goals to end users by organising **two workshops** with operational stakeholders and other researchers and publishing **divulgative material in blogs and other media.**
7) Receiving **international researchers exchange visits and** being **approached by more than 15 domestic and international requests for PhD scholarships or postdoc positions** on the topic of bushfire research. Of particular interest has been our innovative work in LiDAR vegetation mapping.

# END USER STATEMENT

I am pleased to see the good progress on both activities, with much of the work done in association with end users, particularly ACT Parks and Conservation. Publications, and particularly a number of conference presentations and two end-user workshops have demonstrated the researcher's commitment to communicating progress on the research goals. I also endorse the very positive assessment of project end-user engagement from the ACT Parks Service.

As the work progresses, I would like to see close engagement with a larger pool of end users, and more focus on applying the geographically selective results of this work to broader national operations with a much wider geographic scope. This research has potential application to fire predictive services (operational spread modelling) and to the proposed new National Fire Danger Rating System through improvements to operational fuel mapping and fuel condition. It also has the potential to better ground truth soil moisture assessments developed by the CRC Landscape Moisture project, and the NEMP funded grassland curing project led by the Victorian CFA.

**John Bally,** Bureau of Meteorology*, Tasmania Rrgional Office*

# INTRODUCTION

Bushfires can have devastating impacts and are important for ecological dynamics. Understanding and predicting fire behaviour is a priority for fire services, land managers and residents alike. This is an enormous scientific challenge given bushfires are complex processes, with their behaviour and resultant severity driven by complicated interactions among living and dead vegetation, topography and weather conditions.

A good understanding of fire risk across the landscape is critical in preparing and responding to bushfire events and managing fire regimes, and this will be enhanced by remote sensing data. However, the vast array of spatial data sources available is not being used very effectively in fire management.

This project uses cutting edge technology and imagery to **produce spatial information on fire hazard and impacts needed by planners, land managers and emergency services** to effectively manage fire at landscape scales. The group works closely with ACT Parks and Conservation Service and fire agencies in several states to better understand their procedures and information needs, comparing these with the spatial data and mapping methods that are readily available, and developing the next generation of mapping technologies to help them prepare and respond to bushfires.

# PROJECT BACKGROUND

The project is structured in two main activities.

## ACTIVITY 1. FIRE HAZARD MAPPING AND MONITORING

**Spatial information on fuel load, structure and moisture properties** can inform fire preparedness through better fire danger rating and fire behavior prediction and supporting logistics and resources planning by emergency services. It can also improve fire management by helping guide activities such as scheduling and implementing prescribed burning. Insights from discussion with end users indicates that the greatest and most urgent information gap is **spatial information on forest fuel load, structure and moisture**.

**Approach**: We review and analyse the potential added value of new data sources relating to the load and attributes of forest fuel. The utility and feasibility of using a new data source depends on such factors as spatial resolution, accuracy, operational availability and the resources required for data acquisition, processing and interpretation. Where possible, the spatial data derived are evaluated against ground-based measurements of critical fuel hazard scores and moisture content. Where appropriate, the information is developed to fit into the Fire Danger Rating system or fuel classification systems suitable for end users.

## ACTIVITY 2. FIRE IMPACTS ON LANDSCAPE VALUES

In addition to information on fire hazard, land managers also need spatial information on the **expected fire impacts on landscape values, such as water resources, carbon storage, habitat and remaining fuel load**. Relevant issues include the impact of unplanned or prescribed fires and subsequent recovery on catchment water yield and the carbon lost and subsequently taken up again after burning. Current prediction methods are crude and make bold assumptions (for example, about the similarity of the water use patterns between (well-studied) recovering mountain ash forests and (unstudied) other forest types.

**Approach**: We perform a spatial case study for one or more of ACT's water catchments recovering from the 2003 bushfires and nearby NSW forests. We analyse airborne and remote sensing observations and using these observations to improve and set up a spatial forest growth, water use and carbon uptake model. In particular, we test assumptions that are commonly being made about fire impacts on water and carbon, use the observations to improve predictions and understanding of the uncertainty, and produce spatial information that can guide land management actions such as prescribed burning.

# WHAT THE PROJECT HAS BEEN UP TO

## SUMMARY OF MAIN RESULTS

### Activity 1. Fire hazard mapping and monitoring

#### Deriving Forest fuel load and structure at high resolution (<5 m)

We developed and tested an algorithm to classify a dense point cloud derived from a mobile laser scanner (Zebedee) into different vegetation components: ground returns, near-surface vegetation, elevated understorey vegetation (shrubs), tree trunks and tree canopy (Figure 1) (Marselis et al. 2015). The resulting classified point cloud is used to automatically derive important information on the different fuel components essential for fire hazard assessment such as total biomass, fractional cover and height. These results open a promising pathway of automatically deriving detailed vegetation structure information from ground-based LiDAR data essential for local fire management and preparedness, including the success of fuel reduction activities such as prescribed burning or mechanical treatment.

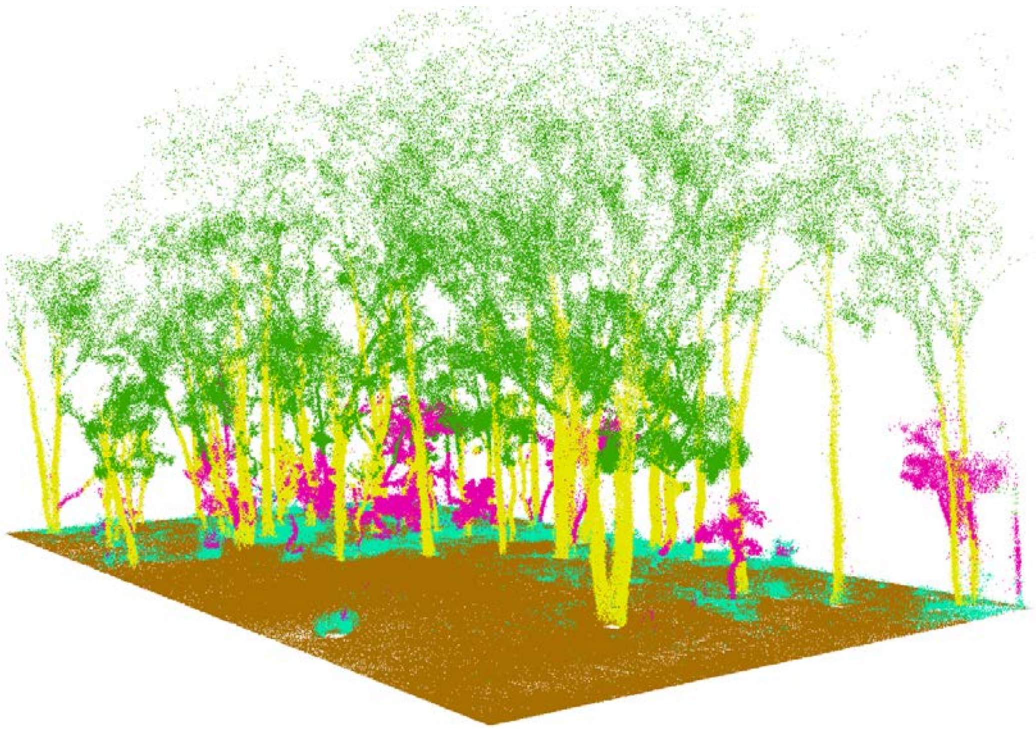

**FIG. 1.** CLASSIFICATION OF LIDAR POINT CLOUD INTO DIFFERENT VEGETATION COMPONENTS USING ZEBEDEE; BROWN = GROUND, AQUA = NEAR-SURFACE VEGETATION, MAGENTA = ELEVATED VEGETATION, YELLOW = TRUNKS, GREEN = CANOPY (MARSELIS ET AL.)

## Live fuel moisture content.

Live fuel moisture content (FMC) is one of the primary variables affecting ignition and spread of wildfires. We developed a method to measure FMC by optical remote sensing (Yebra et al., 2008, Jurdao et al., 2013) that has already been applied for fire hazard assessment across Spain (Chuvieco et al. 2010). During this financial year we tested this algorithm in Australia using Hymap hyperspectral imagery acquired in 2013 over two study sites in the ACT (Figure 2).

The result are very promising when evaluated against field measurements of canopy FMC content sampled in the study sites, obtaining errors in the FMC estimation of 23%.

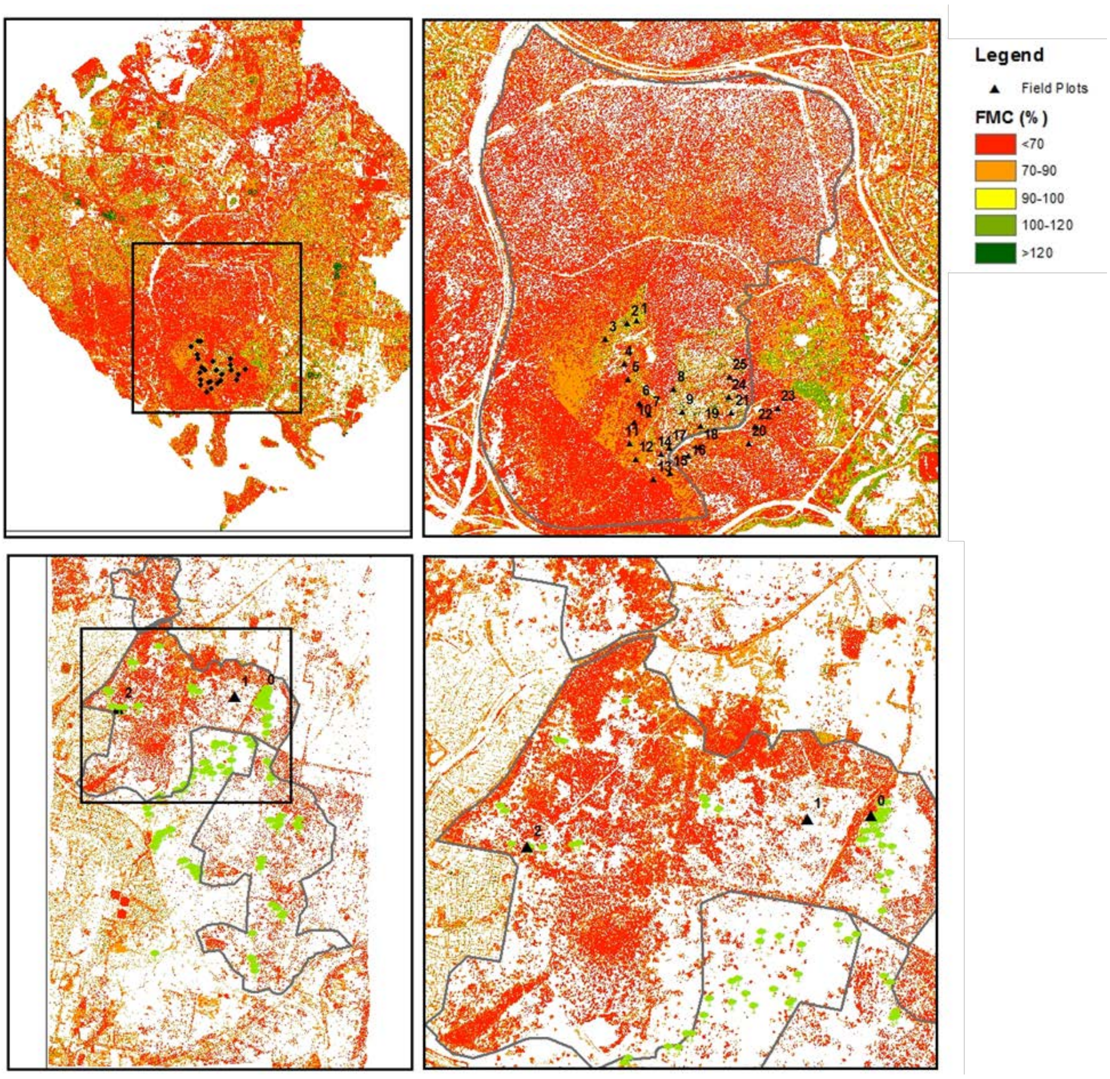


FIGURE 2. OVERSTOREY FUEL MOISTURE CONTENT ESTIMATION AT THE BLACK MOUNTAIN NATURE RESERVE (TOP), THE MULLIGAN'S FLAT AND GOOROOYAROO RESERVE (BOTTOM) AND SURROUNDINGS USING HYMAP HYPERSPECTRAL DATA COLLECTED AT THE ACT AND RADIATIVE TRANSFER MODELLING (JURDAO ET AL. 2013; YEBRA ET AL. 2008). FIELD PLOTS SAMPLED FOR VALIDATION ARE ALSO DISPLAYED.

We are applying the same algorithm to optical data freely available at 30-500 m resolution (e.g. Landsat, MODIS) at National scale to produce the first FMC product for Australia. The accuracy of the final product is evaluated using existing field measurements of FMC across Australia. Although reduction of error in the absolute values of FMC estimates may be needed, these maps will still be useful for fire managers to monitor spatial and temporal dynamics in fuel moisture, thus providing insights into risk of unplanned fire and optimal scheduling of prescribed burning. Discussions with the ACT Parks and Conservation Service have confirmed the potential value of this approach.

## Activity 2. Fire impacts on landscape values

We developed a model to provide best possible estimates on forest fuel load and mositure content and fire impacts on landscape values such as water resource generation, carbon storage and habitat (Figure 3 and 4) (van Dijk et al. 2015). A case study in the Australian Capital Territory (ACT) covering the period 2000 to 2010 was undertaken to assess the feasibility of providing fuel, water and carbon estimates at an unprecedented high spatial resolution of 25 m. We integrated Landsat satellite imagery with terrain information from the TERN's (Terrestrial Ecosystem Reseach Network) Soil and Landscape Grid of Australia and TERN eMAST's 1km daily climate grids.

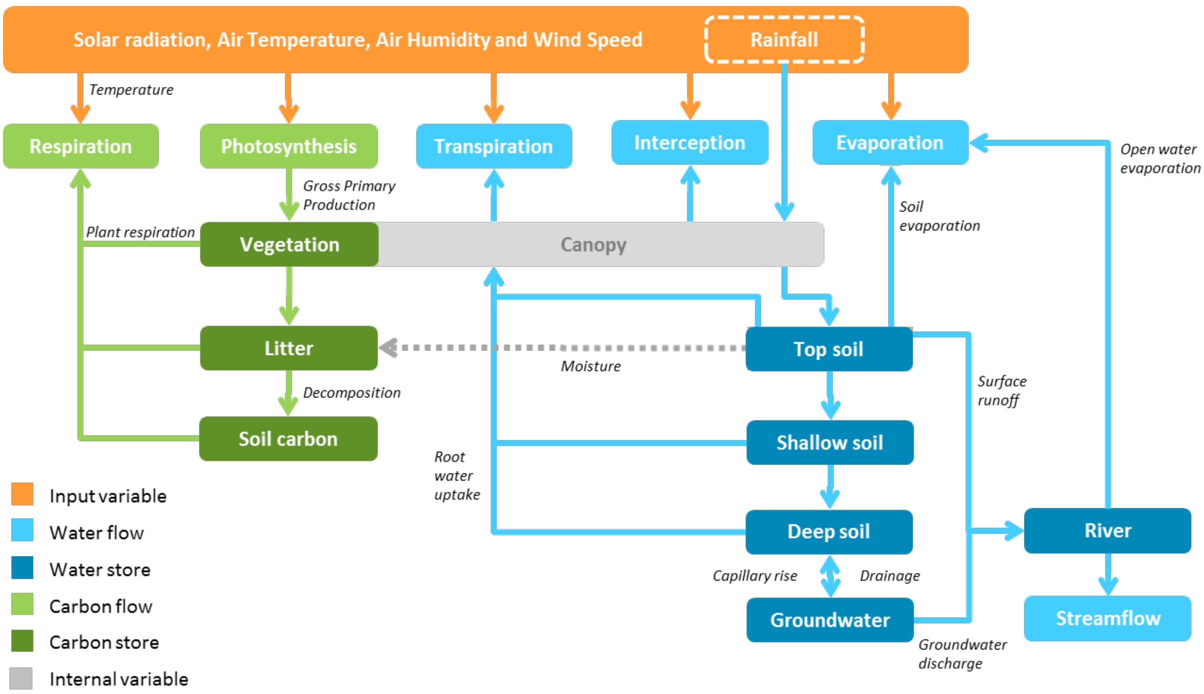


FIGURE 3. ILLUSTRATION OF THE SPATIAL FOREST GROWTH, WATER USE AND CARBON UPTAKE MODEL (VAN DIJK ET AL. 2015).

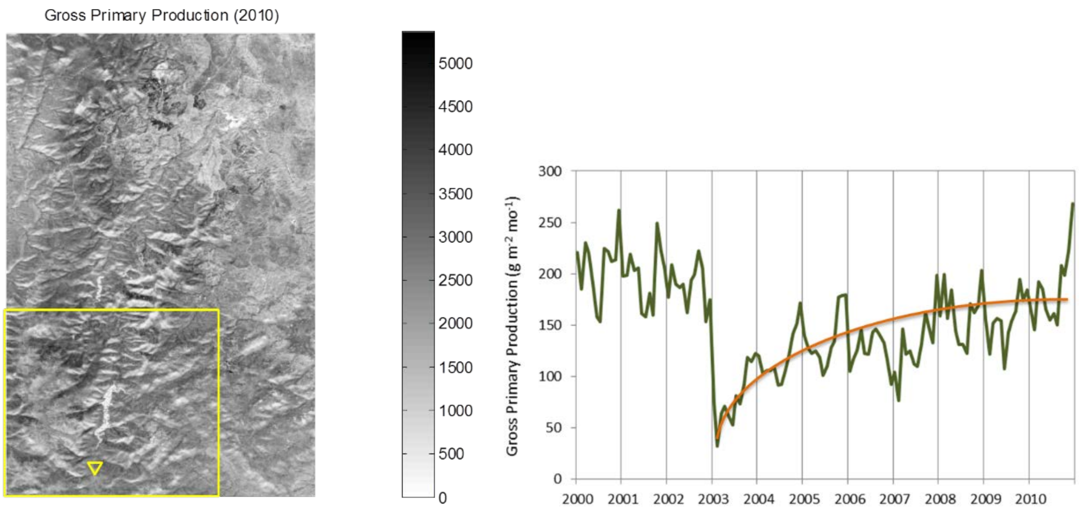


FIGURE 4. LEFT, ESTIMATED VEGETATION CARBON UPTAKE (GPP, G C $M^{-2}$ $Y^{-1}$) FOR THE CASE STUDY IN 2010. RIGHT. AREA-AVERAGE MONTHLY CARBON UPTAKE (GPP, GREEN LINE) FOR THE AREA OUTLINED BY THE YELLOW OUTLINE ON THE LEFT. THE BROWN CURVE IS ADDED TO ILLUSTRATE THE USE OF GPP ESTIMATES TO ENHANCE THE FUEL ACCUMULATION GROWTH CURVE APPROACH (van Dijk et al. 2015).

Having demonstrated that the model framework can generate realistic dynamics of fuel load and availability, water and carbon pools, we are now working with fire managers in several states to develop and trial practical applications for the model, including fuel load and moisture mapping, fire spread modelling and even real-time fire risk forecasting at high resolution.

## WORKSHOPS

### ACT Environmental Sensing Activities

On 13 February, 2015, we organised a one day workshop on 'ACT environmental sensing activities', intended to:

(1) exchange information on relevant recent, current and near-future R&D activities on the ACT through brief presentations;
(2) find common interests and new opportunities for collaboration;
(3) determine priorities in terms of data collection and (web) sharing; and
(4) discuss where coordination or expansion would be beneficial and agree how to go about it.

The day's agenda, participants and presentations can be found at http://www.wenfo.org/wald/workshop-act-environmental-sensing-activities/ .

FIGURE 5. GROUP PICTURE OF THE WORKSHOP ATENDEES TAKEN DURING THE FIELD TRIP TO THE ASULTRALIAN NATIONAL ARBORETUM.

### Fenner School Fire forum

On the 7 August 2014 Geoff Cary chaired a forum to debate which new core knowledge and skills in bushfire science, policy, and fire and land management will be required for highly effective bushfire management in future societies.

## MEETINGS

During this financial year we had four work meetings with end users from ACT Parks and Conservation Service. These meetings have helped us to develop worked case studies and guidelines to describe how each satellite information source might be useful for bushfire management, and how it can be produced and/or used operationally. The meetings were important for determining research and development requirements and priorities to achieve specific objectives, as well as establishing and coordinating in-kind contributions by end-users to the project.

More specifically some of the topics discussed include their particular interest in:

(i) Landsat-type resolution (i.e., 30 m) maps of life fuel moisture content;
(ii) regressions equations relating time since fire to changes in biomass and fuel hazard scores for Australian forest;
(iii) an automated remote sensing tool to measure fuel structure before/after prescribed burning; and
(iv) in-situ sensors for monitoring grass curing and moisture content.

This year we also presented at the Research Advisory Forum in Melbourne (3-4/12/2014) and discussed several aspect of the project with, among others, the following end-users: Belinda Kenny (Office of Environment & Heritage, Department of Premier & Cabinet, NSW), Robert Preston (Public Safety Business Agency, Queensland), Andrew Sturggesand Bruno Greimel (Queensland Fire and Emergency Services), Simeon Telfer (Department of Environment, Water and Natural Resources, South Australia) and Stuart Mathew (NSW Rural Fire Service).

# MAJOR FIELD RESEARCH HIGHLIGHTS

## Grassland curing and fuel moisture content

Five sensors were installed on 5 November 2014 in a grassland in the ACT (E 149 3' 26.509", S 35 16' 55.778" to test their suitability to monitor grassland curing and moisture content (Figure 6). The sensors were funded by TERN AusCover and installed by Dr Darius Culvenor of Environmental Sensing Systems. The sensors are 4-band (Blue, Green, Red and Near infrared), solar powered and transmit the data wirelessly to a base station every 2 minutes. The base station has a meteorological station, a small computer, a modem and an integrated Megapixel camera. Malcom Gale (ACT Parks and Conservation Service) and Lauren De Waal (ANU Honours student) carried out visual assessment of curing and collected grass samples for fuel moisture content measurement each week during the fire season 2014-2015 in order to explore the relationships between these two and the sensor measurements. The results demonstrated very close agreement between visually assessed curing and the sensor measurements, suggesting that the sensor can be used successfully where regular visual assessment is not feasible.

FIGURE 6. IN-SITU SENSORS FOR MONITORING GRASS CURING AND FUEL MOISTURE CONTENT. (TOP LEFT) METEOROLOGICAL STATION; (TOP RIGHT) ONE OF THE 5 SENSOR LOCATED ON THE SITE AND (BOTTOM) VIEW FROM THE RASBERRY PI CAMARA.

## Installation of a Cosmic ray moisture sensor

A cosmic ray moisture sensor with ancillary meteorological and soil moisture probes was successfully installed at Cotter River upstream of Corin Dam in September 2014 (Figure 7). Cosmic ray soil moisture sensing technology is a recent invention that is set to revolutionise our ability to monitor soil and biomass moisture content over large areas in near real time. With the support of the Actew/ActewAGL Endowment Fund and in collaboration with CSIRO Land & Water, we are investigating the potential of this technology for on-ground fire and flood risk early warning in remote areas.

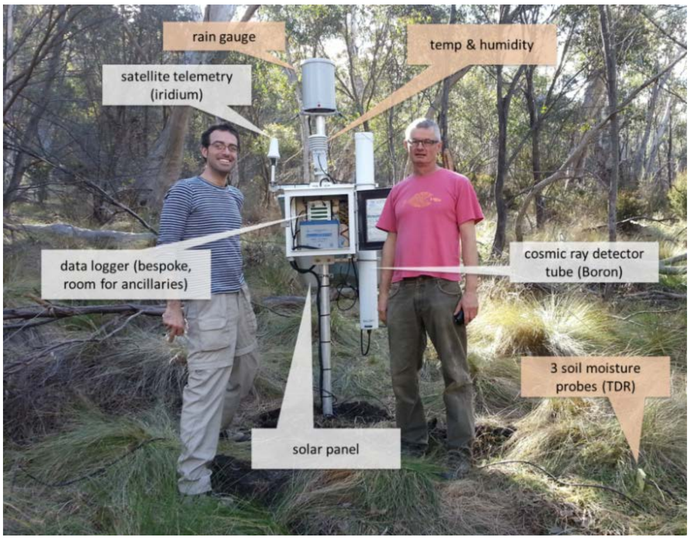


FIGURE 7. (LEFT) LOCATION OF THE NAMADGI COSMOZ STATION, AND (RIGHT) THE STATION COMPONENTS.

## Scan and burn in the ACT.

In March PhD student Yang Chen and Marta Yebra used the Zebedee terrestrial laser scanner to survey 15 plots where prescribe burns were implemented during autumn. The measurements were made with assistance from end user Adam Leavesley (ACT Parks and Conservation Service) and Tom Jovanovic (ANU). A visual assessment of the fuel hazard was also performed, following the Victorian guide. Researchers observed the fire behaviour in 3 out of 15 plots that were scanned during a large, operational prescribed burn. Next steps will be to re-visit all plots that were burned to conduct post-burn scans and visual hazard assessment, and use these to assess the suitability of the instrument to detect changes in fuel structure and load.

FIGURE 8. (LEFT) ADAM LEAVESLEY AND MARTA YEBRA PLANNING THE FIELD WORK. (RIGHT), YANG CHENG SCANNING ONE OF THE PLOTS WITH THE ZEBEDEE HANDHELD LIDAR.

## AIRBORNE DATA COLLECTION

LiDAR and imagery data capture across the whole ACT was commissioned by ACT government and completed late June 2015. Once the data are delivered PhD student Narsimha Galapati will evaluate and extract the forest fuel load information. In the interim we are closely working with ACT Parks and Conservation Service to collect ground truthing information such as geo-tagged photos and other field survey information. These will be used to assess the accuracy of information on vegetation types and structures derived from the new LiDAR data.

## CONFERENCES AND SEMINARS

End users are invited to, and generally attend, our public seminars in order to share the developments of our project, receive their feedback, and promote discussion. Some key seminars include:

- Colouring the dots: Automatically extracting forest characteristics from laser scanning 3D point clouds, by Suzanne Marselis, public lecture, Tuesday 21 April 2015, ANU [ pdf ].
- Satellite remote sensing to understand the water cost of carbon capture at global scale, by *Marta Yebra*, public lecture, 8 April (University of Alcala, Spain) 13 May 2015 (ANU), 27 May 2015 (University of Western Sydney) [ pdf]
- Coupling gross primary production and transpiration for a consistent estimate of canopy water use efficiency by *Marta Yebra*, Oral communication at the EGU General Assembly 2015. Vienna. Austria. [ pdf ]
- Fire in the Alps by Geoff, public seminar at the Frontline of the Australian Alps, 19 - 20 March 2015, ANU.

# PUBLICATIONS LIST

## JOURNAL MANUSCRIPTS


- Yebra, M., Van Dijk, A., Leuning, R., Huete, A., Guerschman, J.P. 2015 Global vegetation gross primary production estimation using satellite-derived light use efficiency and canopy conductance. Remote Sensing of Environment. 163, 206-216.
  *This article presents a model to estimate daily gross primary production (GPP), which is used to assess fire impacts on landscape values.*
- Marselis, S., Yebra, M., Jovanovic, T., van Dijk, A. Automated classification of mobile laser scanning observations to automatically derive information on forest structure and biomass. Remote Sensing of Environment. Under review.

  *This paper presents an algorithm to classify a dense point cloud from a mobile laser scanner into different vegetation and derive important information for bushfire research.*


## CONFERENCE ABSTRACTS


- Brack, C., Schaefer, M., Jovanovic, T., Yebra, M., van Dijk, A. Monitoring vegetation at the Canberra National Arboretum using laser technology. ANZIF 2015. Victoria. Australia.
- Yebra, M., Marselis, S., Van Dijk, A., Jovanovic, T., Cary, G., Cabello-Leblic, A. Mapping Bushfire Hazard and impact. AFAC 2014. Wellington. New Zealand.
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## MILESTONE REPORT


- Yebra, M., Marselis, S., van Dijk, A., Cary, G. J. & Chen, Y. Using LiDAR for forest and fuel structure mapping: options, benefits, requirements and costs. (Bushfire and Natural Hazards CRC, 2015) [pdf]

  *A briefing document that describes and evaluates the maturity and suitability of airborne LiDAR to derive information needed in forest fuel assessment.*
- van Dijk, A., Yebra, M., Cary, G. A model-data fusion framework for estimating fuel properties, vegetation growth, carbon storage and water balance at hillslope scale. (Bushfire and Natural Hazards CRC, 2015).

  *This reports presents a feasibility study in Namadgi National Park (ACT) for the development of a model-data fusion framework to provide estimates on historic fire impacts on landscape values, as well as potentially real-time estimates of current fuel load and flammability.*

## OTHER PUBLICATIONS

- A blog has being created at the BNHCRC webpage with some information about the latest activities undertook by our project. BNHCRC communication officers have advised that the blog has been extremely popular [Link]
- A newsletter was published at TERN newsletter about our recent case study in the ACT to assess the feasibility of providing fuel, water and carbon estimates at an unprecedented high spatial resolution of 25 m using TERN's climate data, alongside a number of other dataset and spatial resources [TERN newsletter].
- The BNHCRC project research featured in a booklet produced by the Fenner School of Environment & Society at ANU.

# CURRENT TEAM MEMBERS

The project team is composed of three principal researches and two PhDs students granted with a BHNCRC top-up scholarship.

## MARTA YEBRA

Research Fellow at the Fenner School of Environment & Society (ANU) and project leader. Her main background is in remote sensing of vegetation biophysical properties, such as fuel load and moisture content for spatial fire risk analysis, and canopy conductance for carbon sequestration and water balance studies.

## ALBERT VAN DIJK

Professor in Water Science and Management at the Fenner School of Environment & Society. He has expertise in retrieving vegetation structure and density information from optical and passive microwave remote sensing, and in the application of remote sensing observations and biophysical models into downstream operational environmental monitoring and forecasting methods.

## GEOFF CARY

Associate professor in Bushfire Science at the Fenner School of Environment & Society (ANU). Geoff's research interests include evaluating fire management and climate change impacts on fire regimes using landscape-scale simulation and statistical modelling, ecological investigation of interactions between fire and biota from genes to communities, empirical analysis of house loss in wildland fire, and laboratory experimentation of fire behaviour.

## YANG CHEN

PhD student from Monash University, who is currently modelling forest fuel hazard change over time using terrestrial LiDAR data. The technique she is developing will be tested at sites of different vegetation ages (time since fire) in southeastern Australia and the ACT.

## NARSIMHA GARLAPATI

PhD student from ANU, who is interested in mapping forest fuel load and structure from airborne LiDAR data. He aims to produce spatially explicit information on fuel load and structure to develop a fire danger index that can be potentially integrated in the National Exposure Information System (NEXIS). He will also assess the accuracy of the LiDAR classification and the derived products based on standard product specifications.

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Marselis, S., Yebra, M., Jovanovic, T., & van Dijk, A. (2015). Automated classification of mobile laser scanning observations to automatically derive information on forest structure and biomass. *Remote Sensing of Environment, Under Review*

van Dijk, A., Yebra, M., & Cary, G. (2015). A model-data fusion framework for estimating fuel properties, vegetation growth, carbon storage and water balance at hillslope scale. In B.a.N.H. CRC (Ed.)

van Dijk, A.I., & Keenan, R.J. (2007). Planted forests and water in perspective. *Forest ecology and management, 251*, 1-9

Yebra, M., Chuvieco, E., & Riaño, D. (2008). Estimation of live fuel moisture content from MODIS images for fire risk assessment. *Agricultural and Forest Meteorology, 148*, 523-536