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DISASTER LANDSCAPE ATTRIBUTION

Annual project report 2014-2015

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Version	Release history	Date
1.0	Initial release of document	26/10/2015

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Publisher:
Bushfire and Natural Hazards CRC

October 2015

Cover: Regrowth around Marysville, Victoria, post-Black Saturday.

Photo: Nathan Maddock, Bushfire and Natural Hazards CRC

Citation: Jones, S, Reinke, K, 2015, Disaster landscape attributions: Annual project report 2014-2015, Bushfire and Natural Hazards CRC

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EXECUTIVE SUMMARY

Jones, S and Reinke, K, *School of Mathematical and Geospatial Sciences, RMIT University, VIC*

This project brings together researchers from around the world including RMIT, the German Aerospace Agency DLR, CSIRO, the University of Twente in the Netherlands and the Bureau of Meteorology. The project will attribute fire landscapes using the latest satellite based thermal earth observation systems for active fire surveillance. Structure from Motion (SfM), Terrestrial Laser Scanning (TLS) and hyperspectral technologies and techniques will also be used for quantifying and mapping changes in the landscape before, and after, a fire event. This report provides a background to the project and discusses the key research questions being asked, and how these can help support end user operations. The methodology used to address each of the research questions is outlined, and key achievements across the last year are described. The report concludes with activities planned for the year ahead and a list of currently integrated project members.

Highlights of 2014-2015 have included:

- Field experiments from the previous year published in Gupta, V., Reinke, K., Jones, S., Wallace, L. and Holden, L. (2015) "Assessing Metrics for Estimating Fire Induced Change in the Forest Understorey Structure using Terrestrial Laser Scanning", *Remote Sensing*, 7, pp. 8180-8201.
- New datasets have been collected and are being prepared for publication in Hillman, S., Wallace, L., Hally, B. and Reinke, K. (in prep.) "Evaluating New Terrestrial Techniques for Estimating Surface and Near-Surface Biomass" to be submitted to *Ecological Management and Restoration*.
- A new full-time postdoctoral research fellow (selected in consultation with a representative end-user) and a new PhD candidate join the research team. Additional short-term research appointments have also been filled.
- Attendance and poster presentations at AFAC, Wellington 2014, and the BNH-CRC RAF, Melbourne 2014.

- Associated PhD student presents his work on “Identifying Spectral Domains and Metrics to Quantify Burn Severity in Australian Dry Sclerophyll Forests” at *Geospatial Science Research (GSR),* Melbourne 2015.
- New end-users join the project from Queensland Fire and Emergency Services, and SA Department of Environment, Water and Natural Resources.
- Project spin-off studies create a fire history atlas used to report the spatio-temporal wildfire patterns in peri-urban areas of Australian capital cities, and more broadly across southern Australia.
- Work on synthetic landscape modelling for fire detection and tracking continues. Initial results for minimum area and fire temperatures detected by TET-1 produced and being extended to compare to other active fire detection and monitoring space systems.
- Fire temperature mapping and monitoring using manual and electronic fire pyrometers trialed during a prescribed burn with Department of Environment, Land and Water Planning in western Melbourne, Victoria.

END USER STATEMENT

David Nichols, *Fire and Emergency Management, Country Fire Authority VIC*

The provision of timely, synoptic cost effective remotely sensed data on bushfires can save resources and time. Accurate observations of a bushfire threatened landscape can potentially enable fire and emergency managers to reduce the area affected and the bushfire impact. The multi-scale delivery of fire severity mapping can enhance information regarding fire occurrence. The Disaster Landscape Attribution project uses the latest satellite based earth observation remote sensing systems for active fire surveillance as well as terrestrial laser scanning and hyperspectral technologies and techniques for quantifying and mappings changes in landscapes affected by bushfire. The project will assist in the collection of vital bushfire information acquired through state-of-the-art remote sensing technology as needed by fire and emergency management now and in the future.

David Taylor, *Fire and Emergency Management, Country Fire Authority VIC*

Work package 1: The existing MODIS sensor has noted limitation in Tasmania; historical ground truthing indicates a question of reliability since fires under tall tree canopy or low fire intensity are not detected along with limitations because of time lag for data acquisition. Interest will be how the new Himwari platform will perform and accessibility to data.

Work-packages 2 and 3: There is tremendous interest around research in this field, a sound and practical application is now required nationwide to fill existing gaps in the vegetation inventory, presently most agencies have some type of vegetation inventory with a correlation to fuel structure. A quantitatively post burn measurement methodology is also required since most present measurement are made by visual referenced and accuracy is questionable,. hyperspectral technologies and techniques for quantifying and mappings changes in landscapes affected by bushfire. The project will assist in the collection of vital bushfire information acquired through state-of-the-art remote sensing technology as needed by fire and emergency management now and in the future.

INTRODUCTION

There is a need for accurate observation and monitoring of active fires in the landscape, and new supporting attributes or metrics for assessment of post-fire effects across the landscape. Emerging earth observation technologies designed for monitoring fire and its effects, combined with the ubiquitous nature of remote sensing means there is an ongoing requirement to understand the fitness-for purpose of new data products. How well do they perform? What are their limitations? What are their advantages for observing fire under different fire scenarios and in different landscapes? Yet at the same time, it is also about utilising existing data sources and procedures currently in operation and developing flexible protocols for integrating current as well as future data products for our end users.

Our vision is to create a world leading approach for monitoring active fire extent and intensity, and subsequent quantification of bushfire severity. To achieve this vision two complementary research activities are proposed using remote sensing technologies for: (1) active fire detection and monitoring, and (2) enhancing pre and post burn landscape attribution.

The outcomes of the project are to build the capacity for integrating current fire information with existing, and next generation, remote sensing satellite information thereby enhancing Australia's operational capabilities and information systems for bushfire monitoring and mapping across a range of spatial scales and landscapes. Ultimately the outcomes of this research will enable measures of active fire and burn severity in terms of areal extent and magnitude to be made which in turn have the potential to inform decisions about bushfire response, fuel hazard management and ecosystem sensitivity to fire; during fire events and post-fire rehabilitation efforts.

The project has practical significance to end users involved in fire ecology, wildfire mitigation and management activities. Recommendations will be made in terms of operational decisions relating to information specifications and protocols necessary for the monitoring and management of wildfire management activities. Land managers, fire scientists and ecologists are turning to remote sensing as a tool for rapidly acquiring fire and vegetation related data over various spatial scales. By supplementing existing data collection and data integration protocols to include new variables that enable integration with remotely sensed observations we will be maximising the efforts made by ground crews plus enhancing capacity for accurate mapping of fire activity, and improving assessments of fire severity through the use of remote sensing technologies. Improving capacity for quantitative and accurate measures of fire- related variables will assist government reporting requirements and informing future wildfire mitigation work plans.

THE PITCH

What is the problem?

Monitoring bushfires requires timely information on their location, intensity and configuration. Their management requires timely information on fuel hazard condition and the efficacy of fuel reduction measures. This project seeks to use remote sensing to acquire this information at multiple spatial scales.

Why is it important?

By enhancing the timeliness and accuracy of observations and measurements of bushfire threatened and affected landscapes, our mitigation activities and response capacities are further strengthened. The provision of quantitative fire severity assessments informs the way in which we protect against the increasing threat of bushfire and inform our immediate to long-term recovery and rehabilitation efforts in response to bushfire events.

How are we going to solve it?

Our project is evaluating and validating current satellite based remote sensing options for active fire detection and surveillance. Using simulations and real world experiments we are determining the accuracy with which fires can be detected, their temperature and shape determined, for a range of landscapes. Our project is also creating new techniques and protocols for the rapid attribution of fire landscapes (pre- and post-fire). These techniques seek to add quantitative vigour to existing fuel hazard estimation practices.

PROJECT BACKGROUND

The project will address the provision of timely and high quality information founded on multi- scale remote sensing and will develop enhanced metrics on active fire extent, intensity and configuration as well as bushfire landscape attributes. The project aims to bridge significant information and knowledge gaps that currently prevent optimal use of earth observing technology. These include accuracy and reliability issues in active fire surveillance, quantitative estimates of post-fire severity, a lack of product validation, and out-of-date approaches to collecting information on landscape condition. The project seek to enhance Australian led existing disaster monitoring (e.g. the CSIRO/GA Sentinel Asia / Sentinel hotspots) and reporting systems with next generation earth observation technology and systems from the DLR and other agencies. The project will be delivered in three integrated work-packages which are summarised below. The research will be placed in “priority landscapes” as identified by end-users and which have been identified as peri-urban areas, desert/mallee systems and closed (multiple canopy) forests in Australia. Figure 1 provides an overview of core activities and application areas.

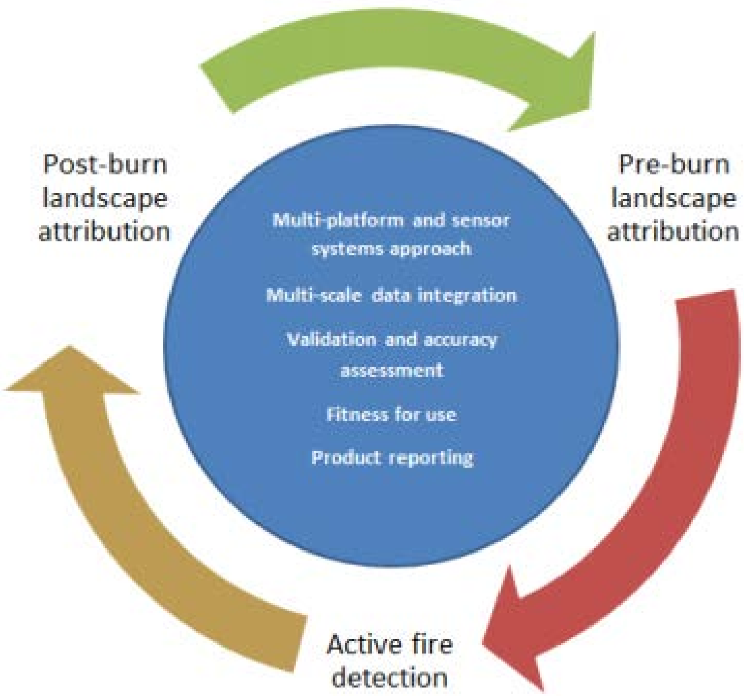


Figure 1. Overview of core research activities and application areas.

WORK PACKAGE 1: REMOTE SENSING FOR ACTIVE FIRE SURVEILLANCE

The current global fire detection system is based on the Moderate Resolution Imaging Spectrometer (MODIS) sensor. The TET-1 satellite and payload (launched in 2012), includes an infrared camera system designed for the detection of High Temperature Events, such as wildfires, evolved from the Bi-spectral Infrared Detector (BIRD) experimental satellite. BIRD/TET-1 can detect fires with a smaller area and lower temperatures (indicators of fires in early stages of burning) than the commonly used MODIS satellite sensing system due to its higher spatial resolution.

This work package will use MODIS, TET-1 (and investigate the use of geostationary satellite systems, such as Himawari-8 –when they come on stream) for active fire surveillance. A literature review has been completed regarding existing and emerging thermal technologies, and to review these against the information sources utilised by fire management agencies.

Field experiments will be used to validate sensor information and this will be a core activity of this work package. In collaboration with research partners and end users, a complex data collection campaign will be undertaken. It will involve deploying in-situ fire loggers and pyrometers on the ground to record temperature (and duration) of fire during a prescribed burn. Aerial imagery will be captured during the time of the burn, and will also be synchronous to data collection taken during satellite sensor pass over. This will result in a truly multi-scale and synchronous dataset of a fire event. Supporting the empirical study, will be a “virtual assessment” of thermal sensor capabilities.

Simulations of different active fire scenarios will be generated to theoretically determine the limits under which active fire detection and mapping accuracy can be achieved by different sensors under differing fire conditions and cross-referenced to empirical studies. An analysis of the spatial and temporal characteristics of wildfires will be described for Australia, and comparisons between states and major cities will be made. Further, generalised fire types, based on spatial characteristics, will provide justification for the different fire scenarios used during simulation studies.

WORK PACKAGE 2 AND 3: PRE-BURN AND POST-BURN LANDSCAPE ATTRIBUTION

This work package considers the need for accurate observation and new supporting attributes or metrics for assessment of post-fire effects across the landscape. Severity assessments, in particular, are largely subjective and have limited capacity for scaling up from the site to the landscape. The next step for these assessments is to move towards being quantitatively measured across the entire landscape of interest, and to have the important capacity to integrate with future information sources. Remote sensing offers the only means to routinely monitor and report on the status of landscape condition over large areas. It is both synoptic and systematic; and offers repeat total sampling in a consistent regular framework.

The goals here are to go beyond reporting the area burnt, to one that captures the spatial complexity or mosaic of burn patterns. On ground technology, coupled with aerial and satellite images gives us a powerful way to validate and link what we see from space to what we see happening on the ground. We consider the typical methods used to map and describe the pre-burn landscape (e.g. fuel hazards) and the post-burn landscape (e.g. burn severity elements); and aims to complement traditional assessment approaches by developing new and reliable information through the addition and integration of remotely sensed metrics of emerging technologies such as LiDAR and SfM.

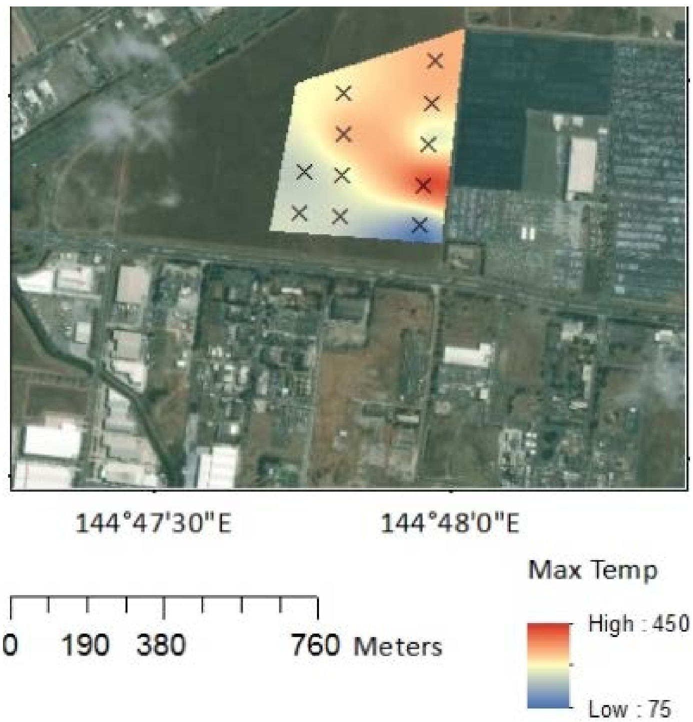
We will demonstrate the use of laser scanning and SfM for quantifying and mapping the change in the landscape, as changes in vegetation or fuel – both live and dead – for a given area. Field experiments will be used to collect laser scans of the same site before, and after, a fire event. Additional experiments will be conducted to collect laser scans and SfM photos of other vegetation communities within Victoria and interstate. Fuel hazard and severity assessments will be made, and correlated against variables of fuel and/or biomass that will be collected through in-situ measurements, and destructive dry weight analyses. The final step will be to consider how we translate remotely sensed measures of the environment into measures that have context and meaning to fire managers.

PROGRESS

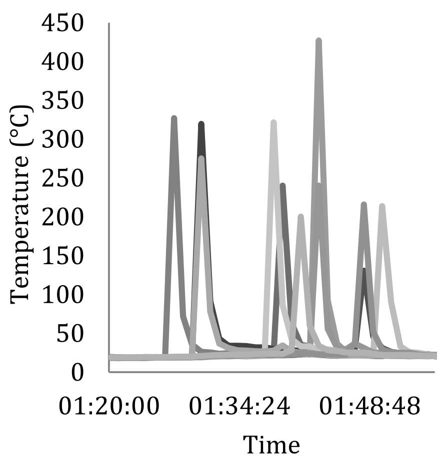
KEY RESEARCH ACHIEVEMENTS

Mapping and monitoring of fire temperature during a prescribed burn in a native grassland reserve using manual and digital pyrometers

An experiment was carried out to track the temperature changes during a prescribed burn event in a native grassland reserve. The area, located in Laverton (Victoria) was carried out during April 2015 by the Victorian Department of Environment, Water, Land and Planning (DEWLP) as part of their planned burn activities. Eleven measuring locations were selected along 3 transects across the burn area (Figure 2a). In each location, a thermocouple and data logger were deployed along with a manual pyrometer. Temperature was recorded for each point every minute for the duration of the burn event. Temperatures at the measuring points reached up to 430°C at the moment of the fire (Figure 2a). All points returned to ambient temperature within three minutes posterior to being on fire (Figure 2b). This study will be repeated for a forested environment and a short report of both studies will be distributed to end-users upon completion.



(A)



(B)

FIGURE 2 MAXIMUM TEMPERATURE RECORDED IN THE BURNED GRASSLAND AREA (A) AND TEMPERATURE REACHED BY EACH SENSOR OVER TIME (B).

Evaluating new terrestrial techniques for estimating vegetation biomass.

A field campaign was undertaken in early 2015 to assess the capabilities of three technologies for sensing fuel hazard across vegetated environments in Warrandyte (Figure 3a), Victoria and representative of the priority landscapes identified by end-users (Figure b-3d). The study applied various algorithms for assessing fuel from the raw data collected using three approaches: (1) A direct approach *rising plate meter*, which is a farm management tool that approximates pasture and surface biomass. (2) A *terrestrial phase-based laser scanner*, setup following the AusCover technical guidelines for TLS scans. (3) Downward looking photos using a *point and shoot digital camera to which Structure from Motion (SfM)* was then applied to generate a point cloud.

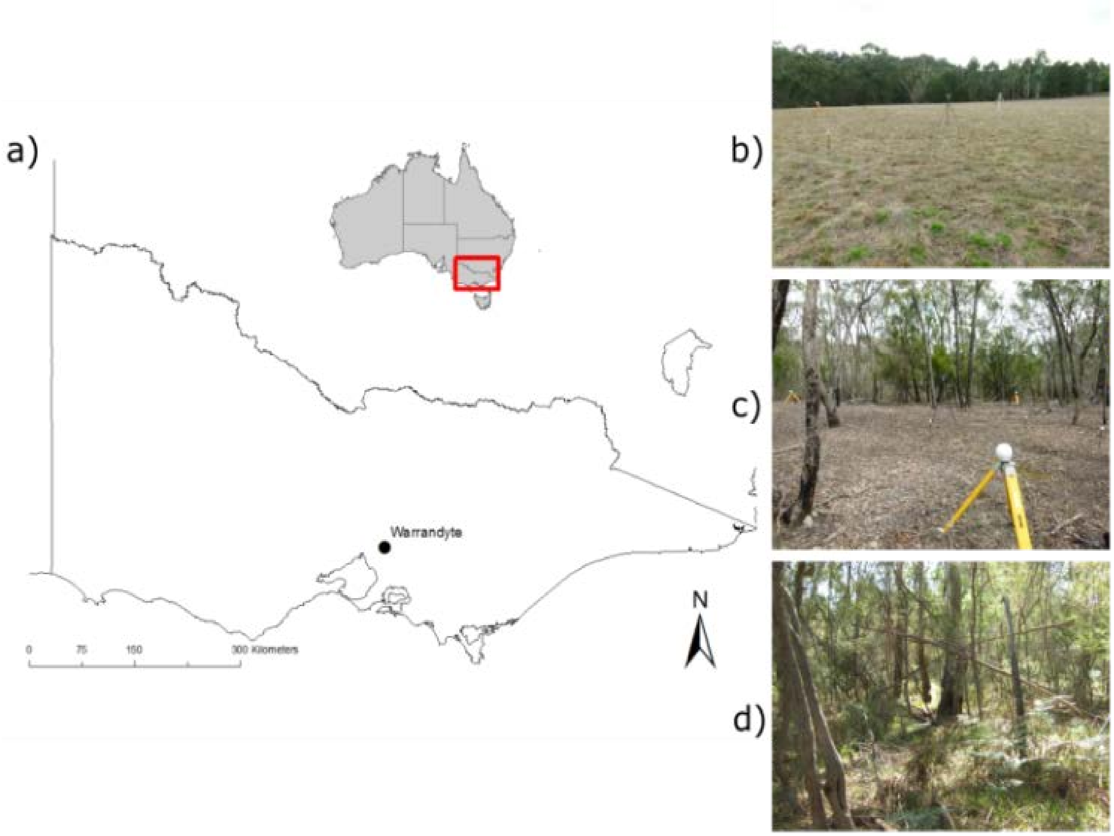


FIGURE 3 - LOCATION OF STUDY AREA IN VICTORIA, AUSTRALIA. B) PASTURE PLOT. C) GRASSY DRY FOREST PLOT. D) FLOODPLAIN RIPARIAN WOODLAND PLOT.

Comparisons were made between the algorithm outputs and destructively sampled dry weight measurements to determine the degree to which the technologies can provide a representation of the fuel load. A manuscript describing this research is currently in preparation and will be submitted to *Ecological Management & Restoration* shortly.

Spatio-temporal patterns of wildfires in per-urban areas of Australian cities from 2000-2013.

This study was completed after the creation of a fire history atlas of southern Australia originally designed to support field experiments and simulation studies of fire. From this fire history atlas, the spatial and temporal characteristics of wildfires in the peri-urban areas of Melbourne, Hobart, Canberra, Brisbane and Adelaide from 2000 to 2013 were calculated. Spatial metrics included fire size, shape and orientation, and temporal metrics included months of peak fire activity and peak fire season. In addition, the results were evaluated in the context of dominant land use. Further, data on monthly rainfall and highest monthly temperature for each of the study areas was collected from the Bureau of Meteorology and charted against the fire history records. This information was then used to compare monthly fire statistics of each capital city to average monthly rainfall and average monthly temperature. Figure 4 is an example of the types of results prepared from this study. A report is being prepared for distribution to end-users.

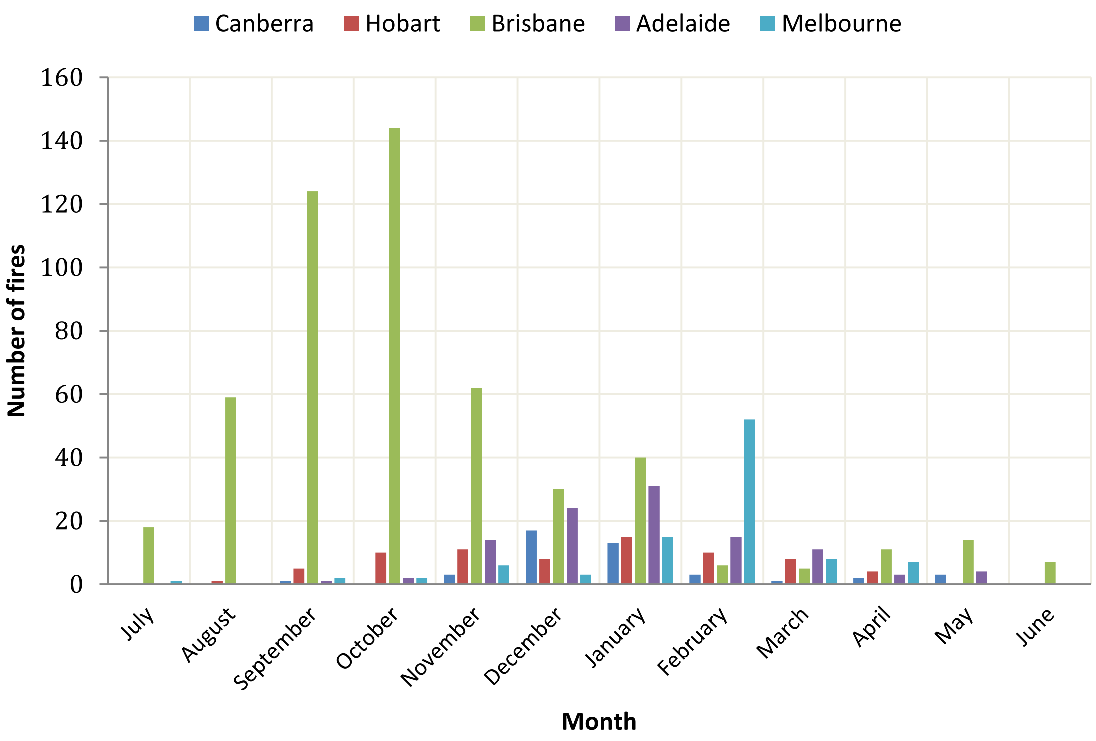


FIGURE 4 - THE NUMBER OF WILDFIRES (NOT AREA) RECORDED PER MONTH FOR FIVE AUSTRALIAN CAPITAL CITIES DURING 2000-2013.

This work is currently being extended to cover all land south of the Tropic of Capricorn and will consider both prescribed fires and wildfires. The analysis will be stratified according to boundaries based on land tenure, eco-region and land use, as examples. The temporal length of the study will be extended to 1990 – 2013. Sophisticated spatial analyses and time-series analyses will be used to provide quantitative answers to questions such as "Are wildfires increasing?" Figure 5 is an example taken for Tasmania showing the general trend that there is an increase in the number of wildfires since 1990. The outcomes from the study is planned for publication in the *International Journal of Wildland Fire*.

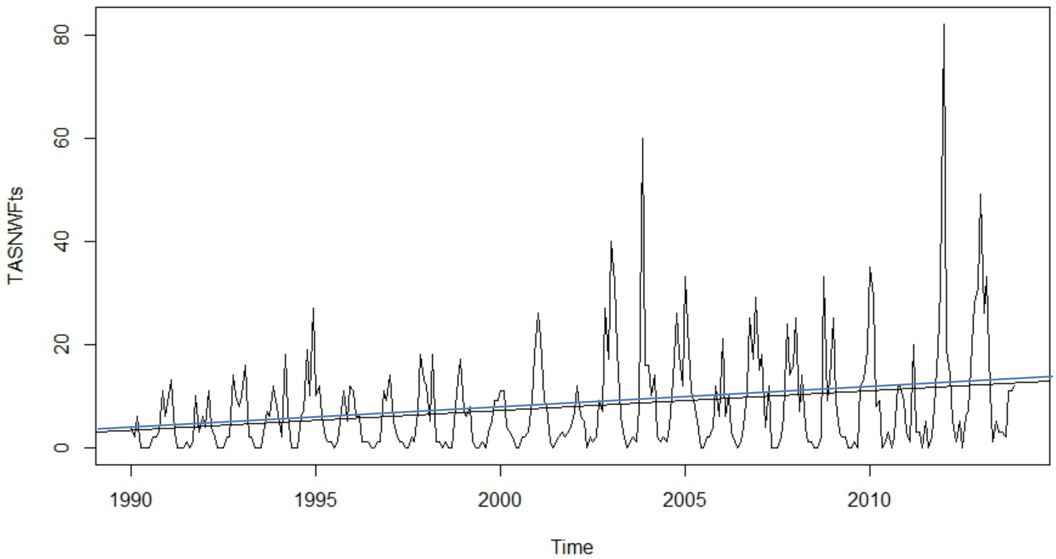


FIGURE 5 - THE NUMBER OF WILDFIRES RECORDED FOR ALL OF TASMANIA FROM 1990 - 2013. THE BLUE LINE INDICATES THE STATISTICAL TREND OBSERVED OVER TIME INDICATING A SMALL INCREASE IN THE NUMBER OF WILDFIRES OCCURING SINCE 1990.

EQUIPMENT

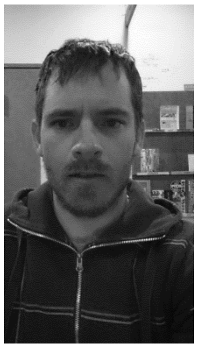
- ***Fire Loggers and Pyrometers.*** 31 Electronic fire loggers and manual pyrometers have been built to be deployed in prescribed burn fire scenarios. These sensors will allow in-situ measurements of temperature to made and used in the assessment and calibration of airborne and satellite sensors.
- ***Photogrammetric PC and software*.** The reconstruction of structure from imagery captured using a variety of sensors onboard different. The purchase of a specilised PC and processing software (Agisoft photoscan) will allow this technology to be deployed in mapping and monitoring fuel hazard.
- ***Google Project Tango Tablet***. This structured light tablet represents an example of emerging technology with the capability to sense the 3D structure of the environment. Purchasing this piece of hardware will allow the research team to assess the suitability of structured light sensors for mapping and monitoring fuel hazard.

APPOINTMENTS

- ***Postdoctoral Fellow Dr. Luke Wallace commenced February 2015.*** Luke received his PhD degree from the University of Tasmania, working with the TerraLuma research group. During his PhD Luke developed a world first mini Unmanned Aerial Vehicle LiDAR mapping system and demonstrated its application in measuring and monitoring plantation forests. Luke has also worked as the primary programmer and spatial analyst in the development of annual bushfire risk models for the Tasmanian Parks and Wildlife since 2011. His current research interests focus on the development and use of remote sensing technology for characterizing and monitoring change in the 3D structure of vegetated environments.

- ***Postdoctoral Fellows Dr. Mariela Soto-Berelov, Dr. Sofia Oliveira and Dr. Lola Suarez Barranco commenced short-term appointments.*** Mariela has a background in GIS, spatial analysis and modelling. Mariela is the lead researcher for compiling the fire history atlas for southern Australia (in collaboration with state agencies) and is a key contributor to the analysis of this database. Sofia leads the spatio-temporal analysis for southern Australia drawing upon her extensive experience in analysing fire patterns in Portugal, Brazil and northern Australia. Lola brings expertise in thermal and hyperspectral remote sensing, and field survey design and collection. She will advise and assist with field experiments and data validation campaigns planned for 2015.

- ***PhD candidate Bryan Hally commenced February 2015.*** A graduate of the Bachelor of Surveying program at RMIT, Bryan has recently returned to RMIT to commence a research candidature position. Since graduation he has spent an extended period in the private sector, in engineering consulting and project management in the water industry. Bryan is looking to complete a dual badged PhD in conjunction with researchers at ITC, at the University of Twente in the Netherlands. The major focus of study of this research is the ability of current remote sensing platforms to accurately detect and describe active fire, which will combine the use of synthetic landscapes with fire growth algorithms, atmospheric modelling and sensor parameters to mimic existing fire detection conditions. The work will provide validation to current fire products derived from remote sensing platforms, describe in detail the influence of environmental factors on sensor occlusion, and expand the use of these platforms for providing accurate extent and intensity of active fire.



PUBLICATIONS LIST

Gupta, V., Reinke, K., Jones, S., Wallace, L. and Holden, L. (2015) "Assessing Metrics for Estimating Fire Induced Change in the Forest Understorey Structure using Terrestrial Laser Scanning", *Remote Sensing*, 7, pp. 8180-8201.

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