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

FIRE NOTE

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FIRE SEVERITY MAPPING: MAPPING THE EFFECTS OF FIRE ON SAVANNA VEGETATION IN NORTHERN AUSTRALIA FROM SATELLITE IMAGERY

ABOUT THIS PROJECT

This research derived a means of mapping the effects of fire on tropical savanna woodlands and open forests using satellite-based remote sensing data.

By collecting data from a helicopter equipped with a hand held version of the satellite sensor just 100 metres above the ground, the research was able to establish precise GPS locations of the area studied. This information was the basis of precise ground sampling to be undertaken to provide validation of the satellite sensor's data. The various levels of visible and near infrared light reflected to the sensor from the burnt area were correlated with the measurements on the ground of the fire effects. The final product is an algorithm to map fire severity using satellite images covering hundreds of square kilometres of frequently-fire affected tropical savanna landscape.

AUTHORS

This research was undertaken by Andrew Edwards (pictured above right) as a PhD research project "Fire Severity Mapping in the tropical savannas of northern Australia". It is being applied in the "Understanding Risk" Program in the project entitled "Northern Fire Mapping" as part of the research program for Bushfire CRC Extension. The original research was funded by a student stipend from the Bushfire CRC, operational and other financial support was provided by Bushfires NT and student support from Charles Darwin University. The current work is funded by the Bushfire CRC with Project Leaders Dr Jeremy Russell-Smith of Bushfires NT and the North Australia Indigenous Land and Sea Management Alliance (NAILSMA), and Dr Mick Meyer of Marine and Atmospheric Research, CSIRO. The Lead End-User of the project is Dr Neil Burrows, Director Science Division in the Department of Environment and Conservation, WA.

SUMMARY

Wildfire in the tropical savannas of northern Australia is frequent and extensive. The annual wildfire cycle requires management for fire prevention to be a continuous and iterative process. The vast areas effected, the low population density, limited infrastructure and remoteness of much of northern Australia have lead fire managers to the use of remote sensed mapping as a critical tool for dealing with fires quickly and effectively. Earlier Bushfire CRC research developed a method of calibrating remotely sensed imagery for mapping fire severity, defined here as the post-fire measure of the affect of fire on vegetation. Calibration is a means of training satellite image information with ground information to classify something on the ground.

A fire severity mapping product will be made available through the web-based North Australian Fire Information mapping system (www.firenorth.org.au) enhancing the sites utility to land managers across north Australia.

CONTEXT

The PhD research under-pinning the current project sought to determine if it were possible to detect various levels of post-fire affects on tropical savanna vegetation using the components of the electromagnetic spectrum (visible and near infra-red light) detectable by sensors on-board satellites regularly orbiting the earth. Models derived from that research are being calibrated and validated in the current Bushfire CRC project to create a map of fire severity with levels of accuracy appropriate to land management in the region.

BACKGROUND

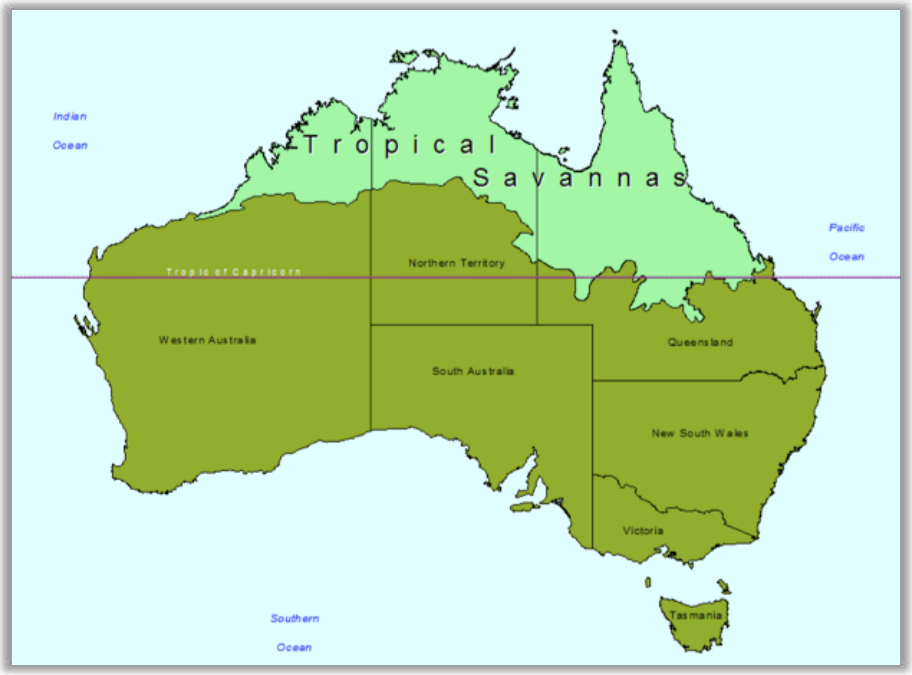
The tropical savannas of northern Australia cover approximately 1.9 million square kilometres (see Figure 1). The dominant vegetation cover is a matrix of eucalypt woodland and open forest with an extensive grassland understorey. Rainfall is highly seasonal, with over 90% of the 1000 mm average annual rain falling in the summer months. Fuel accumulation is rapid during this period and the subsequent annual drought provides ideal conditions for fires annually. Fires are frequent and without planned preventative measures multiple individual fires will extend over hundreds of square kilometres.

Under these extreme climatic conditions prescribed burning is applied widely and strategically to mitigate wildfire. Land managers rely heavily on timely satellite-derived data to detect the presence of fires and to map their extent. The extent of past fires, the 'fire history', is used for the development of strategic fire management programs. Ideally this data would be complemented by information on the fire's effect on vegetation, not just its extent. To date however managers have had to use fire seasonality to estimate the effect of fire; applying a rule-of-thumb that late Dry season fires are more severe than those of the early Dry season. A reliable means of mapping fire severity will provide information about the effectiveness of prescribed burns. It will also inform about the proportion of the various fuel components consumed for greenhouse gas emissions accounting as well as providing a direct correlation with the landscape patchiness of fire for conservation land management and species habitat assessment.

BUSHFIRE CRC RESEARCH

In the Bushfire CRC funded PhD research project undertaken by Andrew Edwards, a set of indices were derived for satellite-based optical sensors enabling modelling of the effect of fire on the vegetation. Measurements were taken in fine detail to assess the influence various ground components have on the light reflected to the satellite-based sensors. In the application of the research through the Bushfire CRC Extension program an extensive set of calibration data points will be collected to test the functionality of the indices. In 2011 over 8,000 data points were collected for the calibration. In future years equivalent ground-based data points will also be collected as a means of further validating the models.

The calibration dataset is required to be extensive both spatially and temporally so as to capture as much variation in fire effect as possible. The ground-based data points were collected across the tropical savannas, throughout the northern fire season, from April to October.



▲ **Figure 1**. The extent of Australia's tropical savannas. Australia's rangelands include the tropical savannas. (Map information interpreted from the Interim Biogeographic Regionalisation of Australia v 6.1)

END USER STATEMENT

"Northern Australia has a lot of fire and very few resources to manage them. The Bushfires CRC Fire Severity Mapping research project will add a significant tool to the suite of remote-sensing aids fire managers rely upon to ensure wildfires have minimal impacts on people, property, biodiversity and greenhouse emissions. Northern fire managers know that not all fires are bad; this tool will enable the characterisation of good and bad fires remotely, at a landscape scale. And that is fantastic."

– Steve Sutton, Director and Chief Fire Control Officer, Bushfires NT

Initially end-user feedback was sought in characterising the effects of fire on tropical savanna habitats, the collation of this information resulted in the development of a user guide published by the Bushfire CRC (Edwards, 2009). Extensive end user involvement has occurred in accessing remote areas in the various regions and in actual data collection for the development of a fire severity map product.

The success of the project relies on its extensive nature, to ensure sampling across a wide spatial coverage, throughout the fire season. It will need to involve many end-users including field ecologists, conservation staff, fire management staff, pastoralists and indigenous rangers and land managers.

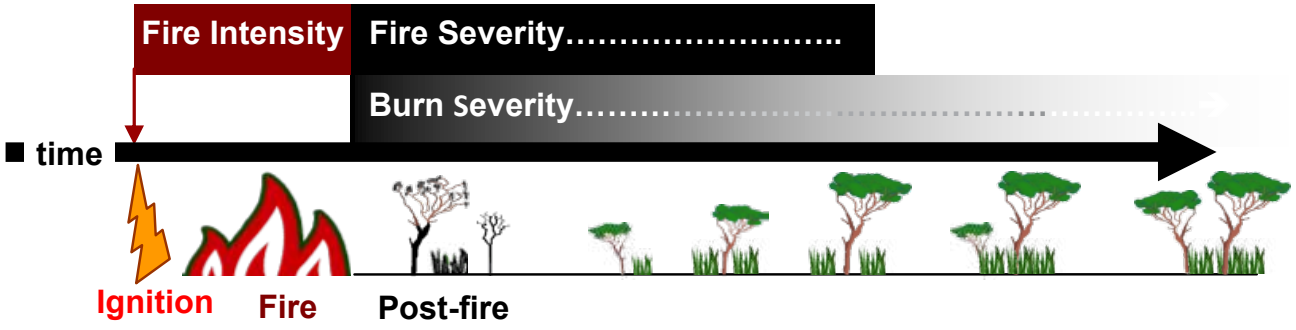
RESEARCH OUTCOMES

Human resources and infrastructure in north Australia are sparse by comparison with the southern states, with approximately 1 person for every 4 km^2. Added to this, the tropical savannas of northern Australia can be one of the most fire prone biomes on the planet. The provision of timely cost effective data can save time and resources and has the potential to enable fire managers to reduce the area affected by fire. The provision of fire severity mapping will enhance information regarding fire occurrence.

The PhD study underpinning the current project developed a method of calibrating remotely sensed imagery for mapping fire severity. It coupled spectra and comprehensive ground measurements. Data were modelled against a fire severity index, the metrics of which were previously developed in collaboration with land managers.

The best model used a ratio incorporating the near infra red (NIR) and the longest short wave infrared region (SWIR2) to separate severe from not-severe fire effects. The near infrared is best for detecting the density of green vegetation, whilst SWIR2 is best at describing fuel moisture. This combines the effects of the reduction in both photosynthetic and non-photosynthetic vegetation. Models were also assessed to discriminate low from moderate fire severity events. The best model centred around the shorter short

FIRE SEVERITY IS DEFINED AS A POST-FIRE MEASURE OF THE EFFECT OF FIRE



▲ **The fire continuum.** Time moves forward from left to right. The illustrations below the time line represent the fire: 1. the Ignition; 2. the Fire Event; and 3. the Post-fire Recovery. The boxes above the line represent the fire terminology with respect to time: 1. as the fire is in progress, the Fire Intensity; 2. post-fire, the Fire Severity, the effect of the fire is measurable for a period of time; and 3. Burn Severity: measures and descriptions of the time and processes to reach a "recovery" state (sensu Lentile *et al*., 2006)..

wave infrared (SWIR1), available as Band 6 from the Moderate Resolution Imaging Spectroradiometer (MODIS) sensor. However, of the two available MODIS sensors, Band 6 is dysfunctional in one, halving the available data and vastly reducing its utility for automation.

As part of the process of identifying a readily available alternative model the data collected in 2011 were calibrated with the reflectance values derived from a time series of MODIS images, mapped by a previously developed burnt area mapping algorithm. The result indicated that MODIS Band 2, the first near infrared band, was able to provide clear distinction between most categories, quite clearly when aggregated into three categories and very definitely in a binary system, severe v not-severe, thereby making this a very useful option.

The added benefits of an algorithm for MODIS Band 2 are:

- It is one of two bands with a 250m pixel size, other Visible/Near Infrared bands are at 500m, and the other 29 are available only at 1,000m.
- It is functional on board the Terra and Aqua satellites, therefore there are 2 possible collections per day, rather than the application of MODIS Band 6 which the modelling demonstrated to be better but is not functional on the Aqua satellite so therefore it only has one pass per day;
- It is already used in the burnt area mapping algorithm for north Australia, therefore, there is very little extra processing required to extract the fire severity information from the satellite imagery.

HOW WILL THE RESEARCH BE USED?

Fire severity mapping will improve the ability of land managers to monitor the efficacy of fires when undertaking strategic fire management. It will provide conservation land managers with greater detail to more effectively assess fire effects on ecological communities, and improve the precision of greenhouse gas emissions calculations by providing a dynamic and spatially explicit dataset.

Prior to satellite derived fire mapping little was known about the extent of fire in northern Australia. The introduction of the North Australia Fire Information web site changed fire management in the north markedly. One of the products, fire "hot spots", maps within an hour of fire occurrence. A land manager sitting at their desk can identify the location of fires, illustrating either the efficacy of their own strategically planned efforts, or the occurrence of a wildfire. If a wildfire is identified, other products such as the prevailing winds and burnt area mapping have been shown to save millions of dollars in reconnaissance and planning. This research will further add to these tools.

Ecological data describing the decline in extent, richness and number for various floral and faunal indicator species suggest that management of Australian landscapes has changed in recent decades. Modern landholdings in the north are managed as immense properties. Fires across these landholdings are also immense, and have reduced landscape heterogeneity beyond the scales representing the habitat range of most fauna. However, studies have also shown that even a high frequency of low severity patchy fires creating small pockets of different fire ages has a positive effect on species richness in savanna woodlands and open forests. The current research will allow land managers to better manage fire in these environments to achieve more balanced outcomes for the area.

The tropical savannas are the largest single source of greenhouse gas (GHG) and particulate emissions in Australia, emitting 2% of Australia's GHGs in 2005. GHG emissions abatement is achieved in savanna ecosystems by introducing fire management practices that reduce the amount of biomass consumed by fire, that is, by reducing the area burnt and severity of the fires. The fire prone savannas in north Australia have attracted funding from polluters interested in offsetting their GHG emissions, and the introduction of the Carbon Farming Initiative, makes the accurate calculation of emissions mandatory for large parts of the north. The outcomes from this research will significantly assist in this process.

FUTURE DIRECTIONS

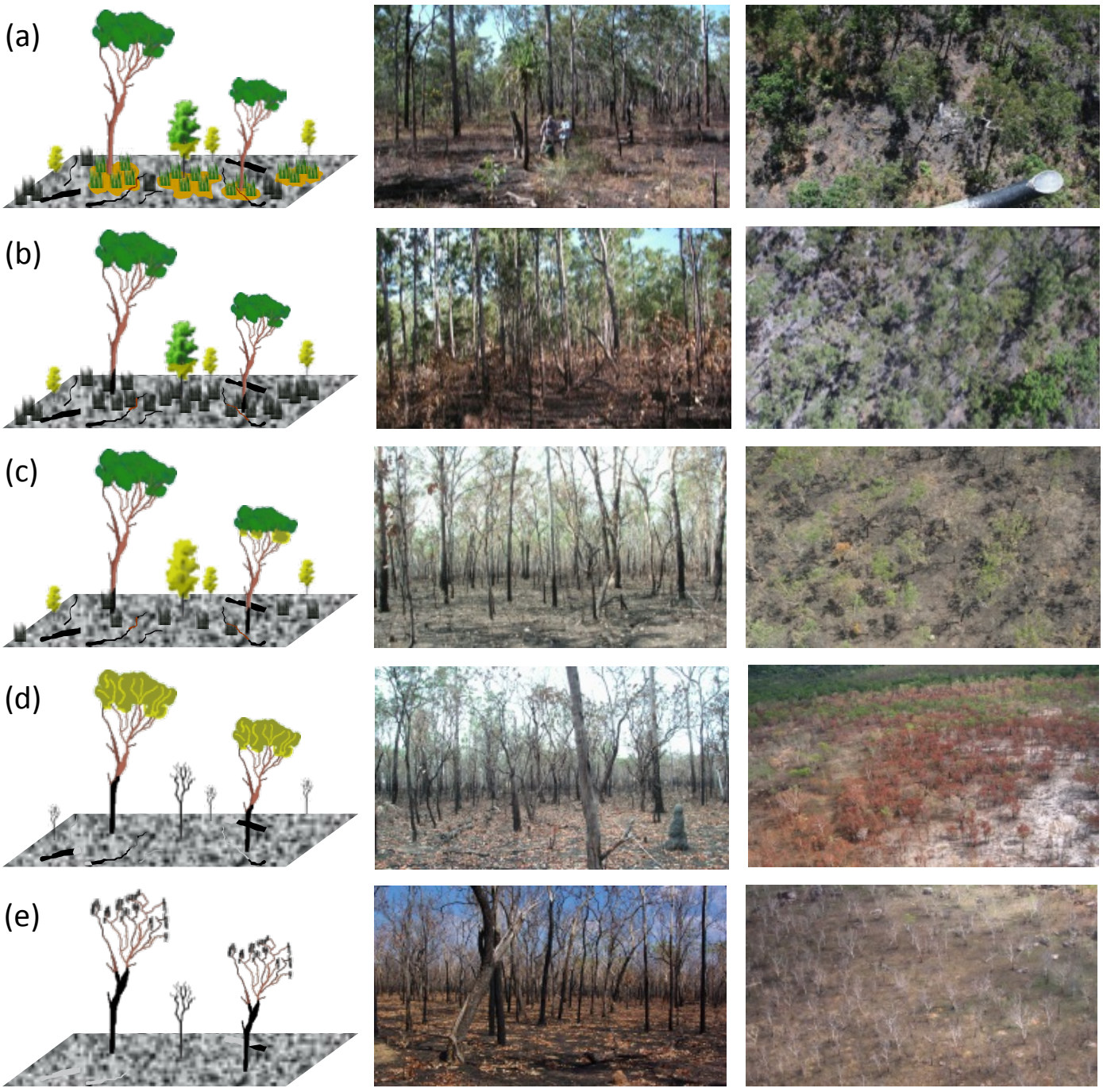
As a result of this research we have multiple fire severity mapping algorithms for application using different satellite sensors and at multiple scales across the tropical savannas throughout the whole fire season. Future analyses will determine if there is a need to create a range of algorithms based upon habitat and seasonality. A larger dataset that samples additional areas at various points in the seasons is required to extend this work to other remote parts of Australia. Once these algorithms are developed, it will be possible to expand the service to cover the rangelands which, when added to the tropical savannas, cover approximately 75% of the continent.

REFERENCES /FURTHER READING

Edwards AC (2009) *Fire Severity Categories for the Tropical Savanna Woodlands of northern Australia: A Field Guide.* Published by the Bushfire Cooperative Research Centre: Melbourne, Victoria, Australia.

Lentile LB, Holden ZA, Smith AMS, Falkowski MJ, Hudak AT, Morgan P, Lewis SA, Gessler PE, Benson NC (2006) Remote sensing techniques to assess active fire characteristics and post-fire effects. *International Journal of Wildland Fire* **15**, 319-345.

CATEGORIES OF FIRE SEVERITY IN THE TROPICAL SAVANNAS OF NORTHERN AUSTRALIA



▲ Simplified illustrations and photos of fire severity categories: (a) PATCHY, small trees and shrubs scorched to 2m, < 80% burnt ground layer patchiness; (b) LOW, small trees and shrubs scorched to 2m, > 80% burnt ground layer patchiness; (c) MODERATE, scorched leaves through the mid-storey (> 2 and < 8 m) perhaps into the lower parts of the upper canopy; (d) HIGH, complete canopy scorch and; (e) EXTREME, all foliage removed or charred.

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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 35 full and 10 affiliate member organisations.