FIRE NOTE

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REMOTE SENSING OF FOREST CANOPIES TO QUANTIFY BURN SEVERITY

The object of this project was to develop improved approaches for assessing fire impacts across the landscape that will enable better application of prescribed fire and other land management strategies for wildfire hazard reduction, biodiversity conservation, and the protection of water resources

ABOUT THIS PROJECT

B4.2 Multi-scale Patterns in Ecological Processes and Fire Regime Impacts is part of Bushfire CRC Program B: Fire in the Landscape.

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RESEARCH BACKGROUND

Management of fire-prone forest landscapes requires objective and repeatable methods for mapping and quantifying fire impacts.

Remote sensing is the most practical method for mapping and quantifying fire impacts at landscape scales. Sensors on board earth observation satellites or other platforms measure the radiation emitted and reflected from the earth surface at distinct wave-lengths.

Fires change the spectral properties of the earth surface by defoliating vegetation, scorching stems, removing surface litter, or through ash deposition, which means that burnt areas can be detected on satellite imagery.

A simple measure of fire severity can be obtained by quantifying differences between pre- and post-fire imagery. This approach is straightforward and sound in the sense that dramatic changes in reflectance tend to correspond to areas that have been more severely burnt while small changes in reflectance correspond to areas that have been burnt less severely.

However, for most environments it is unclear how changes in reflective properties detected on imagery relate to the magnitude of the impacts fire has had on particular ecosystem attributes. This makes interpretation of commonly used spectral indices such as the Differenced Normalised Burn Ratio (changes in NBR) difficult to interpret in terms of changes in vegetation structure, productivity or other key ecological processes.

BUSHFIRE CRC RESEARCH

This project evaluated the potential for using remotely sensed changes in leaf area index (ΔLAI) as a measure of burn severity of eucalypt forests. LAI is a key input to models of forest ecosystem functioning, controlling fundamental processes such as

SUMMARY

An enhanced approach to mapping of burn severity in forested landscapes is proposed based on the remote sensing of changes in leaf area index (LAI). Quantifying burn severity in terms of a well-defined biophysical attribute such as LAI, means that we can apply burn severity measurements to a range of fields (e.g. hydrology, ecology), and importantly, this approach is transferable in space, time and across vegetation types. The magnitude of change in forest LAI after fire indicates flame lengths and scorch heights during the passing of the fire, which in turn are a good proxy for fire intensity in a given forest type. LAI can be objectively measured in the field as well as by remote sensing, and changes in LAI for the quantification of burn severity is also justified from a spectral point of view. The method has been trialled in the Jarrah Forest of the Perth Hills, Western Australia.

RIGHT: MEASUREMENT OF OVERSTOREY LEAF AREA INDEX IN THE JARRAH FOREST. **PHOTOS: ECOSYSTEMS RESEARCH GROUP – THE UNIVERSITY OF WESTERN AUSTRALIA.**

FURTHER READING

Boer, M.M., Macfarlane, C., Norris, J., Sadler, R.J., Wallace, J., Grierson, P.F., 2008. Mapping burned areas and burn severity patterns in SW Australian eucalypt forest using remotely-sensed changes in leaf area index. *Remote Sens Environ* 112, 4358-4369.

Campbell, J.B., 1996. *Introduction to Remote Sensing.* Taylor & Francis, London.

Cheney, N.P., 2007. Karragullen - Mundaring Fire January 15-25, 2005 (Perth Hills Fires 71-81). In: Department of Environment and Conservation - Western Australia, Kensington, Western Australia, p. 24.

Chuvieco, E., Riano, D., Danson, F.M., Martin, P., 2006. Use of a radiative transfer model to simulate the postfire spectral response to burn severity. *Journal of Geophysical Research-Biogeosciences* 111.

Key, C.H., Benson, N.C., 2006. Landscape assessment (LA) In: Lutes, D.C., Keane, R.E., Caratti, J.F., Key, C.H., Benson, N.C., Sutherland, S., Gangi, L.J. (Eds.), *FIREMON: Fire effects monitoring and inventory system.* Gen. Tech. Rep. RMRS-GTR-164-CD. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station., pp. p. LA-1-55.

ABOVE: MEASUREMENT OF UNDERSTOREY ABOVEGROUND BIOMASS IN THE JARRAH FOREST.

photosynthesis and water use. Further, the magnitude of change in forest LAI after fire is indicative of flame lengths and scorch heights during the passing of the fire, which in turn are a good proxy for fire intensity in a given forest type. LAI can be objectively measured in the field as well as by remote sensing, and ΔLAI for the quantification of burn severity can also be justified from a spectral point of view (Chuvieco et al. 2006).

This project tested changes in LAI measured through remote-sensing as a measure of burn severity of jarrah forest (*Eucalyptus marginata*) that was burnt during the Perth Hills wildfires of January 2005 (Cheney, 2007), which burnt over 27,000 ha of forest and woodland. An empirical model for the prediction of LAI from spectral vegetation indices was developed from field measurements (October 2006) and Landsat Thematic Mapper imagery (January 2007). Field measurements included ground-based digital photography (photos pages 1 and 2) to quantify overstorey LAI across the Mundaring and Jarrahdale State Forests. Plots (40 m x 40 m) encompassed the full range of canopy densities present in the study area as well as variation in the time since the last fire prior to January 2005. Understorey biomass was also measured by destructive harvesting of 4 m x 4 m sub-plots.

Regression models for the prediction of LAI were developed using NBR, the Normalised Difference Vegetation Index (NDVI) or the Simple Ratio (SR) as the independent variable. The NBR is computed from the reflectance in the near-infrared (NIR) and mid-infrared (MIR), while the NDVI and SR are ratios of reflectance in the near-infrared and red wave-lengths (Campbell, 1996). All three LAI models had equally high coefficients of determination (R2: 0.87) and small root mean square errors (RMSE: 0.27-0.28). The (linear) SR-based model was preferred for subsequent analysis.

Maps of pre- and post-fire LAI were computed using the SR-based regression model on Landsat TM imagery of 15 January 2004 and 2 February 2005. ΔLAI was quantified by subtracting the pre- and post-fire LAI predictions. Confidence bounds for predicted ΔLAI were quantified by bootstrapping (a statistical sampling technique).

RESEARCH OUTCOMES

Across the forest impacted by the Perth Hills fire, pre-fire LAI varied from about 0.5-1.0 in the lower rainfall eastern sections to about 3.0-3.5 in the more productive stands of the higher rainfall western sections. The estimated average loss in LAI due to the January 2005 fire was at 0.8-0.9 across the entire area. Remotely sensed ΔLAI was consistent with qualitative observations of burn severity on the ground. Using the ratio of ΔLAI and pre-fire LAI as a defoliation rate, around 70% of the total fire-affected area lost 50% or more of its leaf area. However, ΔLAI varied strongly spatially. These spatial patterns in burn severity are the key to improving understanding of fire behaviour and the relative importance of different driving factors (i.e. fuel, terrain, and weather). The results also provide a basis for further in-depth assessments of fire impacts and monitoring of recovery processes as burn severity expressed as a change in LAI has direct relevance to forest growth and water use.

Existing remote sensing indices of burn severity, such as the widely used DNBR (Key and Benson, 2006), may be highly sensitive to fire-related changes in the reflective properties of soil and vegetation but index values cannot be readily compared across space or time like ΔLAI. This study has been the first to address this problem. Our case study of the January 2005 Perth Hills wildfires showed that LAI of the jarrah forest can be accurately mapped from limited but high-quality field data coupled with readily available Landsat imagery. Importantly, the ΔLAI mapping does not depend on qualitative observations – it is independent of the observer and hence completely reproducible, and can be readily

SPELLING IT OUT

LAI – leaf area index

ΔLAI – changes in leaf area index

Landsat TM imagery – Landsat Thematic Mapper imagery

MIR – mid-infrared

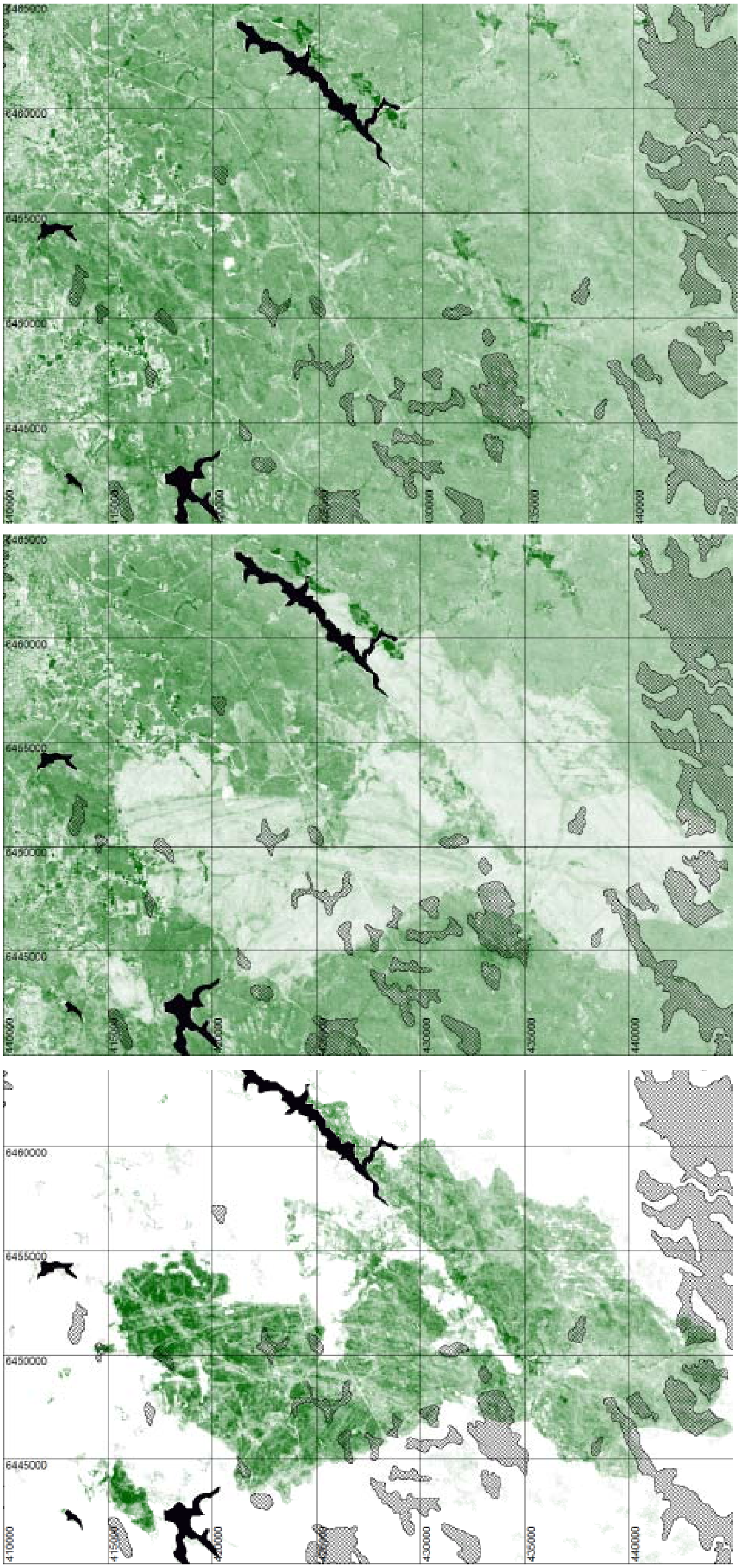
NBR – normalised burn ratio

NDVI – normalised difference vegetation index

NIR – near-infrared

RMSE – root mean square error

SR – simple ratio



RIGHT: PREDICTED LEAF AREA INDEX (LAI) FOR THE STUDY AREA ONE YEAR BEFORE THE FIRE (TOP) AND JUST AFTER JANUARY 2005 PERTH HILLS FIRES (CENTRE). THE BOTTOM PANEL SHOWS THE PREDICTED CHANGE IN LAI IN THE FIRE AFFECTED AREA. BLACK POLYGONS ARE RESERVOIRS. BLACK HATCHED AREAS ARE NON-JARRAH FOREST.

interpreted by ecologists, hydrologist or other scientists involved in impact assessment and rehabilitation. As discussed in our recent paper (Boer *et al.*, 2008), ΔLAI should also be an accurate measure of burn severity across a wide range of fire-prone forests, woodlands and shrublands.

CRC RESEARCH AT WORK

This study has raised an important issue in fire impact assessment, namely the need to base assessments on objectively measured changes in ecologically relevant attributes. The researchers recommend using biophysical attributes, such as LAI, for fire impact assessments (or more generally in fire ecology) wherever feasible as the approach is reproducible regardless of the operator and is not dependent on extensive field experience. While scores and ratings with undefined units have been very useful in many aspects of fire management, they have limited application to interpreting and quantifying key processes such as carbon and water fluxes. Here, it has been shown that both scientific and management value can be added to remotely sensed burn severity maps by quantifying the impact in terms of a change in LAI (with units $m^2.m^{-2}$).

This LAI-based method can be applied to archived satellite imagery to quantify burn severities of past fires in the jarrah forest. Again, as burn severities would be quantified in terms of ΔLAI rather than a rating or score, severities at a single site in different fires or different sites in the same fire could be compared. This approach opens the way for a range of other analyses, such as:

- quantifying the role of pre-fire LAI and fuel age (as surrogates for fuel load) in determining burn severities of unplanned fires
- quantifying differences in burn severity (patterning) between planned and unplanned fires
- quantifying impacts of burn severity patterns on ecological functioning at plot and landscape scales (e.g. productivity, water use/yield, carbon fluxes).

Some of these analyses are currently underway as part of project B4.2.

This *Fire Note* provides an outline and the key results of a peer reviewed journal; the full Paper on this study was published late 2008 in *Remote Sensing of Environment* (Boer *et al.*, 2008). Results of further analyses (above) will be presented at both national and international meetings and published in international peer-reviewed journals.

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Download at www.bushfirecrc.com/publications/fire_note.html

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Issue 23: **Recruiting and retaining women fire service volunteers.** A summary report of four studies on female participation as volunteers.

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

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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.
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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 26 full and 10 affiliate members.