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

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FIRE NOTE

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ASSESSING GRASSLAND CURING BY SATELLITE

SUMMARY

Grass characteristics such as water content and degree of curing (senescence), determine the vulnerability of grasses to ignite and to propagate and carry fire. In order to improve the assessment of grassland curing across Australia and New Zealand, this research has developed an improved algorithm to estimate curing using EOS MODIS (Moderate resolution Imaging Spectroradiometer) satellite data. MODIS satellite observations were compared with in situ observations of curing at over 30 field sites of improved pastures and native grasses. Using a multiple linear regression (MLR) of the normalised difference vegetation index (NDVI) with two MODIS mid-infrared (MIR) bands, this algorithm is able to monitor curing with an error of 10% for different grass types and in different bioclimatic regions.

ABOUT THIS *FIRE NOTE*

Project A1.4 Grassland Curing, is part of Bushfire CRC Program A: Safe Prevention, Preparation and Suppression.

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▲ Firefighters at work on a grass fire in Bunyip State Park. Photo: Martin Anderson, CFA.

Grassland curing (the percentage of dead grass) is currently assessed using data from the NOAA AVHRR (Advanced Very High Resolution Radiometer) satellite remote sensor by a method that was developed for south-eastern Australia only, and using data from *in situ* visual observations, which have inherent problems leading to inaccurate assessment of curing.

In order to produce a better satellite-based grassland curing index, this research has established algorithms to estimate grassland curing across different grass types and in different regions, using a more accurate field technique: Levy rod sampling (Anderson *et al.*, 2005), and using vegetation indices from MODIS satellite data.

BACKGROUND

Both Australia and New Zealand are abundant in grass, whether it is sparse or dense, native or an improved pasture. It is, therefore a vital vegetation type to explore in regards to fire. Regardless of meteorological conditions, the chance of grass igniting and propagating a fire is dependent on the fuel moisture content (FMC) (Cheney and Sullivan, 1997), which is assumed to be tracked by the stage of senescence, known as curing (Anderson *et al.*, 2005; Barber, 1990; Dilley *et al.*, 2004; Paltridge and Barber, 1988; Tucker, 1977). This assumption may be acceptable for some species; however, it cannot be generalised for all ecosystems (Ceccato *et al.*, 2001). This encourages the need to assess curing over a wide range of grass types and species. Since the 1980s, the AVHRR satellite sensor has been used operationally to produce a satellite curing index across southeastern Australia. The MODIS sensor, used in this current research, can provide more detailed assessments

Co-author Danielle Martin, a Bushfire CRC PhD candidate with the Bureau of Meteorology in Melbourne, and RMIT School of Mathematical and Geospatial Sciences, conducting field work in South Gippsland using a hand-held spectroradiometer.

of vegetation than AVHRR, and has the potential to provide better curing estimates due to its greater number of spectral bands, higher spatial and spectral resolution, better calibration and cloud detection, and lower susceptibility to atmospheric effects.

BUSHFIRE CRC RESEARCH

For some time, the Bureau of Meteorology has produced satellite-based maps of grassland curing for southeastern Australia, based on an algorithm developed initially by CSIRO and the Victorian CFA (Paltridge and Barber, 1988) and most recently revised by Dilley *et al.* (2004). However, the curing data on which this algorithm was initially developed and validated were only collected in Victoria. Rather than using Victorian data alone, *in situ* data were collected for this research from over 30 selected grassland sites, covering a variety of climate, topography, soil and grass types.

Three *in situ* methods were initially considered to estimate curing: 1) visual observations, 2) destructive sampling, and 3) Levy rod sampling. Destructive sampling involved collecting grass samples in the field and sorting them into live and dead material in the laboratory, then oven-drying and weighing these live and dead components to calculate the proportion of dead fuel. The Levy rod method is a modification of that proposed by Levy and Madden (1933), and entailed counting live and dead grasses that come in contact with a thin steel rod placed vertically into the ground at several points along a transect (Anderson *et al.*, 2005). This method was found to exhibit the most accurate results, and was therefore used to develop a new satellite algorithm.

END USER STATEMENT

"Queensland Fire and Rescue Service Rural Operations Division collect grassland curing values weekly and provide this information to the Bureau of Meteorology for a number of fire weather products.

"The current method of collecting curing values relies on field assessments taken over 48 sites representing the 13 BoM Weather districts throughout Queensland. The method of collection is usually by visual observation which can be subjective and inconsistent between observers.

"The use of assessing grassland curing by satellite will present consistency in the curing values and provide more representative values throughout weather districts. In addition, the data source and format complements the use of spatial mapping integration into a range of fire management and community safety strategies."

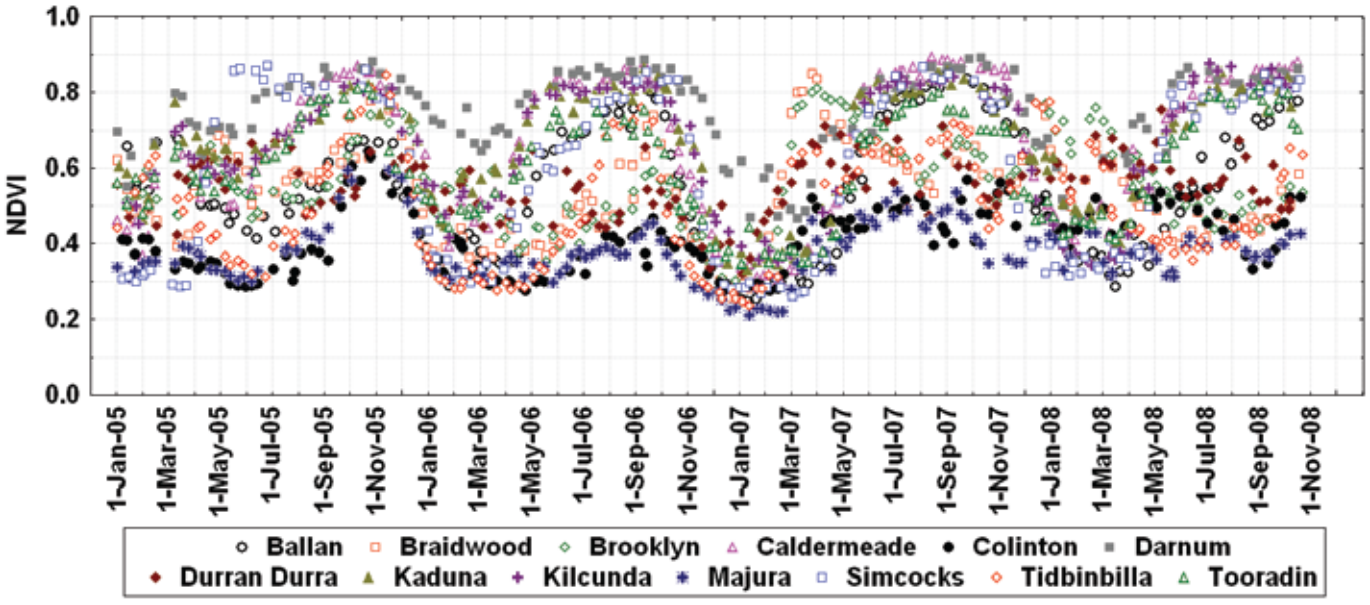
– Fergus Adrian, Manager Planning and Research, Rural Research and Training, Rural Operations, Queensland Fire and Rescue Service.

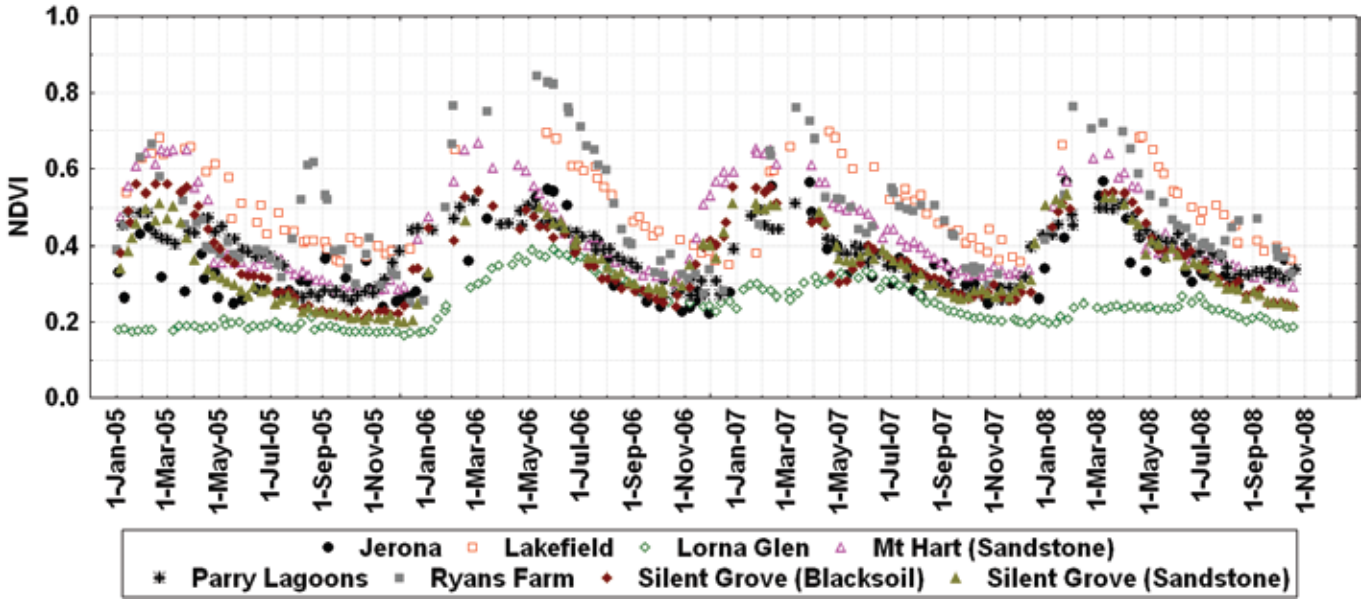
In order to correlate the Levy rod measurements with satellite data, this research had an advantage of using MODIS rather than AVHRR. Generally, MODIS provides higher quality data, and also comprises more spectral bands. In this research, these bands were combined in many ways to create various vegetation indices that track grass phenological features such as chlorophyll content, water content and cellular structure.

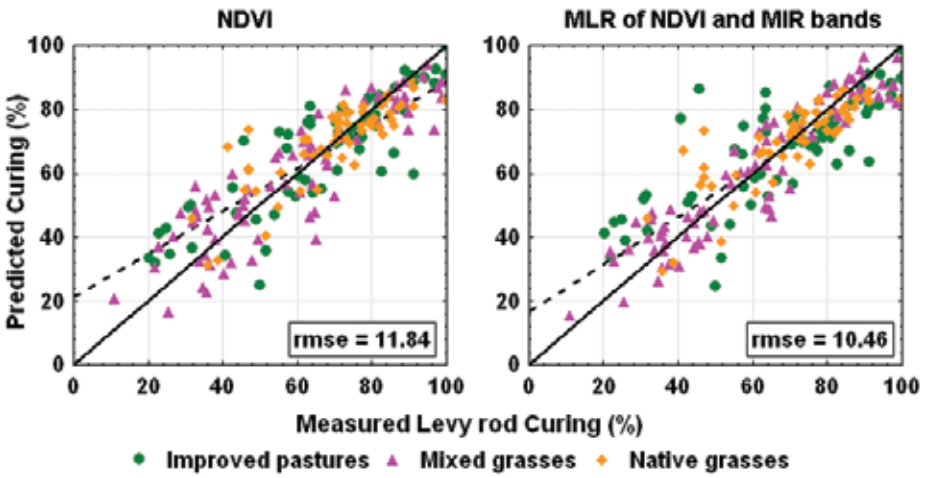
This project is addressing the issue of inaccurate curing assessment. A collection of three years of curing measurements across Australia and New Zealand has been utilised to develop an algorithm for the processing of MODIS satellite imagery so that accurate curing maps can be delivered to fire management agencies in a timely manner.

RESEARCH OUTCOMES

The MODIS sensor provides a range of spectral bands which respond to various physiological characteristics of grasses as they cure. These include bands at visible wavelengths (red, green and blue), for which the vegetation response is largely controlled by chlorophyll content, and infrared wavelengths, which are dominated by vegetation internal structure and absorption by water. Bands associated with visible colour were found to correlate well with curing levels. However, the MODIS-curing relationships slightly varied with grassland type, with the largest differences highlighted between improved pasture and native grasslands.







▲ **Figures 1 and 2:** NDVI time-series of sites in southern Australia (top) and northern Australia (cnetre).

◀ **Figure 3:** Correlation between Measured and Predicted Curing.

Initially the project focused on common satellite-based vegetation indices such as the NDVI, a widely used measure of vegetation greenness, and indices sensitive to vegetation moisture content. The characteristic time series of a vegetation index for a grassland site includes a distinctive seasonal pattern that is directly related to the curing cycle (Figures 1 and 2).

A selection of vegetation indices was tested, both for separate grassland sub-categories (improved pastures, native and mixed grasses) and for the field dataset as a whole. The results showed that no other index performed significantly better than NDVI. However, a MLR of NDVI with a ratio of two MODIS bands in the MIR wavelengths predicted curing with the least error. The ratio of these two bands was able to distinguish dry vegetation from bare soil (Guerschman *et al.*, 2009) (Figure 3).

SATELLITE REMOTE SENSING: A NON-DESTRUCTIVE APPROACH

Unlike traditional methods of vegetation assessment, satellite remote sensing provides a non-destructive and instantaneous monitoring approach at various landscape scales. As plant pigments absorb visible light, growing vegetation usually has a low reflectance in the visible part of the spectrum. Owing to water absorption, the reflectance is also low in the mid infrared (MIR). Plants tend to exhibit, however, a high reflectance in the near infrared (NIR) part of the spectrum owing to intercellular scattering.

Vegetation indices, based on values of reflectance, are formed from a combination of spectral bands whose values are divided, multiplied or added together to obtain a single value that indicates the amount or status of vegetation cover. Vegetation indices are the most widely used remote sensing tools for making quantitative estimates of properties of vegetation as they tell us how densely or sparsely vegetated a region is, and how much light that could be used for photosynthesis is being absorbed by vegetation.

The most commonly used index is the Normalised Difference Vegetation Index (NDVI), which is a combination of red (R) and near infrared (NIR) bands that is sensitive to vegetation chlorophyll content and cover:

$$NDVI = \frac{NIR - R}{NIR + R}$$

The NDVI has been used to map various characteristics of vegetation such as biomass, vegetation health and phenological stage. It is this latter application that makes the index of particular interest in the area of grassland curing.

By using four algorithms, including the two regressions shown (NDVI alone and a MLR of NDVI with the mid-infrared bands), the researchers of this project are conducting a pilot trial, which will apply their research to the production of regularly updated curing maps across the whole of Australia. This system will be trialled by a number of agencies to determine if the products are being produced to the accuracy required, or whether more regional-specific algorithms are necessary.

HOW IS THE RESEARCH BEING USED

Any system for mapping grassland curing needs to be available to end users in the shortest possible time and in an appropriate format so that it can be readily integrated with other information into fire-danger rating systems. To determine the requirements of fire management agencies and to assist with the implementation process, a survey was undertaken to gather this information and ensure that products from the research meet the needs of end users.

Based on the feedback from the survey, a pilot trial of the grassland curing system commenced in October 2009 and is planned to run into the summer. The pilot system is running from the Bureau of Meteorology in Melbourne and is initially making data available to southern regions of Australia. During this pilot trial period, researchers will be working with the relevant fire management agencies to refine the system so that it meets the expectations of end users when the full rollout starts in 2010.

FUTURE DIRECTIONS

The level of ongoing support and development for the system is likely to depend on how well the curing data is integrated into existing fire-management systems and the evidence of benefits to the users. The researchers will be working with agencies to ensure appropriate application of this new data source and to ensure the maximum impact on existing systems. In parallel with work to implement the research results for Australia into an operational system, the research experience gained for Australia will be applied to field and satellite data collected for New Zealand, and the research approach extended as necessary, in order to develop a similar curing product suitable for implementation in that region.

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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.