THE AUSTRALIAN FLAMMABILITY MONITORING SYSTEM

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Marta Yebra, Albert Van Dijk, Xingwen Quan, Geoff Cary and Pablo Rozas

Fenner School of Environment and Society, Australian National University, College of Medicine, Biology and Environment, ACT
University of Electronic Science and Technology of China, Chengdu.
National Computing Infrastructure, Australian National University.

LIVE FUEL MOISTURE CONTENT (LFMC) IS ONE OF THE PRIMARY VARIABLES AFFECTING BUSHFIRE FLAMMABILITY. WE HAVE DEVELOPED THE FIRST AUSTRALIA-WIDE FLAMMABILITY MONITORING SYSTEM FOR OPERATIONAL PREDICTION OF LFMC AND FLAMMABILITY USING SATELLITE DATA

1. LIVE FUEL MOISTURE CONTENT

- LFMC estimates are **physically-based** using reflectance data from MODIS satellite and radiative transfer models Look-up Table (LUT) inversion techniques(Fig. 1).
- The algorithm is able to explain 64% of the measured LFMC with an RMSE of 31% evaluated using existing field measurements of LFMC across Australia (Fig. 2) (Yebra et al. 2016).

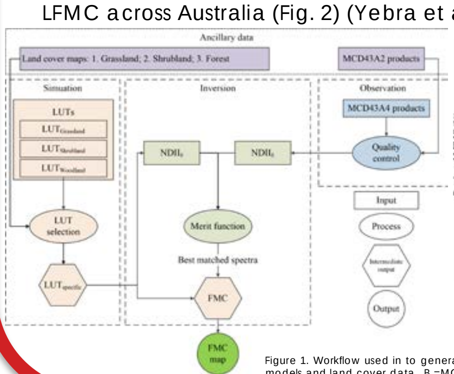

Figure 1. Workflow used in to generate a map of LFMC from MODIS, radiative transfer models and land cover data. B_x=MODIS band number x. $NDII_6$=(B2-B6)/(B2+B6)

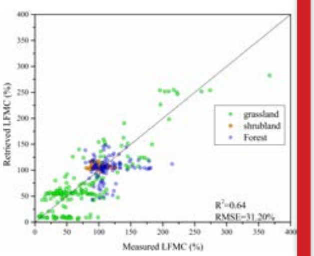

Figure 2. Relation between measured and retrieved LFMC at all validation sites symbolized by fuel class.

2. FLAMMABILITY INDEX

- The method used to obtain the flammability index across Australia is based on **logistic regression modelling** of fire occurrence, estimated from the burned area product developed by Giglio et al. (2009), using several explanatory variables derived from the LFMC product (Eq. 1, Table 2).
- Areas not affected by fires were selected from cells surrounding the burned pixels using the semi-variogram geostatistical technique (Jurdao et al., 2012) (Fig. 3)

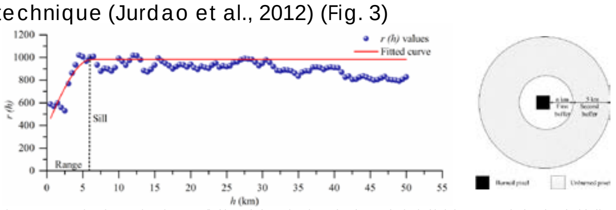

Figure 3. Example of a semi-variogram (left) and the selection of unburned pixels (right). 'Range' is the threshold distance at which spatial autocorrelation in LFMC disappears. 'Sill' is the distance at which variance achieves a stable maximum value.

- **Three logistic regression models** were developed for grassland, shrubland and forest (Table 1), obtaining performance metrics of 0.81, 0.78 and 0.83, respectively, out of a maximum of 1.

$$p = \frac{1}{1+e^{-(a+\beta_1 x_1+\beta_2 x_2+\cdots+\beta_n x_n)}} \quad (1)$$

where p is the flammability index, a is the model intercept, $\beta_1, \ldots, \beta_n$ are the equation coefficients, $x_1, x_2, \ldots, x_n$ are the independent variables

Class	Variables in the equation ($a+\beta_1 x_1+\beta_2 x_2+\cdots+\beta_n x_n$)	AUC
Grass	0.64-0.03**LFMC*$_{t-1}$+0.05**Difference*-0.25**Anomaly*	0.81
Shrub	1.29-0.04**LFMC*$_{t-1}$+0.06**Difference*-0.11**Anomaly*	0.78
Forest	3.98-0.06**LFMC*$_{t-1}$+0.01**Difference*-0.19**Anomaly*	0.83

Table 1. Logistic regression results. ***LFMC$_{t-1}$***= LFMC corresponding to the 8-day period prior to the 8-day period including the fire date, ***Difference***=LFMC variation between *LFMC$_{t-1}$* and *LFMC$_{t-2}$*, where *LFMC$_{t-2}$* is the LFMC corresponding to the 8-day period prior to *LFMC$_{t-1}$*, ***Anomaly***=Departure of LFMC$_{t-1}$ from the average LFMC value for that period for the time series (2002-2014). AUC=Area under the curve.

3. CASE STUDY: CANBERRA 2003 FIRES

- LFMC gradually decreased and flammability increased in the months before the fires (Figs. 4 and 5)

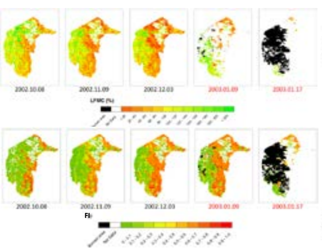

Figure 4. Spatial and temporal distribution of LFMC (Upper) and flammability (FI, Lower) before and after the Canberra 2003 fires. White cells correspond to urban areas or low quality reflectance data.

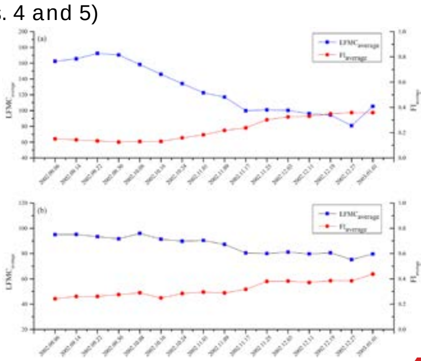

Figure 5. Temporal evolution of LFMC and the flammability index (FI) of grassland (a) and forest (b) areas burned during the Canberra 2003 fires.

4. CONCLUSION AND FUTURE WORK

- We developed the prototype of the **first Australia-wide Flammability Monitoring System** for operational prediction of LFMC and flammability using satellite observations.
- LFMC is not the only variable that is related to fire occurrence, and therefore the importance of other factors (e.g. fire weather and total biomass) should also be considered for a comprehensive characterization of fire risk conditions.
- We plan to assimilate the estimates of LFMC and flammability in the High-resolution Fire Risk and Impact (HiFRI) model-data fusion software (Van Dijk et al. 2015) to forecasts FMC and flammability at a resolution between 25 and 5000 m, depending on management requirements.
- These tools can **support the development of the new National Fire Danger Rating System** and, with further development, be made available as software tools for fire managers

END USER STATEMENT

'The new technology described here has enormous potential to improve the efficiency of bushfire operations across Australia and drive an expansion of our capability. The provision of accurate, spatially explicit, near real-time estimates of FMC and flammability at a range of spatial resolutions would permit more accurate targeting of scarce bushfire fighting resources in time and space. It would no longer be necessary to estimate jurisdiction-wide readiness based on anecdotal extrapolation of conditions at a few locations'.

Adam Leavesley, ACT Parks and Conservation Service

Australian Government Department of Industry, Innovation and Science
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Australian National University

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