HAZARD NOTE

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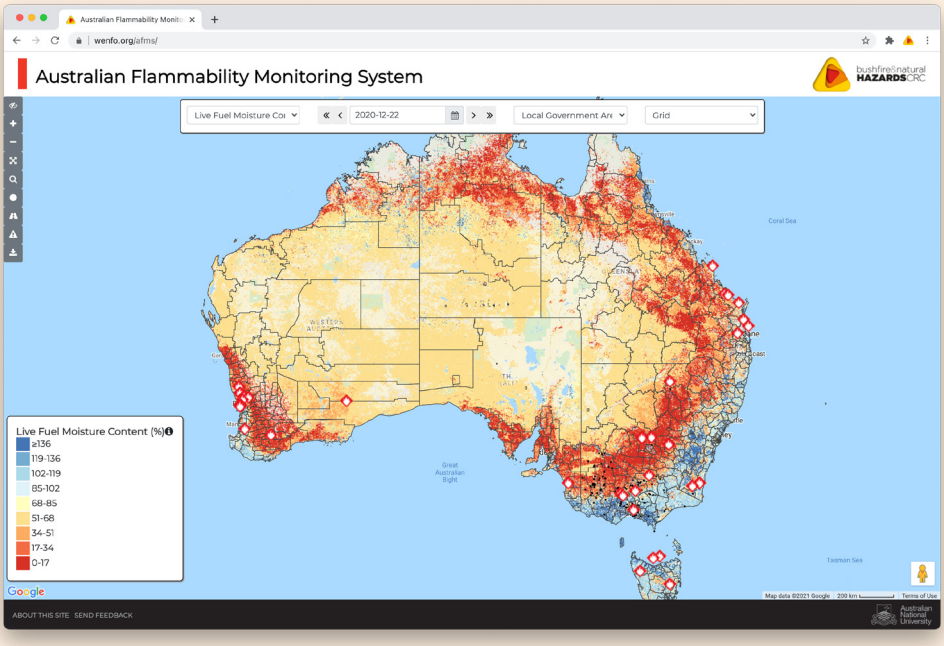
TOPICS IN THIS EDITION | FIRE | FIRE IMPACTS | REMOTE SENSING

THE AUSTRALIAN FLAMMABILITY MONITORING SYSTEM: PROVIDING A CLEAR PICTURE OF LANDSCAPE DRYNESS



Above: THE AUSTRALIAN FLAMMABILITY MONITORING SYSTEM SHOWS FIRE INCIDENTS (AS SEEN ON 22 DECEMBER 2021) AND LIVE FUEL MOISTURE CONTENT, WITH DARKER BLUE INDICATING MORE THAN 136% MOISTURE (VERY DAMP) AND DARKER RED INDICATING BETWEEN 0 AND 17% MOISTURE (VERY DRY).

ABOUT THIS PROJECT

This *Hazard Note* summarises the research from the Bushfire and Natural Hazards CRC's *Mapping bushfire hazard and impacts* project. The research produced the Australian Flammability Monitoring System (AFMS), which provides a clear interactive map showing vegetation and soil dryness across the Australian landscape.

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SUMMARY

This project developed the first near real-time web application in the world that uses satellite data to provide a clear picture of live fuel moisture and soil moisture content at a continental scale, to improve the understanding of the flammability of trees, shrubs and grass. The Australian Flammability Monitoring System (AFMS) is a website that allows users to see where there are high levels of vegetation and soil dryness, which are the perfect conditions for a severe bushfire. It makes spatial information on fuel moisture content and flammability easier and faster to access for fire behaviour analysts, land managers, prescribed burning planners and fire behaviour analysts to manage fire at landscape scales. The AFMS is the first national-scale, pre-operational fuel and soil moisture content and flammability monitoring system in Australia, delivering accurate spatial information in near-real time. Access the AFMS at http://anuwald.science/afms.

CONTEXT

Understanding and predicting fire danger and behaviour is a priority for fire agencies, land managers, and sometimes individual businesses and residents. This is an enormous scientific challenge given the complexity of bushfires, with fire behaviour and severity driven by complicated interactions involving vegetation, topography and weather conditions. A good understanding of bushfire danger across the landscape depends on accurate spatial information about fire hazards, in order to prevent, avoid and manage impacts.

The amount of vegetation in an area, also known as fuel load, is one of the main drivers of the rate of spread of a fire. Therefore, an accurate assessment of the quantity and flammability of fuel loads in any given area, coupled with an assessment of how those fuel loads vary over time, may improve wildland vegetation management and help design more efficient fire management strategies. A key determinant of flammability of fuel and fire spread is the condition of the vegetation (fuel), for example, the moisture content, continuity, structure and quantity/load of the fuels.

Prior to this research, there has been limited emphasis on routinely providing and using spatial information on landscape-related hazard factors, such as fuel load or condition, in determining fire danger. This is partly because of a lack of timely, reliable, consistent,

The Australian Flammability Monitoring System was recognised with the Outstanding Achievement in Research Utilisation Award from the CRC in 2019.

accurate and long-term information. This project developed, tested and refined different methods to produce accurate spatial information on fuel condition and fire danger. The resulting technology is crucial for planners, land managers and emergency services. It supports a wide range of fire risk management and response activities, such as prescribed burning, pre-positioning firefighting resources and, in the long-term, informing enhancements to the new Australian Fire Danger Rating System.

BUSHFIRE AND NATURAL HAZARDS CRC RESEARCH

Phase One: testing the methods

In the first phase of the research, between 2014 and 2017, researchers investigated several different methods of mapping flammability. These methods were categorised as either 'in-field' or 'national-scale':

- 'In-field' mapping methods included on-ground networks of field sensors and ground-based Light Detection and Ranging (LiDAR) laser scanning. These data sources provide detailed information about the height, cover and density of different overstorey and understorey plant layers, at a plot scale of metres to hectares. While these data are often more accurate and spatially concentrated, this approach is costly to develop and maintain.
- 'National-scale' methods are generally derived from existing satellite imagery and other spatial data, and measure things like fuel moisture content and soil moisture content. Although these sources provide slightly less accurate data than the in-field methods, they are often much cheaper to implement and use in near-real time. Researchers developed two national-scale methods for the purposes of this project – the AFMS and the High-resolution Fire Risk and Impact (HiFRI) framework. The HiFRI produces an unprecedented level of detail and accuracy when estimating fuel condition.

Researchers then compared the relevance and value of all these methods for their practical feasibility and costs of use – depending on spatial resolution, accuracy, operational availability, and resources required for data acquisition, processing and interpretation. Where appropriate, the information was developed so it could be used as an input into the current Fire Danger Rating system or fuel classification systems suitable for end-users.

National-scale methods were found to represent the best return on investment and generated greater interest among end-users, therefore having greater utilisation potential. This became the focus of the second phase of the project.

Phase Two: refining the Australian Flammability Monitoring System

The second phase of this research, between 2017 and 2020, focused on ensuring that the AFMS – the preferred national-scale method – was refined and adopted by end-users. Together with end-users, researchers identified improvements that could be made to the AFMS that would help overcome any constraints.

The AFMS provides the first Australia-wide product of flammability from satellite estimates of live fuel moisture content (Yebra et al. 2018). The flammability index was adjusted using a continuous logistic probability model between fire occurrence and live fuel moisture content. Researchers evaluated the feasibility and relative benefits of using different satellite sources, and worked with Geoscience Australia to develop high-resolution datasets and a proof-of-concept code that computes products using satellite data at a grid resolution of 20 metres giving detailed information of topography driven fuel moisture content (FMC) differentials.

While live fuel moisture content is important when assessing flammability, this research also considers the roles of other important factors, such as fire weather, dead fuel moisture content, fuel load and ignition. The result is a comprehensive characterisation of flammability, providing a more observation-based assessment (van Dijk et al 2019).

RESEARCH FINDINGS

The Australian Flammability Monitoring System

In response to the needs expressed by end-users, researchers developed and refined the AFMS – an experimental, operational, near-real-time flammability data service. The AFMS can be accessed at http://anuwald.science/afms.

The prototype system is the first web application in the world that uses satellite data to provide a clear picture of fuel and soil moisture content and flammability at a continental scale. See the figure on page 1 for an example of the system map. It shows where there are high levels of vegetation and soil dryness, which are the perfect conditions for a severe bushfire. It makes spatial information on fuel moisture content and flammability easier and faster to access.

Specifically, the AFMS provides easier and faster access to spatial information on:

- live fuel moisture content, in kg water per kg dry matter
- uncertainty in the fuel moisture content values, in the same units
- a flammability index, providing a relative measure of fuel flammability between 0 (low flammability) and 1 (maximum flammability)
- soil moisture content near the surface (0-10cm), in m3 water per m3 soil volume
- soil moisture content in shallow soil (10-35cm), in the same units.

When using the AFMS, different filters and settings give users (such as emergency services and land management agencies) a new way to evaluate the risk of a bushfire occurring in certain areas, based on the dryness of the soil and fuels, and the flammability of vegetation. It also offers flexibility to incorporate other relevant spatial information that might be currently available, for example, fire weather or grassland curing or predicting the likely state of fuels in the near future (fuel loads, dead FMC).

Light Detection and Ranging (LiDAR) technology

LiDAR technology, although a mature product that is readily available, was found to be insufficient for fuel mapping as it lacks standardised data specifications and processing methods. Researchers reviewed the technology and developed a specification for deriving analogues of the overall fuel hazard from LiDAR. This was applied to an ACT LiDAR dataset to produce spatially explicit fuel maps at resolutions of 2m, 5m and 25m – the 25m maps were found to be easiest to use, with resolutions suitable for operational use.

Researchers also identified several priority areas for research and development of LiDAR, to achieve more cost-effective and successful use for fire management, including the development of standardised methods for fuel mapping, validation of these methods using field measurements, and investigation of full-waveform LiDAR as a promising alternative to current LiDAR methods.

A High-resolution Fire Risk and Impact (HiFRI) framework

Researchers developed a framework (model-data fusion) to provide estimates on

historic fire impacts on landscape, as well as real-time estimates of current fuel loads and flammability. They applied this framework to a case study of data for the western ACT between 2000 and 2010 (including native forests, plantations and grasslands), to analyse the value of different airborne and remote sensing observations. Results showed that the framework is capable of producing accurate estimates of the impacts of fire on water and carbon balance variables (such as transpiration, evaporation, photosynthesis etc), and that these balances are impacted by solar irradiance and vegetation regrowth.

In pursuit of more comprehensive fire danger ratings

Researchers developed an objective and observation-based approach to fire danger assessment that considers spatial data on the occurrence of actual fires, as well as of fire factors that are already produced every day in Australia. This project's methodology could be used to incorporate new fire danger predictors into the current system. Evidence was provided that suggests the current Forest Fire Danger Index could be improved by the use of either a model-based precipitation index or a soil moisture satellite measurement – both of which would more accurately estimate soil moisture than the current method (Keetch-Bryam Drought Index).

HOW IS THIS RESEARCH BEING USED?

The AFMS is currently in its test-use phase and has gained a lot of national and international interest. Several key emergency services and land management agencies have been using the AFMS to make informed decisions about where a fire may ignite and spread, and what areas should be prioritised when sending resources and equipment to fight fires. These include the NSW Rural Fire Service, the NSW National Parks and Wildlife Service, the ACT Parks and Conservation Service, the Department of Defence, South Australia's Department for Environment and Water, Queensland Fire and Emergency Services and the Tasmania Parks and Wildlife Service. A/Prof Marta Yebra worked alongside the NSW RFS at their headquarters in November 2019 during a peak fire danger period, providing data to assist the RFS make informed decisions about where fires may spread, and what areas should be prioritised when sending resources and equipment.

Fire managers are using the system to understand when parts of the Australian landscape are either not going to burn, burn in a way that will allow them to control a fire, or are so dry that if a fire starts it will become very dangerous and difficult to control.

During the 2019/20 bushfire season (between November 2019 and February 2020), the AFMS received around 1,500 visits from users in nearly all states, which averages around 15 sessions per day during that time, with sessions averaging six minutes. Key users were the NSW Rural Fire Service and NSW National Parks and Wildlife Service, highlighting how beneficial this tool is for both fire agencies and land management agencies.

The AFMS is now being used as part of preseason planning, when fire agencies and land management departments formulate their seasonal outlook for fire and map at-risk areas. It is also being used in prescribed burn planning, particularly in mountainous locations where flammability changes depending on the terrain.

The AFMS and its algorithms have also been used in Europe, South Africa, Argentina, the United States and China, including being implemented in the emissions assessment and smoke-dispersion module of the European Commission's Forest Fire Information System. This provides the Commission and the European Parliament with updated and reliable information about bushfires.

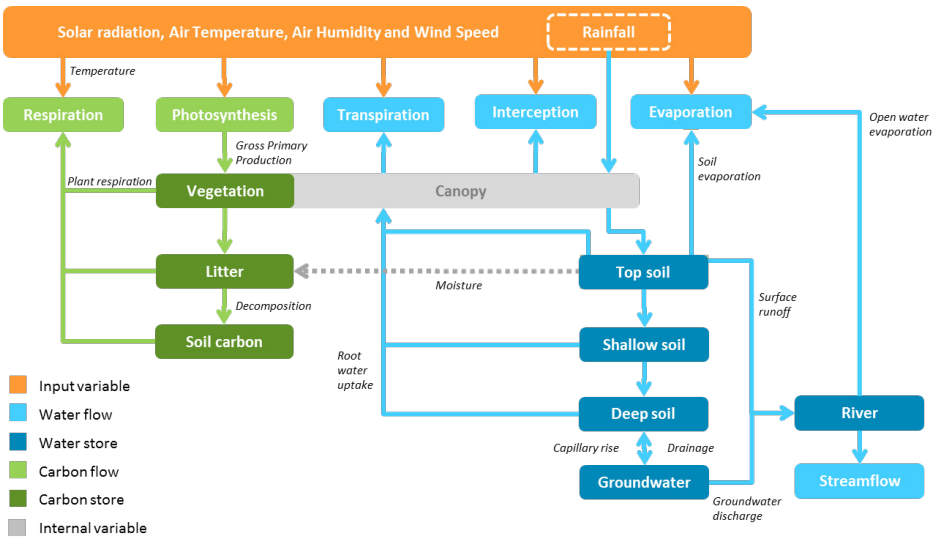

Figure 1: ILLUSTRATION OF THE HIFRI FRAMEWORK. THE GREEN COMPONENTS WERE NOT INTEGRATED INTO THE OPERATIONAL MODEL.

FUTURE DIRECTIONS

In the future, the AFMS website will be hosted by Geoscience Australia, as well as integrating near-real-time soil moisture information through the JULES-based Australian Soil Moisture Information System (JASMIN). JASMIN estimates soil moisture on four soil layers over the top three meters of soil, and takes into account the effect of different vegetation types, root depth, stomatal resistance and spatially varying soil texture.

The research team are conducting ongoing tests of the AFMS to identify where it can be further used by fire managers and the community. The findings are being

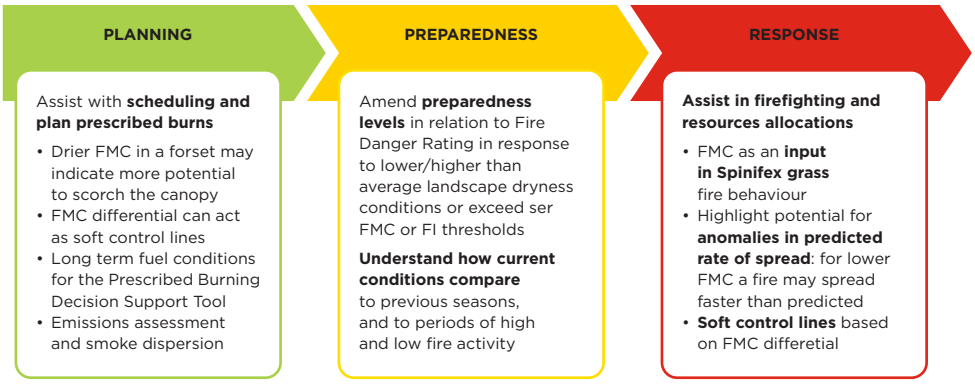

Figure 2: CURRENT AND POTENTIAL USES OF THE AFMS IN FIRE MANAGEMENT.

shared with key stakeholders through education events, and researchers invite end-users to provide comments and suggestions about what can be improved to make the website more useful.

While the AFMS is in its prototype form, researchers are focused on developing specific, operational applications and integrating the information into agencies' current and future decision-making processes and tools. Future use of AFMS could expand to individual community members and private landowners, such as farmers. Those on the land could use the mapping to assess the dryness of their land when managing their agricultural productivity, and when preparing for the fire season.

The constant expansion of satellite-based imagery provides opportunities to develop more sophisticated multi-sensor system(s) that could display daily information on flammability and fuel condition from whatever satellite sensor has collected an image over Australia, including high-resolution satellite imagery. The use of high-resolution satellite imagery will provide an unprecedented level of detail and accuracy when estimating fuel condition bringing the system closer to use in operations. However, the data volumes and large computing resources currently required to store and generate these high-resolution products remains a challenge. Future approaches should also focus on developing methodologies for computing fuel condition that can provide up to date estimations that require reduced data storage and computing resources, for example, using state-of-the-art artificial intelligence algorithms.

In the longer term, there is a need for a bespoke high-resolution space-based fuel monitoring sensor tuned to the Australian landscape, with spectral wavelengths designed specifically to look at live FMC and fuel load, thus informing at the highest possible accuracy, when and where forests are approaching critical dryness levels and fuel loads. This is because all the data explored in this project to retrieve fuel condition is collected by sensors onboard satellites that are not fully fit-for-purpose in terms of readiness, spatial resolution and signal sensitivity in Australia's eucalypt-dominant forests.

END-USER STATEMENTS

"The Australian Flammability Monitoring System has been useful not only in sharing research outputs with operational users, but also allowed users to provide feedback during the project, leading to an improved interface to the data. These efforts are building an integrated suite of observational and modelling tools that will enable users to better understand and predict potential fire occurrence and behaviour."
Dr Stuart Matthews, Principal Project Officer – Operations/ Predictive Services, NSW Rural Fire Service.

"The *Mapping bushfire hazards and impact* project has significantly advanced knowledge and operational capability of fuels and fuel condition. The main research effort aimed at deriving continent-wide spatially explicit estimates of live FMC at near real-time has been achieved. The estimates returned at a resolution of 500m × 500m have been consistent with observed fire behaviour during bushfires and prescribed burns. Besides, the system has succeeded in capturing terrain-driven differences in fuel moisture content relevant to prescribed burning operations.

The project has delivered significant advancements in the operational capability to capture spatially explicit information about the distribution of fuels and the effects of fire. The project developed a specification for deriving analogues of the Overall Fuel Hazard from LiDAR and then applied the method to an Australian Capital Territory-wide LiDAR dataset to produce spatially explicit fuel maps at resolutions of 2m, 5m and 25m.

The overall outcome from the project has been to significantly advance knowledge and operational capability for fire managers in understanding the distribution of fuels and their condition. The bushfire sector is well-placed to rapidly take up these advances and deliver better advances for communities across Australia."
Dr Adam Leavesley, Bushfire Research Utilisation Manager, ACT Parks and Conservation Service

FURTHER READING

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The Bushfire and Natural Hazards CRC is a national research centre funded by the Australian Government Cooperative Research Centre Program. It was formed in 2013 for an eight-year program to undertake end-user focused research for Australia and New Zealand.