HAZARD NOTE

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SOIL MOISTURE PROTOTYPE IMPROVES FORECASTS

ABOUT THIS PROJECT

This research was conducted as part of the *Improving land dryness measures and forecasts* project, which is developing more accurate and detailed measurements to improve the management and warnings for bushfires and floods.

AUTHORS

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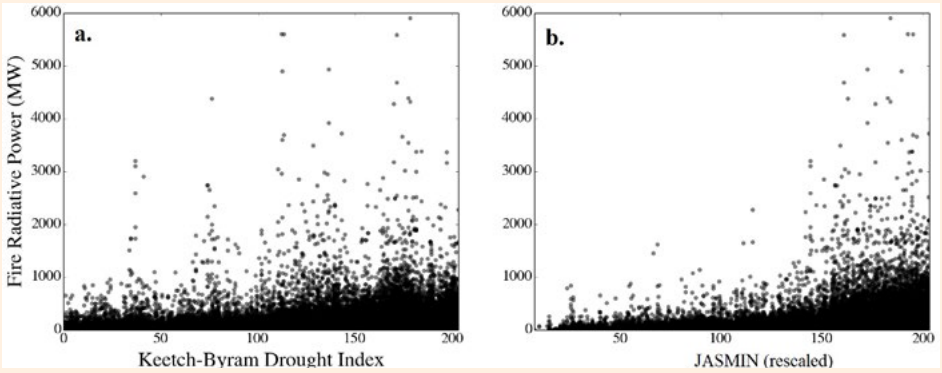
SUMMARY

This research has developed a prototype, high-resolution soil-moisture analysis system called JASMIN, which is a significant improvement in accuracy compared to currently used models. It is based on research that examines the use of land surface models, remotely sensed satellite measurements and data assimilation techniques to improve the monitoring and prediction of soil dryness. The new information will be calibrated for use within the existing fire prediction systems. This retains the accuracy, temporal and spatial resolution of the new product without changing the overall climatology of Forest Fire Danger Index and other calculations based on soil moisture.

Immediate benefits for emergency and land management agencies will be improvements to the fire danger rating and warning system, fire behaviour and flood prediction models, which will flow on to emergency warnings issued to the public. The project's long-term goal is to integrate JASMIN's outputs into the new National Fire Danger Rating System.



▲ **Above:** FIGURE 1. SCATTER PLOT DEPICTING MODIS FRP PRODUCT AGAINST A) KBDI, AND B) RESCALED JASMIN PRODUCT. THE DATASETS SPAN FROM JANUARY 2013 TO DECEMBER 2013.

CONTEXT

This project is addressing a significant limitation in the ability to accurately estimate soil moisture, a key parameter in the prediction of bushfire, flood and heatwave danger. Accurately predicting potential danger directly supports pre-event planning and hazard forecasting, core elements of a resilient community.

BACKGROUND

The current operational forest fire danger rating system uses very simple, outdated models for estimating soil dryness. These models either oversimplify or neglect critical factors that influence soil moisture dynamics. This leads to large uncertainties in the predicted soil dryness, undermining the quality of operational fire warnings. The project aims to develop a high-resolution, soil-moisture analysis system based on satellite measurements and advanced physics-based models, for use in fire danger prediction systems.

BUSHFIRE AND NATURAL HAZARDS CRC RESEARCH

This research is producing a more accurate soil dryness estimation system than the current, simple models used in fire prediction. The benefits of this new product will also extend to landscape management by assisting with planning for fuel-reduction burns, improvements to water resource management, weather and seasonal forecasts, and hydrological monitoring.

The project's significant progress is demonstrated by the development of a prototype, high-resolution soil-moisture analysis system that is a significant improvement in skill compared to currently used models. The system is based on the Joint UK Land Environment Simulator land surface model (JULES LSM) and is called JULES-based Australian Soil Moisture Information (JASMIN). Work is well advanced to re-scale the new system to produce a product that the fire agencies can directly use in place of the current ones without changing any of their existing infrastructure.

RESEARCH FINDINGS

This study suggests that analyses of soil moisture can be greatly improved by using physically based land-surface models, remote sensing measurements and data assimilation. A prototype of the JASMIN system has been developed with a spatial resolution of five kilometres. JASMIN can predict surface soil moisture, which is closely related to dead-fuel moisture content, and also root-zone soil moisture that provides information on live-fuel moisture content. Verification against ground-based soil moisture observations shows that this prototype system is significantly more skilful than the traditional models.

For ease of use within existing operational fire prediction systems, the new system has been calibrated to have the same dynamic range and statistics as the old models. The researchers investigated four variants of

END-USER STATEMENT

The results so far are both encouraging and tantalising. Fire danger forecasting and operational fire-behaviour prediction is limited by the relatively crude soil moisture modelling we commonly use. The availability of the advanced, fine-scale, multi-layer soil-moisture information arising from this project will be a boon to fire behaviour analysts everywhere in Australia, even though the richer data will be a challenge for us to understand, exploit and communicate.

– Mark Chladil, Fire Management Planning Officer, Tasmania Fire Service

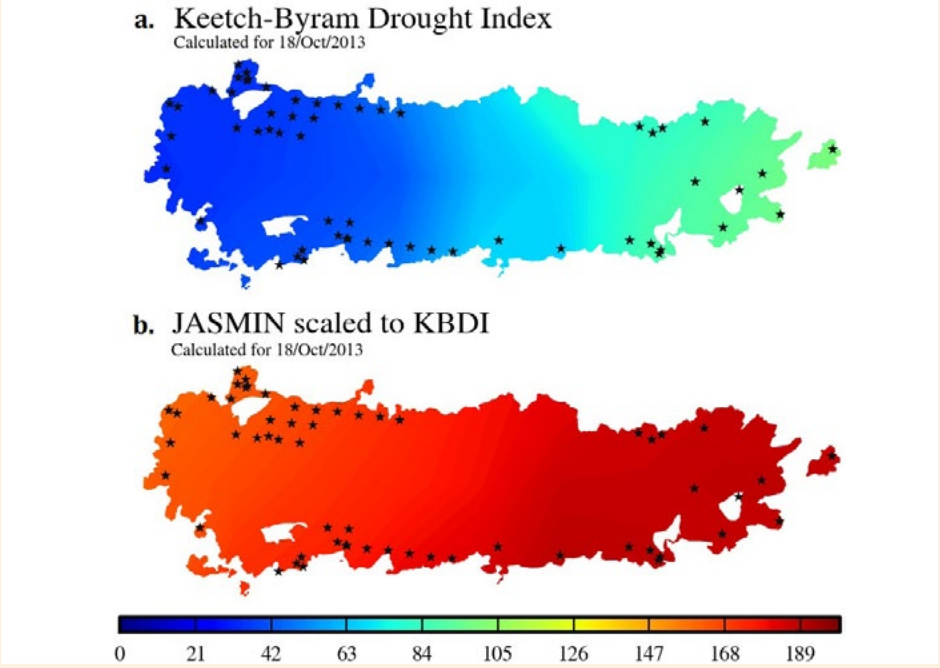
calibration approaches. The correlation with ground observations indicates that all matching techniques have similar skill. Evaluation of the soil dryness products against Moderate Resolution Imaging Spectroradiometer (MODIS) fire radiative power data shows that the JASMIN rescaled product is generally drier than the traditional models (Figure 1, page 1).

HOW COULD THIS RESEARCH BE USED?

The new, more accurate soil dryness analysis system, JASMIN, has been calibrated to enable immediate adoption within the current infrastructure.

The rescaled outputs will be evaluated using many case studies, including past bushfires and fuel reduction burns. These documented case studies are selected and evaluated with the help of end-users and could be used as training documentation by fire agencies.

A pilot project is being initiated, where rescaled outputs from routine JASMIN runs with daily updates will be published in registered user webpages for fire agencies to assess. The routine updates will also be disseminated to the Bureau of Meteorology's extreme weather desk, where the severe weather forecasters can assess the product using the forecasting tools (for example, the Bureau of Meteorology's Visual Weather product) available to them. Also, fire agencies using Visual Weather will be able to use the outputs directly.



▲ **Above:** FIGURE 2. (A) THE KEETCH-BYRAM DROUGHT INDEX AND (B) RESCALED JASMIN SOIL DRYNESS FOR THE STATE MINE FIRE IN NEW SOUTH WALES. THE KBDI IS EXPRESSED AS A SCALE FROM 0–200, WHERE THE NUMBER REPRESENTS THE AMOUNTS OF RAINFALL (IN MILLIMETRES) TO RETURN THE SOIL TO SATURATION. THE PLOT IS VALID FOR 18 OCTOBER 2013. THE SHAPE OF THE PLOT REPRESENTS FINAL FIRE BOUNDARY. THE BLACK STARS DEPICT HOT SPOTS DETECTED BY THE MODIS INSTRUMENT.

KBDI VERSUS JASMIN

One of the cases being studied as part of evaluation is the State Mine Complex fire, which occurred in New South Wales in October 2013. Figure 2a depicts the operationally used Keetch-Byram Drought Index (KBDI) calculated at five-kilometre resolution for 18 October 2013. The JASMIN product for the same date is given in figure 2b. The black stars show hot spots detected by the MODIS instrument. The JASMIN product is far drier compared to the traditionally used KBDI. The KBDI here may be under-predicting the soil dryness, as verifications have shown that it generally has a large wet-bias.

FUTURE DIRECTIONS

Future work will explore the downscaling of JASMIN outputs to a spatial resolution of one kilometre using remotely sensed measurements of land-surface temperature. The NASA Land Information System will be used to increase the number of remotely sensed measurements used by the JASMIN system. Longer term work will integrate JASMIN outputs into the new National Fire Danger Rating System.

FURTHER READING

Vinodkumar, Dharssi I, Bally J, Steinle P, McJannet D, and Walker J (2017), Comparison of soil wetness from multiple models over Australia with observations, *Water Resources Research* **53**, pp. 633-646, doi:10.1002/2015WR017738.

Vinodkumar and Dharssi I (2017), Evaluation of daily soil moisture deficit used in Australian forest fire danger rating system, Bushfire and Natural Hazards CRC.

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