National Fire Behaviour Knowledge Base- Bringing together the best information for best decisions

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Abstract

The estimation of fire behaviour is an important component of any fire management approach, allowing the determination of the impacts of fire on ecosystem components, public safety and warnings, and supporting bushfire management decision-making. Fire behaviour prediction combines quantitative and qualitative information based on experience and scientific principles describing the combustion and behaviour of fire influenced by topography, weather and fuel. Predictions based on mathematical models integrate these important factors in a consistent way. The National Fire Behaviour Knowledge Base (NFBKB) is a new software-based tool that consists of four primary components (fuel models, fuel moisture models, wind models, and fire behaviour models) to predict expected fire characteristics (e.g., rate of spread, flame height, fireline intensity, onset of crowning, spotting potential, etc). This paper details the current development of the fire behaviour component of the NFBKB system as well as how this will be integrated with the Australian bushfire fuel classification project currently being undertaken by AFAC. The fire behaviour component integrates a suite of models covering the main fuel types of Australia: eucalyptus forests, exotic pine plantations, grasslands, shrublands and Mallee-heath.

In the near future further CSIRO development of the National Fire Behaviour Knowledge Base will integrate the latest fire behaviour, fire weather, and fuel dynamics knowledge and science to help fire managers better predict bushfire behaviour and better plan prescribed burns. The paper also presents an overview of how these proposed future components of the knowledge base will be brought together.

Additional keywords: bushfire, fire spread, fire prediction, software development, workspace, workflow.

Introduction

Bushfires (wildland or forest fires as they are known in other parts of the world) are one of the world's most complex and dangerous natural phenomena, involving interactions of chemistry, physics and biology across a broad range of temporal and spatial scales. Bushfires affect all populated continents. In recent years devastating bushfires with a heavy human toll occurred in Australia, Russia, the USA, Greece and Spain.

In Australia, more than 300 people have been killed by bushfires in the last 50 years and in 2001 they were estimated to cause, on average, over $77M damage each year (BTE, 2001). The Black Saturday fires in Victoria in 2009 burnt more than 400,000 ha, killed 173 people (Teague et al., 2010) and caused over $1B damage (Insurance Council of Australia, 2010) with a total estimated cost of $4B (Teague et al., 2010). The largest of these, the Kilmore East fire, burnt over 100,000 ha in 12 hours (Cruz et al., 2012) and killed 121 people.

Predicting the behaviour of a bushfire is essential for the effective and timely management and control of fire in the landscape. Knowing how fast a bushfire will spread, where it will be at a given time in the future, how resistant it will be to control efforts, and what future efforts would be effective in reducing reoccurrence are essential to fire fighter safety, community protection and safety, planning and execution of fire suppression efforts. Assessment of fire behaviour potential is also essential for planning and conducting hazard reduction burns and creating fire-smart landscapes, i.e., landscapes with a low likelihood of large fire development. As such, fire behaviour knowledge provides critical situation awareness for all levels of fire management, from the front line fire fighter who needs to identify localised life-threatening conditions, the sector commander who needs to ensure the safety of fire crews, to the incident controller who is charged with looking out for the safety of all personnel on a fire ground and the general public.

In Australia, there are a number of operational fire prediction systems (Sullivan, 2009a), all of which are empirical in formulation (Sullivan, 2009b). These systems generally take the form of statistical regression models that relate a number of key independent variables that are commonly environmental in nature (e.g. fuel, weather, topography) to a range of dependent variables such as rate of forward spread, flame height, spotting distance, etc). Each is generally defined for a particular type of fuel (e.g. grassland, forest litter, forest crowns, heath) under a restricted range of burning conditions and thus has individual strengths and weaknesses. The physical forms of these systems range from circular slide rules (McArthur, 1966, McArthur, 1967) and nomograms to tables (Gould et al., 2007a, Gould et al., 2007b), spreadsheets and computer programs.

The major challenge for many operational fire behaviour prediction systems is the broad range of conditions under which wildfires occur. Being generally statistical in origin, fire behaviour models are excellent at dealing with continuously varying parameters such as weather (wind speed, air temperature, etc.) and fuel moisture. However, vegetation is much more difficult to quantify for such purposes, primarily due to the natural biological variations found in morphology and quantity, even within homogeneous vegetation.

For simplicity, vegetative fuels are frequently categorised into a set number of discrete groups that allows useful physical description and quantification. Inevitably, however, the classified groups do not match the breadth of diversity of fuels found in the natural world. Individuals making fire behaviour predictions constantly find fuel conditions that do not seem to “fit” any standard fuel classification. They are then left to guess at how to classify this fuel, with the knowledge that even when classified, the predicted fire behaviour will not match observations due to differences between the local fuel and the most appropriate standard classification. In addition to this, the new trend to “engineered” vegetation complexes through vegetation management and mitigation (to reduce fire behaviour potential) introduces a whole new suite of fuel complexes not accounted for within the current suite of fire behaviour models.

While tools have been developed around the world to automate the prediction of the behaviour and spread of fire across the landscape for various operational purposes (e.g. FARSITE (Finney, 1998), SiroFire (Coleman and Sullivan, 1996), Phoenix (Tolhurst et al., 2008), PROMETHEUS (Tymstra et al., 2010), FSPro (Finney et al., 2011)), by linking fire perimeter propagation with geographic information system databases for topography, vegetation and other landscape features, these for the most part utilise the available operational fire spread prediction models and therefore suffer the same fuel class-related issue as the less advanced systems.

The proposed solution to this seemingly intractable problem is not the development of yet another model for a particular type and arrangement of fuel. We propose the development of a fire behaviour knowledge base that supersedes existing physical forms of fire behaviour prediction systems and allows fire practitioners to view existing fire behaviour observations directly, with a richness and depth of information unachievable in traditional modelling.

A National Fire Behaviour Knowledge Base

This paper presents a proposal for a National Fire Behaviour Knowledge Base aimed at addressing the needs of fire managers in regards to improving access to critical fire behaviour information in a timely, effective and efficient manner. This includes information on fuel (type, condition, state, hazard), expected fire danger, and the prediction of site specific fire behaviour. The purpose of the system is to integrate all available and peer-reviewed fire behaviour knowledge into a single user-friendly interface that enhances the overall information quotient available to the fire manager and enables linkages to other critical sources of information such as current and forecast weather.

This system will consist of a suite of tools that can be used by fire managers to deal with fire management issues over a range of spatial and temporal scales as well as levels of decision making complexity. Such a system will enhance fuel management programs, lead to more effective and safer firefighting, improve protection of rural communities, infrastructure and other assets and reduce detrimental effects to natural resources.

The National Fire Behaviour Knowledge Base (NFBKB) is envisioned as a searchable, extendable database that allows users to:

- describe their current fuel complex and have the computer search through a database of existing fuel and fire behaviour observations to find similar conditions;
- review photos of similar fuel complex and select those that best match their current area of concern;
- review available general and detailed data concerning the weather, topography and resultant fire behaviour for each of the selected fuel complexes;
- review available images and video taken before, during and after fires burning in similar conditions;
- plot the data against existing mathematical model results to see how existing models predict parameters for selected fuel complex matches;
- access publications linked to the displayed observations for in-depth information and analysis; and
- insert data and documentation (photos, video) of their own fires in particular fuels to build the knowledge base.

The heart of the NFBKB is comprised of two distinct kernels (Figure 1): the fire behaviour models module (current work) and a fire behaviour knowledge base module (future work). The fire behaviour module is the engine of the system, providing fire behaviour predictions aimed at answering a wide range of fire management questions (Cruz and Gould, 2009). It will initially be populated with the state of the art fire behaviour models for prescribed burning and wildfire propagation. These fire behaviour models will be augmented with observational data sets derived from experimental fires as well as reliably documented case studies of wildfire events. The main fire behaviour quantities that will be determined by the fire behaviour kernel are:

- sustainability of fire spread,
- initial fire development potential (area and perimeter assuming point ignition),
- rate of forward fire spread and intensity of surface fire,
- flame dimensions (height, depth, angle) and residence time,
- spotting potential,
- onset of crowning and crown fire behaviour, and
- fine and coarse woody fuel consumption.

Ensemble calculations of fire behaviour will be carried out to incorporate the inherent spatial and temporal variability in weather and fuel conditions, providing users with measures of uncertainty associated with specific fire behaviour forecasts.

Notwithstanding the comprehensiveness of the core fire behaviour dataset (based on six decades of field-based fire experimentation and wildfire analysis), the system will still not cover all possible burning conditions (fuels, weather and topographic combinations) that may be encountered by fire managers. That is, it does not solve the problem of a user encountering a set of burning conditions that do not match any observations in the historical record, which might increase the uncertainty of the system outputs.

A unique aspect of the system architecture planned for the NFBKB is the ability for the knowledge base to be user extendable. By allowing users to document their own fuel complexes, burning conditions and associated fire behaviour observations, in as much detail as they wish, it means the NFBKB will eventually become a comprehensive crowd sourced database that is applicable to the broad range of combinations of fire conditions. The observations that users make and the knowledge they gain from making those observations will be made available (after necessary quality control) to the larger fire management community to enhance the quality of decision making. That is, the next person will be able to search the knowledge base for similar fuel complex and burning condition to review and compare previous fire events with those expected and be able to make better judgement on fire behaviour predictions and thus decisions.

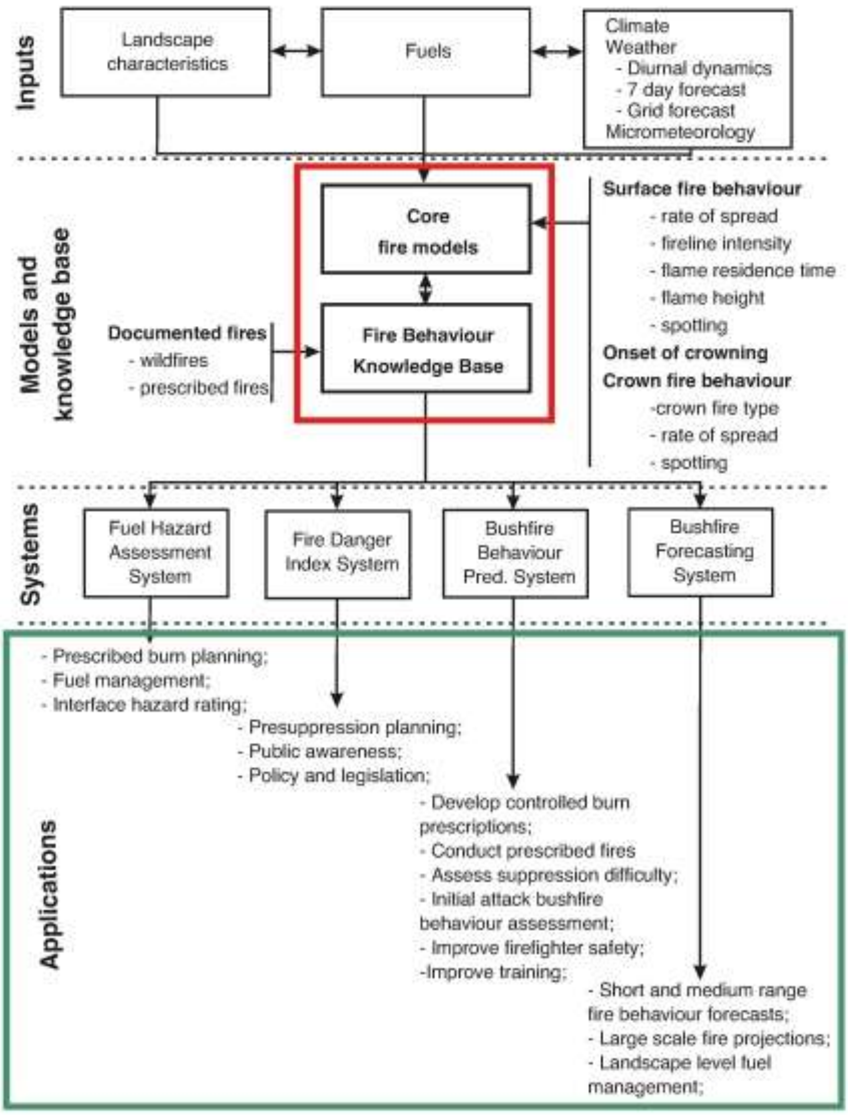

Figure 1. Flow diagram of proposed National Fire Behaviour Knowledge Base (NBFKB) structure, illustrating the link between fire drivers, the knowledge base (models and data) and output systems and potential applications (Source: Cruz and Gould, 2009).

Software development

The NFBKB will be built using the Workspace workflow environment which has been developed by the CSIRO Computational Informatics (CCI) Computational Modelling Group.

A Workspace workflow is made up of a series of "operations" (Figure 2) shows one such operation). Each operation has a series of input and output ports on its left and right side respectively. An operation can perform a calculation based on its inputs and then output some data. A user can connect a number of operations together to perform a complex series of calculations on streams of data, thus forming a workflow.

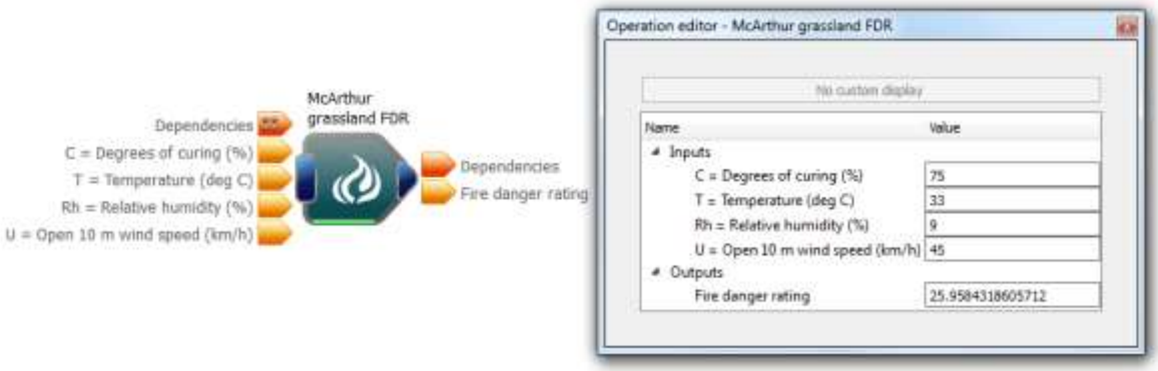

Figure 2. Workspace operation example that calculates the fire danger rating for grasslands. Input and output values of the operation are shown in the operation editor window. This custom built operation is one of many such operations that will be part of the NFBKB (Source: Rucinski, 2013).

Workspace users may construct, modify and execute workflows using an intuitive graphical editor (Figure 3). This editor allows users to inspect and modify any input or output on the workflow using custom built display widgets allowing interaction with workflows as they are executing.

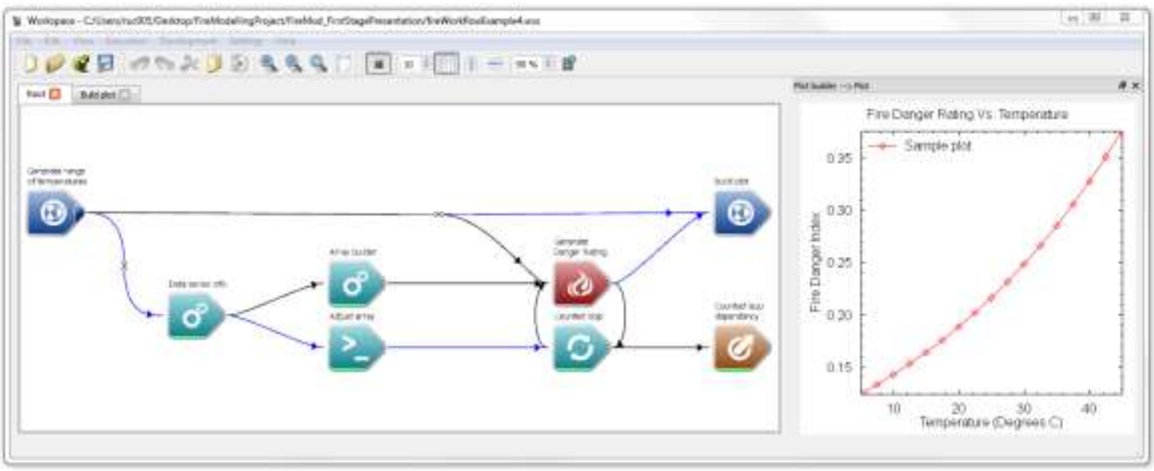

Figure 3. A workflow that plots temperatures against fire danger indices using newly developed fire model operations (Source: Rucinski, 2013).

Workspace users can access a large suite of built-in operations and data types. New operations, data types and display widgets, such as those developed for bushfire models, can be added easily. Workspace assists users in this task by providing extensive tutorials and wizards.

Workspace also supports the creation of complete custom Graphic User Interfaces (GUI) to simplify end-user interaction with workflows (Figure 4). As Workspace is built upon the Qt framework, it includes a large library of GUI widgets out of the box. Developers can also define new widgets or derive new widgets from existing ones.

Workspace is developed and maintained by a team of software engineers, all of whom have backgrounds in commercial software development and utilise software industry best practices. Software quality is a major focus of the team as well as a critical requirement in any safety system.

Workspace has been chosen as the development platform because it is a cross-platform scientific workflow engine available on Windows, Linux and OSX. Workspace is written predominantly in C++ which is inherently beneficial in terms of scalability and performance.

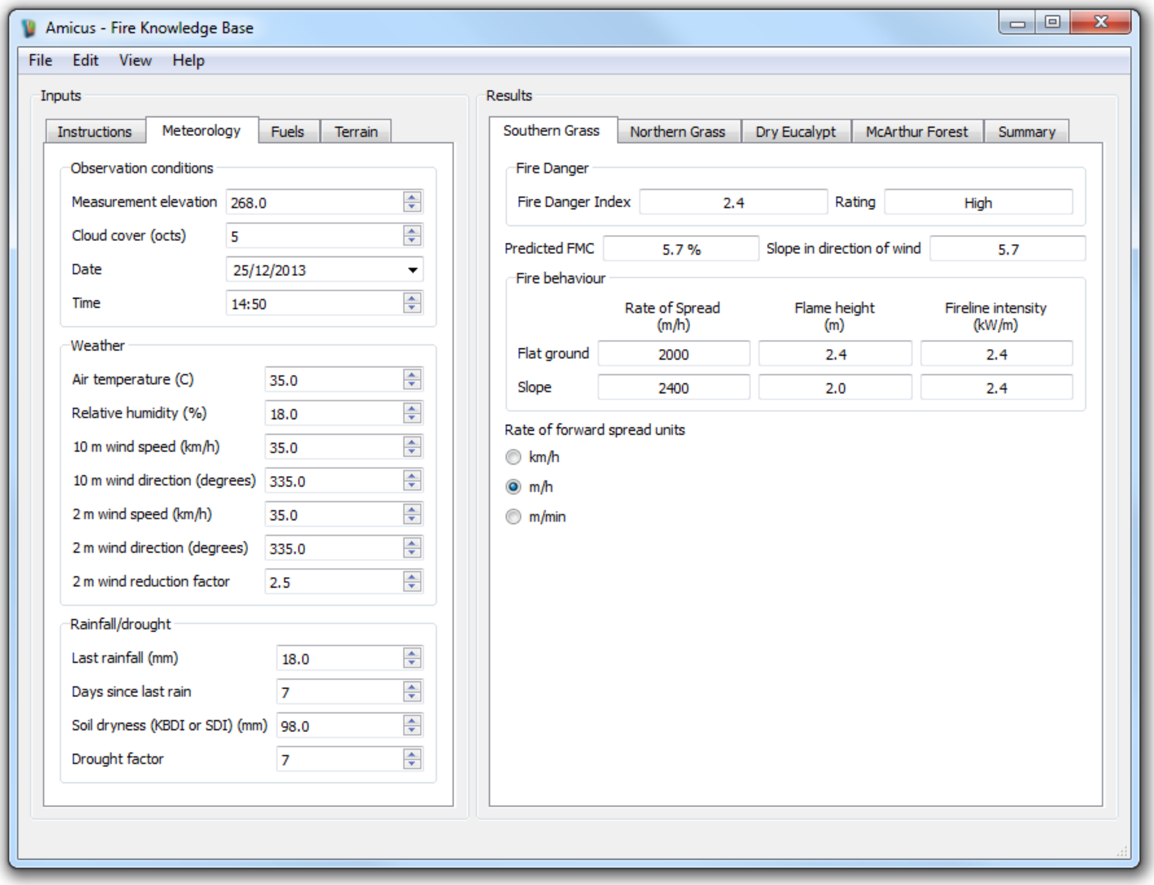

Figure 4. A preview of the NBBKB (Amicus software) application currently under development. This front-end provides a simple interface for end-users to control a workflow.

Agency Linkages and use

The NFBKB will be a powerful tool for fire behaviour analysis and prediction. However without a cohort of well-trained individuals to predict fire behaviour, the tool will enjoy little effective use. Trained and experienced Fire Behaviour Analysts (FBANs) are a critical part of any fire intelligence team reporting into an incident command team. Development and delivery of a training program for FBANs is essential for the true potential of the NFBKB to be realised. The NFBKB is first and foremost an operational tool for FBANs. As such it is expected that a multi-agency cadre of FBANs and other users and researchers would oversee database management, ensure data quality and recommend improvements to the software.

A second benefit of the NFBKB is a centralised repository of national fire behaviour data. These data will then be easily accessible to scientists for a variety of research purposes as well as to agency staff. This data set, larger than any existing single dataset, could provide powerful insights into the nature of fire in Australia and how best to manage it.

Finally, because the NFBKB has the capacity to include photo (and video) documentation of pre-, during and post-burn observations, there will be application to prescribed burning planning and preparation. Users can search or input the fuel complex of interest, view the range of post-burn results, select the appropriate post-burn consequences that they would like to obtain and then review different weather and fuel scenarios conditions required to achieve the burning objective.

Conclusions and Future Work

The development of the NFBKB is at an early stage. However its simple encompassing concept is garnering interest in many locations. Because it is not dependant on any single fire behaviour prediction system, it is seen as a complement to existing fire behaviour modelling tools and as an essential element for front line fire behaviour prediction and operational decision making.

While the fuel complexes in Australia vary quite markedly across the continent, there are some that have similar attributes or that burn in a similar manner. The merging of the fuel data from the developing National Fuel Classification System (Hollis et al., 2011, Gould and Cruz, 2012) can only improve our overall understanding and prediction of fire nationally. If the NFBKB develops beyond the implementation of the current fire behaviour prediction systems into a truly national tool integrating the large pool of observational fire behaviour data sets, the resulting knowledge base will be unparalleled in richness and depth, and vastly improve the quality of both fire behaviour prediction and decision making for all.

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