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# A REPORT ON WRF SOFTWARE DEVELOPMENT (PRELIMINARY)

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Cover: Flagstaff Gully at night. Source: BNHCRC.

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# ABSTRACT

Bushfire is one of the major natural hazards Australia encounters every year because of its dry weather and widespread bushlands. During the dry season, occurrence of simultaneous bushfires at different locations is quite common. The fire management authorities face challenges on deployment of resources (human and other logistics) properly to mitigate multiple bushfires. To prioritize, they depend on the modelling of real-time behaviours of the fire under consideration. Fire rate of spread (RoS) is one of the most important parameters that the authority wants to determine before proceeding to resource allocation. RoS during forest fire can be slowed by reduced sub-canopy wind. In operational models, it is accounted by a parameter, wind reduction factor (WRF). Current values used as WRF are not based on science. In this work, we are presenting a software (preliminary version) that can calculate WRF scientifically. We apply a dynamic WRF obtained from a mathematical model in an operation model, Spark. This will lead to better prediction of RoS, once fully implemented.

# INTRODUCTION

Wind reduction factor (WRF) is dynamic i.e., it changes with the wind velocity and fuel cover. However, for simplicity, fire behaviour analysts use a pre-decided constant value of WRF for a specific fuel type for operational fire prediction models. Table 1 represents WRF used for the McArthur model with PheonixRapidfire by RFS, NSW.

TABLE 1: WIND REDUCTION FACTOR GUIDE.

| Wind Reduction Factor | Vegetation Type |
|---|---|
| 1 | Herbfield |
| 1.2 | Grassland, sedgeland |
| 1.5 | Heathland, Mallee woodland |
| 2 | Tall shrubland (>1.5 m) |
| 2.5 | Eucalypt woodland (>6 m) |
| **3** | **Open Eucalypt Forest (standard McArthur forest)** |
| 3.5 | Shrubby open forest |
| 4 to 5 | Damp forest with shrubs, Karri |
| 4 to 6 | Wet eucalypt forest, Mature plantation |
| 5 to 9 | Rainforest |

We intend to apply dynamic WRF, based on research conducted using fluid dynamics and physics-based modelling. Although research into complicated fire-canopy interactions is ongoing, we are developing a framework for the application.

Predicting the rate of spread (RoS) and intensity of bushfires is essential for emergency and disaster management organisations. Factors, such as localised topography, weather conditions, vegetation, and terrain have a varying range of influences on RoS, which makes the prediction highly complex. Currently, RoS predictions are achieved by implementing simplified operational models that have the useful attribute of providing results on time scales commensurate with the requirements of the emergency managers.

# METHODOLOGY

In our study, we are using Harman-Finnigan model [1] model to calculate dynamic wind reduction factor (WRF). The Harman-Finnigan model for flow within and above a uniformly distributed tree canopy is a three layers model:

1. Subcanopy – the *Inoue Model* [2] is used for subcanopy flow within the canopy
2. Shear layer across the top of the canopy and immediately above the canopy – the *Raupach Model* [3] is used, and
3. Displace *Log-Layer* above the canopy.

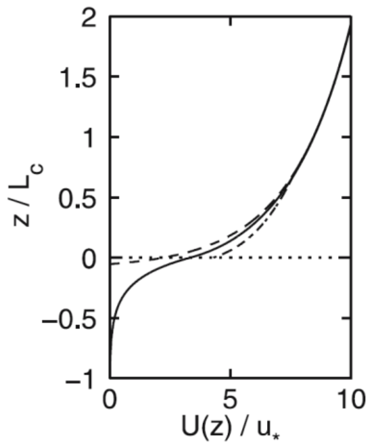


**Figure 1: Predicted wind speed profile for neutral conditions in natural [1].** Solid line represents the fully coupled profile; dashed line represents the extrapolated surface layer profile; and the dash-dotted line represents the predicted profile from Physick and Garratt [4]. Horizontal dotted line indicates the canopy top.

Forest canopy and wind velocity play important roles in wildfire propagation. However, these roles vary due to the reduction of wind velocity during fire moving through the forest canopies of different leaf area index (LAI). Taking these two factors—wind velocity and LAI—into consideration, we first obtain sub-canopy wind profiles (as shown in Figure 1) using Harman-Finnigan model [1]. The implementation detail of the Harman-Finnigan model is included in *Appendix A*.

We then calculate wind reduction factor (WRF) by taking the ratio of open wind speed at 10 m above the ground ($U_{10}$) and sub-canopy wind velocity at various height (u(z)) as shown in Equation (1).

$$WRF = \frac{U_{10}}{u(z)} \quad (1)$$

# RESULTS OF PRELIMINARY STUDY

In our preliminary study, we generated WRF (as shown in Figure 2a) from synthetic data to model the varying wind velocity and hence, predicting the RoS. It is due to the fact that for a dynamic fire passing through a canopy, the relationship between the wind speed and RoS appears more complicated than can be described by a constant wind reduction factor [5] [6]. Figure 2(b) and (c) are the profile of sub-canopy wind and open wind, respectively, based on Finnigan model.

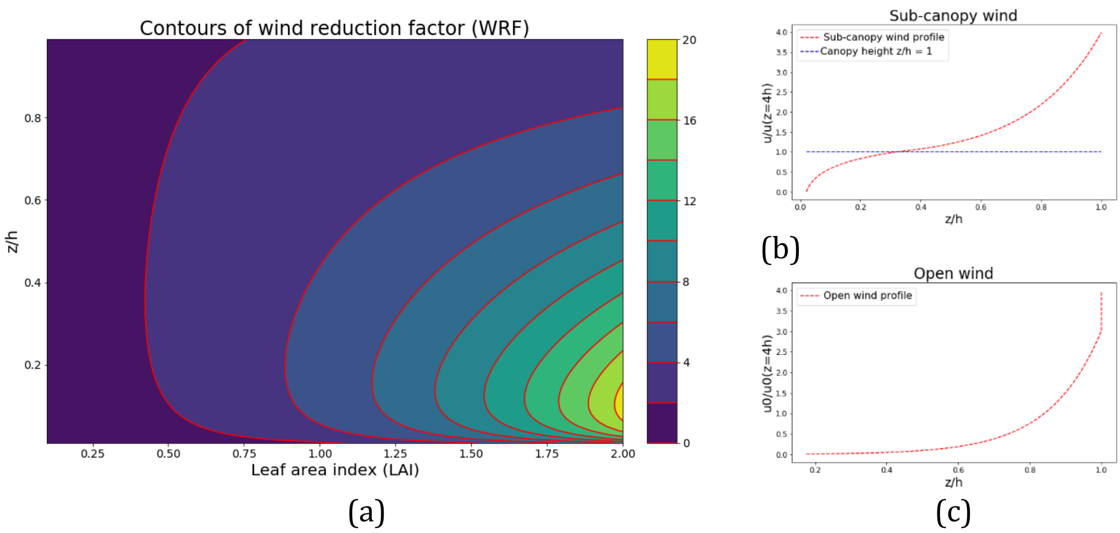


**Figure 2: Profiles towards calculating wind reduction factor.** (a) A map of wind reduction factor derived from synthetic data using Harnan-Finnigan Model; (b) and (c) are the profile of sub-canopy wind and open wind, respectively, based on Finnigan model.

We implemented this software into CSIRO Data61's operational platform, Spark. The WRF is calculated within Spark running a C script by implementing Harman-Finnigan model (Harnan and Finnigan 2007) and a logarithmic model of the canopy-free wind speed. These models are based on leaf area index (LAI) which is relatively easily available from Landscape Data Visualiser [7]. Note that LAI only provides a dimensionless measure of vegetation per unit of ground area and uniform across the canopy height. This work is the first step towards implementing the dynamic wind reduction factor (based on fluid dynamics theory) in an operational model.

We conducted a simulation on Spark before implementing WRF. The output of the fire propagation without WRF is shown in Figure 3. This is a point source ignition and the fire spreads assuming the wind speed is uniform across the landscape irrespective of the fuel types.

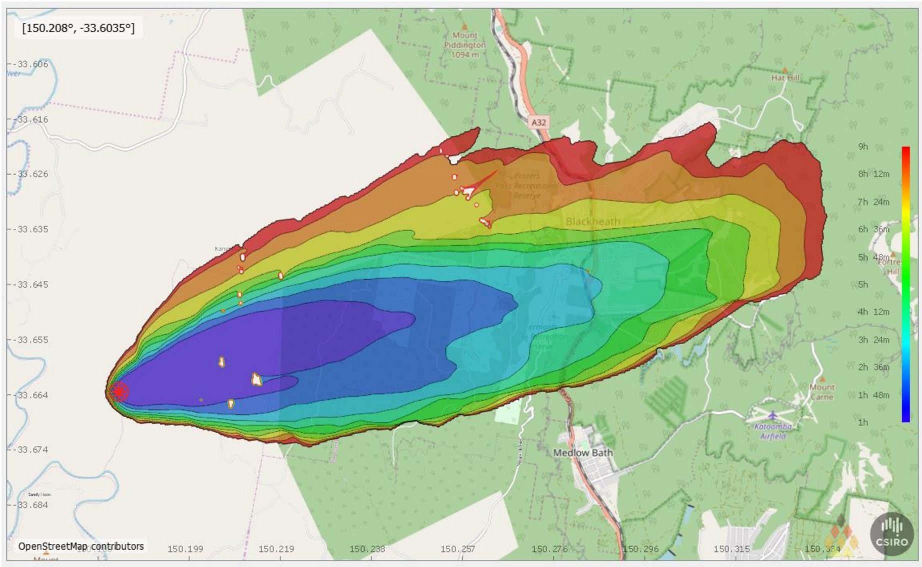


**Figure 3: Fire propagation without WRF.** Fire rate of spread simulation in Spark operational model without wind reduction factor. The fire spreads assuming the wind speed is uniform across the landscape irrespective of the fuel types.

Then we simulated the same case after implementing a WRF layer that is calculated using a leaf area index of 0.2. The fire propagation is presented in Figure 4. The fire propagation clearly shows that as soon as the fire-fronts hit the forest canopy, the effect of WRF is felt, which eventually decreases the RoS.

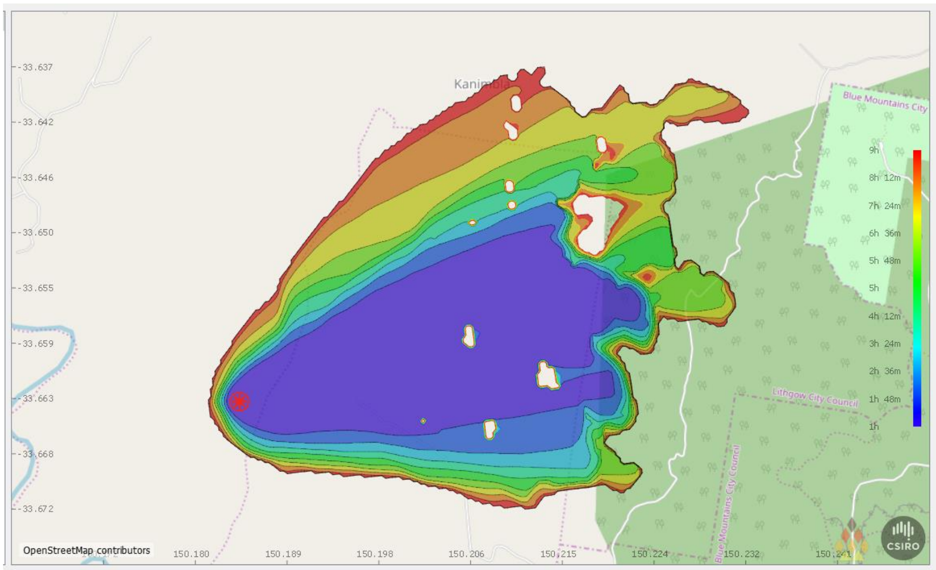


Figure 4: **Fire propagation with WRF.** Fire rate of spread simulation in Spark operational model after applying wind reduction factor calculated using our model for a leaf area index of 0.2 (forest). The fire propagation clearly shows that as soon as the fire-fronts hit the forest canopy, the wind reduction factor increases, which eventually decreases the wind speed and RoS.

The Figures 5 and 6 are the same as Figure 4. However, in Figure 4 a raster layer of different fuels (vegetation) is visualised. On the other hand, in Figure 5 a raster layer of WRF is visualised.

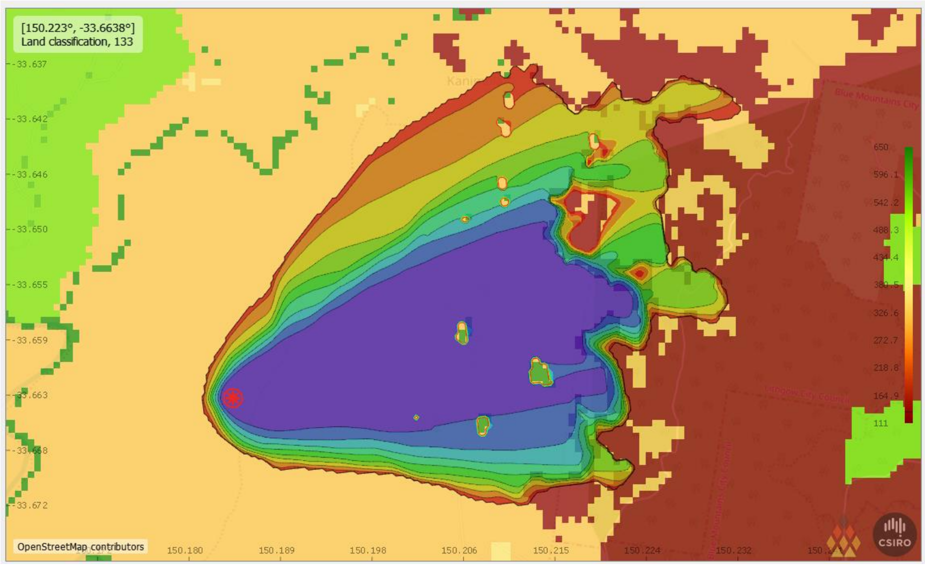


Figure 5: **Fire propagation with WRF.** Fire rate of spread simulation in Spark operational model after applying wind reduction factor calculated using our model for a leaf area index of 0.2 (forest). The land classification layer is switched on in this figure.

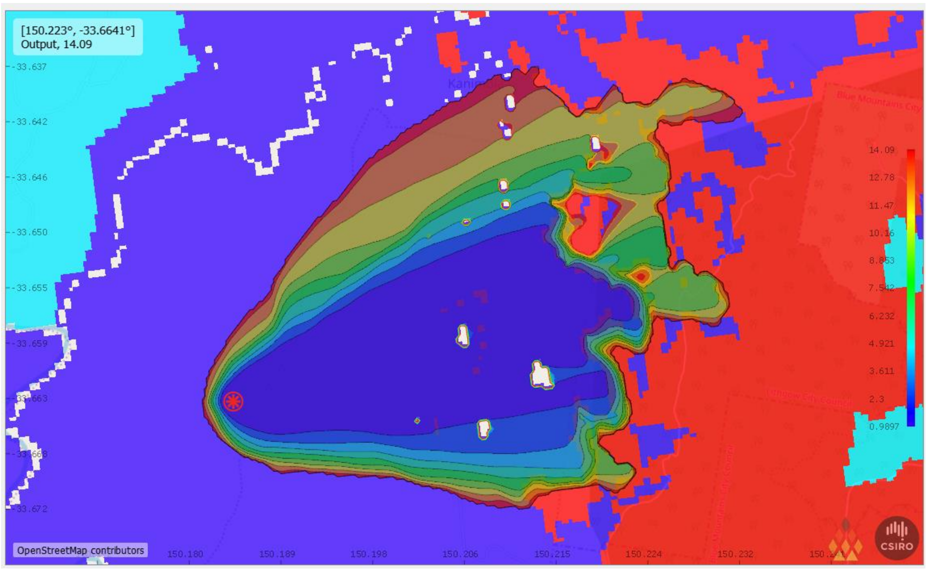


Figure 6: **Fire propagation with WRF.** Fire rate of spread simulation in Spark operational model after applying wind reduction factor calculated using our model for a leaf area index 0.2 (forest). The WRF layer is switched on in this figure.

# WORK IN PROGRESS

We are currently working on developing a robust WRF utlisation software where we aim to include a LAI layer in Spark operational model that will dynamically calculate WRF from the gridded LAI and provide more accurate RoS. LAI and LAD data will be obtained from Water and Landscape Data group of Australian National University [7].

# CONCLUSIONS

Application of dynamic wind reduction factor in predicting fire rate of spread will help the fire management authority to analyse the behaviour of fire before allocating resources to mitigate the fire. We have completed our initial studies and developed a software (preliminary version) to investigate the effect of WRF in RoS. We are on track towards developing the final version of the utilization software and we hope that the operational model, Spark with dynamic WRF will be delivered in the due course.

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