FINDINGS

Dynamic wind reduction factors have **considerable effects** on forest fires where **variable canopy heights** play important roles.

Dynamic wind reduction factor in predicting fire rate of spread

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The behaviour of fire is primarily governed by the wind flow and fuel types on the affected area. For the forest fire, tree canopies play an important role by reducing the wind velocity when it passes through the forest. The objective of this research is to apply a dynamic wind reduction factor (WRF) in an operational model to predict the fire rate of spread (RoS).

Introduction

Wind reduction factor is dynamic in nature, i.e., it changes with the wind velocity and fuel structures. For simplicity, fire behaviour analysts use a *rule-of-thumb* to estimate the WRF for a specific fuel type for operational fire prediction models e.g., in Spark [1], an operational fire simulation model developed by Data61 of CSIRO, the value of WRF is 3 for Eucalyptus forests. For a dynamic fire, passing through canopies, the relationship between the wind speed and RoS appears more complicated than can be described by a constant value as illustrated by Moon et al. [2], Sutherland et al. [3]. Although research on complicated fire canopy interactions is ongoing, we have made a significant progress in enhancing RoS prediction in an operational model.

Methods

In our study, we are using Harman-Finnigan model [4] model to calculate dynamic WRF. The Harman-Finnigan model for flow in and above a uniformly distributed tree canopy is a three layers model:

- Subcanopy - the Inoue Model [5] for subcanopy flow is used within the canopy
- Shear layer - across the top of the canopy and immediately above the canopy - the Raupach Model [6] is used, and
- Displaced Log-Layer - above the canopy.

In our model WRF is calculated as:

$$wrf = \frac{U_{10}}{u_z}$$

where, U_{10} is open wind speed at 10 m above the ground and u_z is the sub-canopy wind velocity at various heights.

Towards calculating WRF, we prepare raster maps of leaf area index (LAI) and vegetation height data respectively obtained from [7] and [8] to feed in Spark (e.g., Figure 1 (a) and (b) are the prepared raster maps of the area of 2009 Kilmore Fire, VIC).

Results

We tested our model with synthetic leaf area density (LAD) data to calculate WRF and apply that to Spark. The outcome of Spark's two variant (i) base spark and (ii) spark with our model applying WRF are presented in Figure 2 (a) and (b).

Further, we run our model on eight actual bushfire cases (e.g., Lithgow 2013, Kilmore 2009, Forcett 2013, Wangary 2005 and others) to assess capability of our model. Figure 3 (a) and (b) present the outcomes of the 2009 Kilmore fire where 3(a) represents the fire without applying WRF and 3(b) represents fire after applying dynamic WRF. Black lines represent the final perimeter of the actual fire.

Discussion

In our results, the effects of dynamic WRF is evident, which is producing better predictions relative to the results with constant WRF. However, we observed some inconsistency in RoS in a few cases and our initial assumption is, this might happen because of very low resolution (*1km x 1km*) of the vegetation height data in comparison to Spark's high resolution (*30m x 30m*). We aim to investigate further to find the root-cause.

References

1. C. Miller, J. Hilton, A. Sullivan, M. Prakash, Spark - a bushfire spread prediction tool, Environmental Software Systems, 2015
2. K. Moon, T. Duff, K. Tolhurst, Sub-canopy forest winds: understanding wind profiles for fire behaviour simulation, Fire Safety Journal, 2016
3. D. Sutherland, J. Philip, A. Ooi, K. Moinuddin, Large eddy simulation of flow over stream-wise heterogeneous canopies: Quadrant analysis, Australasian Fluid Mechanics Conference, 2018.
4. I. Harman, J. Finnigan, A simple unified theory for flow in the canopy and roughness sublayer, Boundary-Layer, 2007
5. E. Inoue, On the turbulent structure of air flow within, Journal of the Meteorological Society of Japan, 1963
6. M. R. Raupach, Drag and drag partition on rough surfaces, Boundary-Layer Meteorology, 1992
7. TERN and ANU - Landscape Data Visualiser, https://maps.tern.org.au/#/, 2019
8. M. Simard, N. Pinto, J. B. Fisher, A. Baccini, Mapping forest canopy height globally with spaceborne lidar, Journal of Geographical Research, 2011.

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Tables and figures

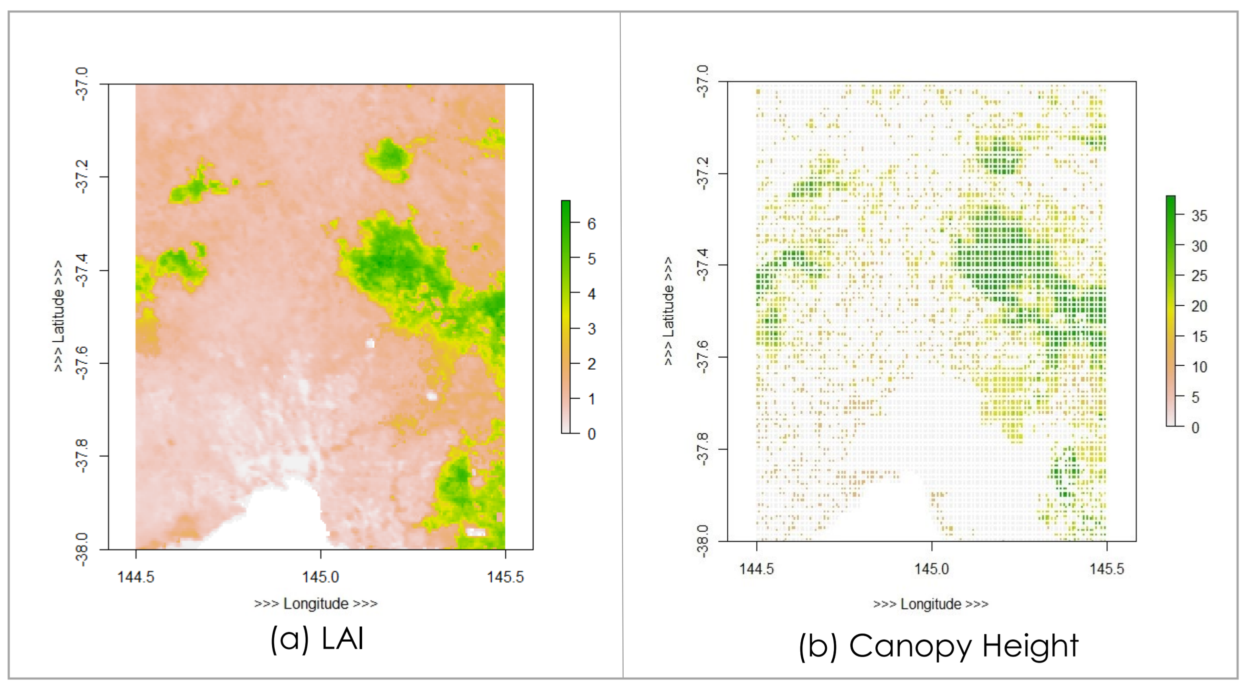

Figure 1: The raster maps of 2009 Kilmore fire incident area in Victoria. (a) the LAI raster map obtained from landscape data [7] and (b) the canopy height raster map obtained from Vegetation Height for Australia [8].

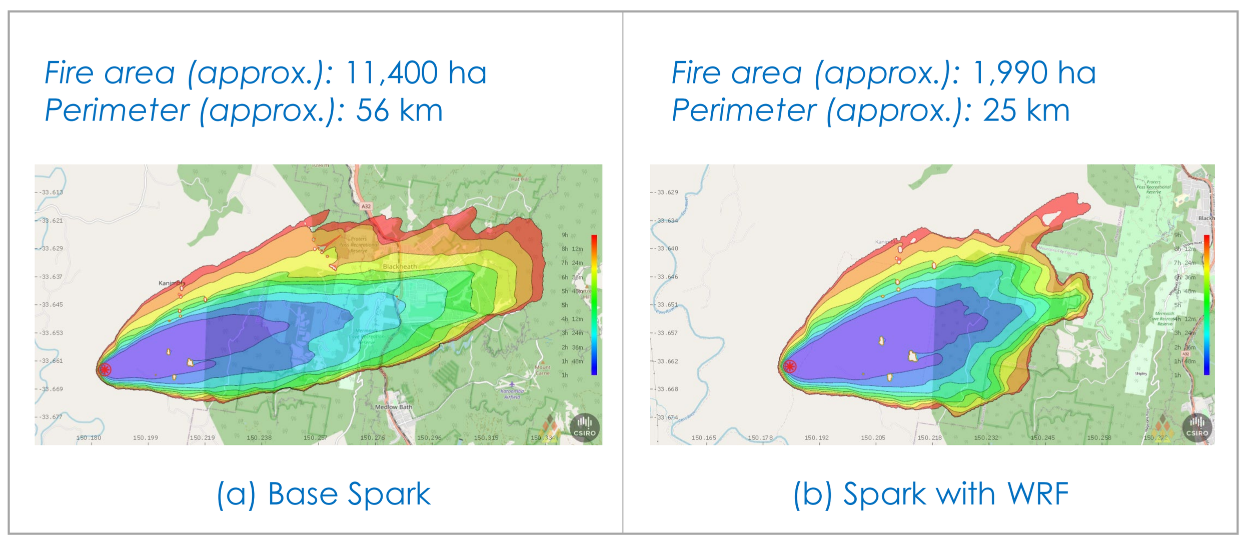

Figure 2: Effect of WRF on RoS on a random point fire. (a) the outcomes of Spark's base implementation; (b) the outcome of Spark after implementing our model with a calculated WRF obtained from a LAD value of 0.20.

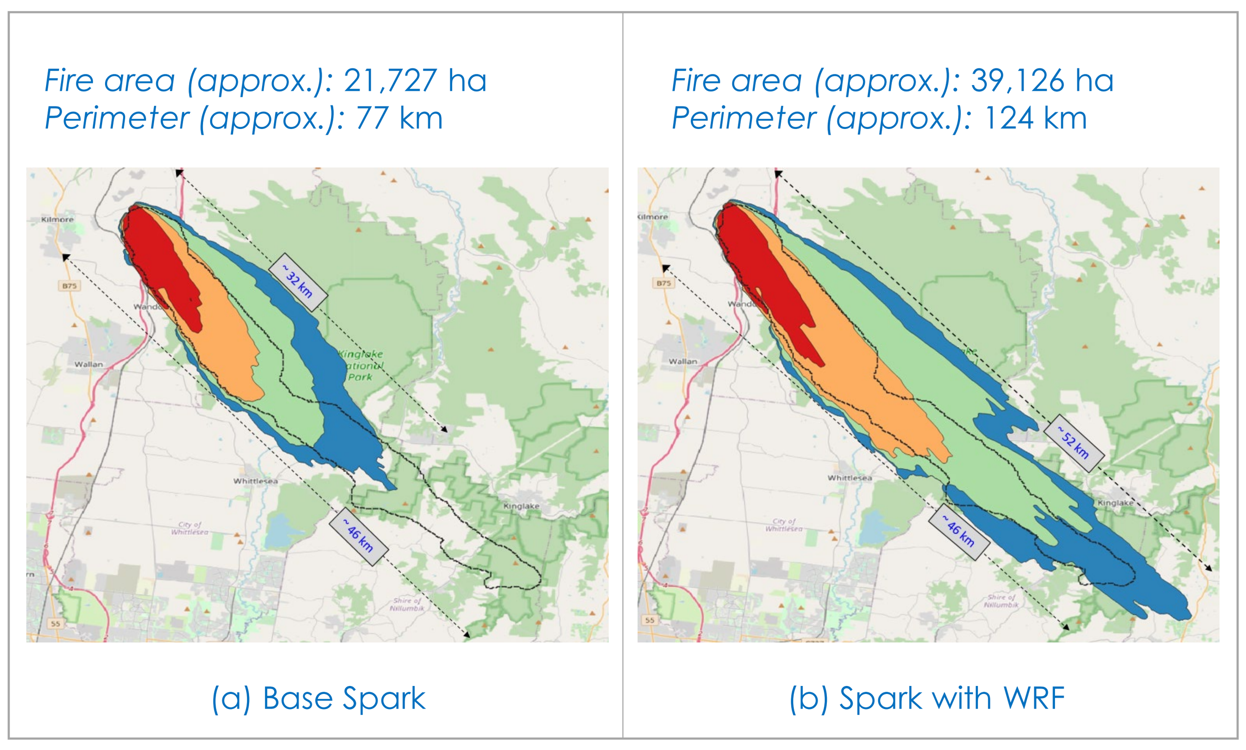

Figure 3: Kilmore Fire, VIC, 2009. towards finding and and applying WRF, (a) LAD is worked out from LAI raster data shown in Figure 1(a) using a uniform canopy height of 10 metres; (b) LAD is worked out from LAI raster data using actual height raster data shown in Figure 1(a) and (b) respectively. The black dotted line represents the recorded fire perimeter.

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