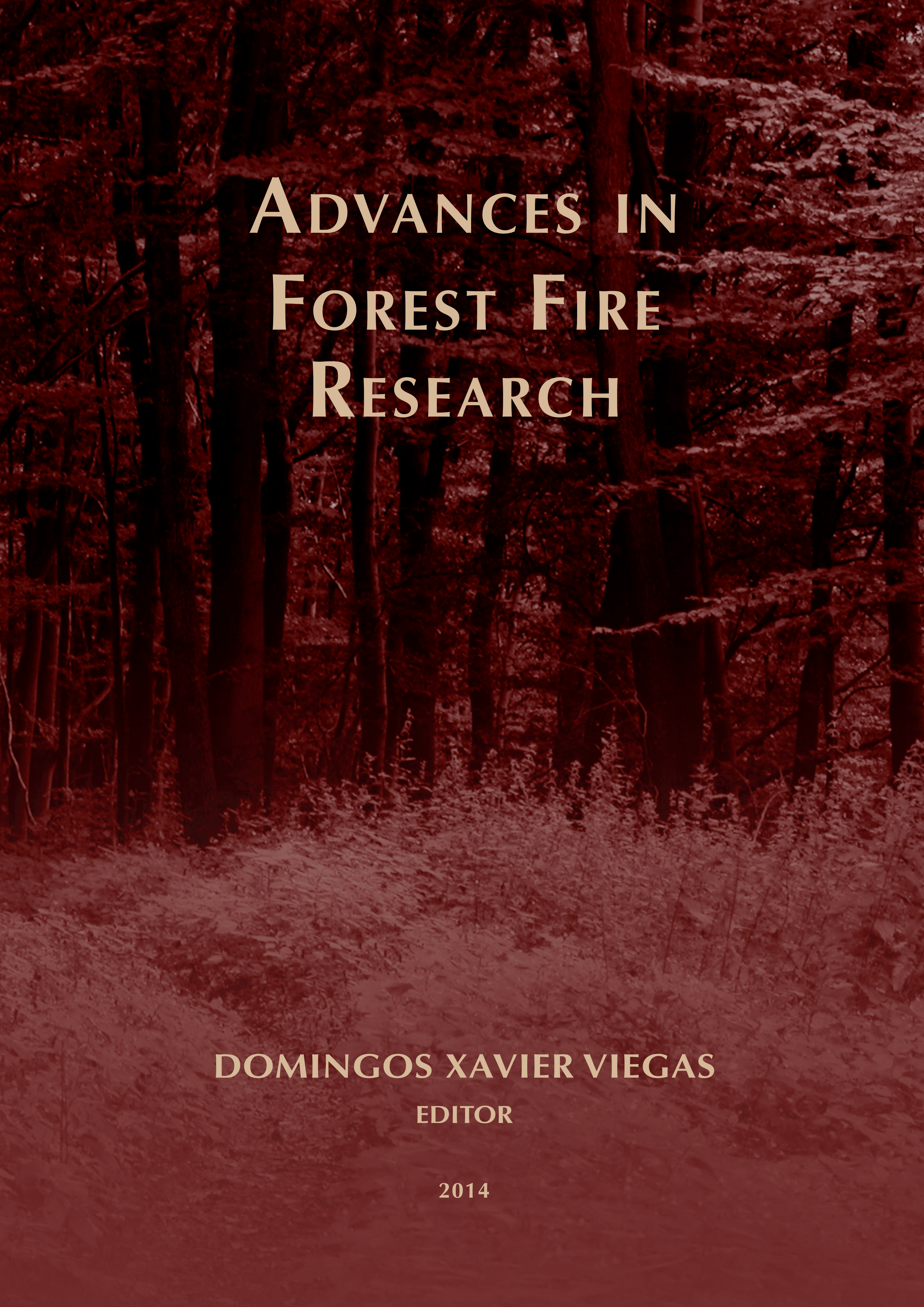

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High resolution spatial and temporal variability of fine dead fuel moisture content in complex terrain

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Abstract

The moisture content of fine dead fuel plays an important role in forest fire behaviour, affecting the probability of ignition at the fire front, the probability of night-time extinguishment, and the availability of the depth of fine fuel for burning. A recent review of dead fuel moisture research by Matthews (2014) concluded that one of the key research and modeling needs is the capacity to represent the complexity of vegetation structure and topography and forecast fuel moisture content across the landscape. Fine fuel moisture content varies at a range of spatial scales due to many factors, however in complex, steep and dissected landscapes, topographic aspect can play a significant role in small-scale (ie. scales in the order of 10's ha) variability.

Experimental sites for monitoring microclimate variables and moisture content in litter and in near-surface soils were established at a control site and on four contrasting aspects (north, south, east and west) in southeast Australia. At each of the four microclimate sites sensors are arranged to measure the soil moisture (2 replicates), fine dead surface fuel moisture at 2.5cm depth (12 replicates), precipitation throughfall (3 replicates), radiation (3 replicates), and screen level relative humidity, air temperature, leaf wetness, and wind speed (1 replicate of each). Temperature and relative humidity are also measured within the dead fine surface fuel using Ibutton's (4 replicates).

All measurements are logged continuously at 15 min intervals. The moisture content of the fine dead surface fuel is estimated using high-replication of low-cost continuous soil moisture sensors placed at the centre of a 5cm deep sample of fine dead surface fuel, referred to here as "dead fine fuel packs" . The dead fine fuel packs were constructed from fuels collected from the area surrounding the microclimate site. The initial results show the moisture regime on the forest floor was highly sensitive to the incoming shortwave radiation, which was up to 6 times higher in the north-facing (equatorial) slopes due to slope orientation and the sparse vegetation compared to vegetation on the south-facing (polar facing) slopes. Differences in shortwave radiation resulted in peak temperatures within the litter that were up to 2 times higher on the equatorial-facing site than those on the polar-facing site. For instance, on a day in November 2013 with maximum open air temperature of 35o C, the temperatures within the litter layer at the north-facing and south-facing sites were 54o C and 32o C, respectively, despite air temperature at the two sites differing by less than 2o C. The minimum gravimetric water content in the litter layer on the same day was 21% on the equatorial-facing slope and 85% on the polar-facing slope. The experimental data is being used to calibrate and test models of fuel moisture spatial variability against an independently collected gravimetric fuel moisture dataset.

***Keywords**: aspect, litter, wildfire,*

1. Introduction

The moisture content of fine dead fuel plays an important role in forest fire behaviour, affecting the probability of ignition at the fire front, the probability of night-time extinguishment, and the availability of the depth of fine fuel for burning. A recent review of dead fuel moisture research by Matthews (2014) concluded that one of the key research and modeling needs is the capacity to represent the complexity of vegetation structure and topography and forecast FMC across the landscape.

Fine fuel moisture content varies at a range of spatial scales due to many factors, however in complex, steep and dissected landscapes, slope orientation (aspect and slope) can play a significant role in small-scale (ie. in the order of 10's ha) variability. This is because ddifferent topographic positions are often associated with different soils, soil moisture conditions, and forest structure. Forest canopies create distinct understory micro-climates (Geiger 1995, Lee 1978, Oke 1987, Mc- Caughey *et al*. 1997, Grimmond *et al*. 2000). Below the forest canopy, solar radiation and day-time temperature and wind speed is reduced, while humidity is increased. All these factors affect the dead fine fuel moisture content and therefore spatial patterns of fuel moisture (Sharples 2009).

The relationship between slope orientation, soil, vegetation structure, micro-climate and fine fuel moisture dynamics is poorly understood and has not been sufficiently represented or parameterised in models. This project aims to improve the prediction of short- range variability in dead fine fuel moisture using field measurement of aspect related differences in soil, vegetation and microclimate.

2. Methods

2.1. Topographic micro-climate experimental sites

Experimental sites for monitoring microclimate variables and moisture content in dead fine fuels and in near-surface soils were established in March 2013 on the upper slopes of four contrasting aspects (north, south, east and west) within a 0.5km radius in the Upper Yarra Catchment in Victoria, southeast Australia. Rainfall, ambient air temperature, geology, and drainage position, are similar across the four sites, so measured differences between the experimental sites at the ground level are assumed to be due to aspect-related microclimatic-variability. An additional weather station was established in a nearby open, ridgetop position to quantify precipitation, temperature, relative humidity, windspeed and direction for the area. Measurement from these five sites is ongoing.

2.2. Microclimate instrumentation

At each of the four microclimate sites sensors are arranged to measure the soil moisture (2 replicates), fine dead surface fuel moisture at 2.5cm depth (12 replicates), precipitation throughfall (3 replicates), radiation (3 replicates), and screen level relative humidity, air temperature, leaf wetness, and wind speed (1 replicate of each). Temperature and relative humidity are also measured within the dead fine surface fuel using ibuttons (Hydrochron, DS1923) (4 replicates). All measurements are logged continuously at 15 min intervals. The layout of the sensors at each microclimate site is illustrated in Figure 1.

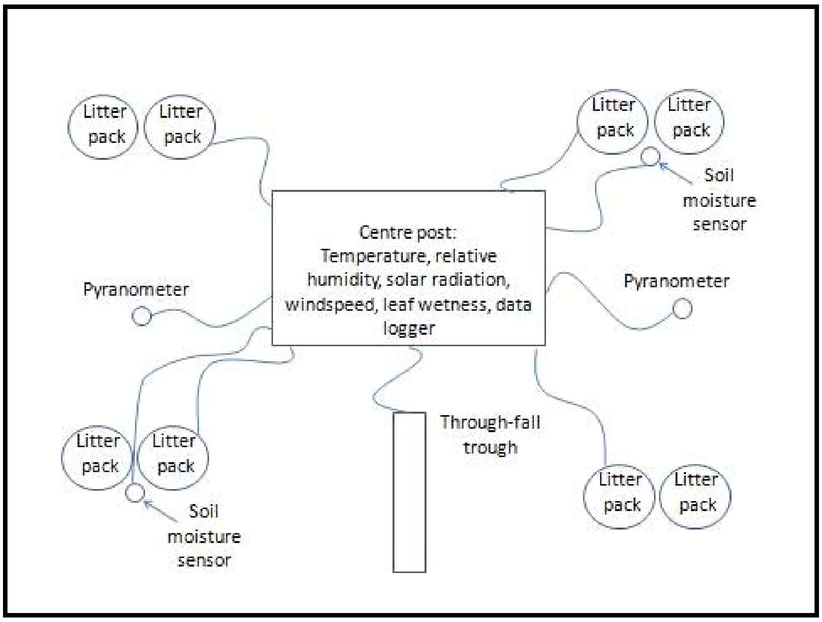

Figure 1 –An illustration of the layout of the instrumentation and sensors at one of the four instrumented microclimate sites.

There have been few attempts to continuously measure fine fuel moisture under field conditions. Here, the moisture content of the fine dead surface fuel is estimated using high replication of low-cost continuous soil moisture sensors (VH400, Vegetronix, Inc., Riverton, USA) (see Figure 2) placed at the centre of a 5cm deep sample of fine dead surface fuel, referred to here as "litter packs".

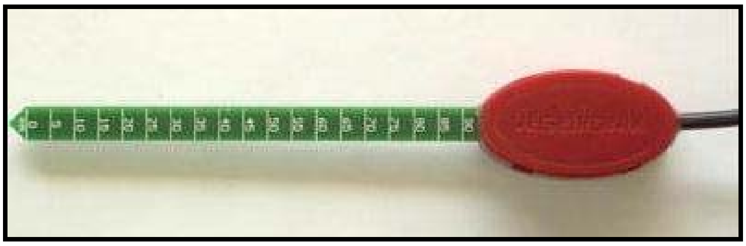

Figure 2. A vegetronix VH400 soil water content probe, used in this study to continuously estimate the gravimetric water content of fine dead surface fuels. (Source: www.vegetronix.com) .

The litter packs were constructed from fuels collected from the area surrounding the microclimate site. Each of the pairs of fuel packs (4 pairs, a total of 8 litter packs at each micro climate site) includes one continuously monitored pack (logged every 10 mins) that contains 3 Vegetronix soil moisture sensors, and one pack that is used to measure fuel moisture content gravimetrically during field visits. The gravimetric litter pack was used to build an empirical relationship between the measured gravimetric fuel moisture content, and the Vegetronix voltage output, under field conditions. This relationship was used to produce a continuous estimate of the fuel moisture content of the dead fine fuel layer. An example of the dead fine fuel packs installed at one of the microclimate sites is shown in Figure 3.

Figure 3. Two of the dead fine surface fuel sample packs used in this study to monitor fuel moisture. The left hand pack is fitted with three Vegetronix VH400 soil water content sensors, recording every 15 minutes. The right hand pack is used for manual gravimetric measurements during field site service visits. (Source: www.vegetronix.com).

The continuous fuel moisture monitoring methods described above were supported by four seasonal field campaigns to quantify dead fine fuel moisture content from 3 additional replicated locations for each aspect, and to measure variability in fine fuel depth, density and spatial arrangement as a function of aspect.

3. Results & Discussion

The first year of data from the microclimate sites is currently being analysed and the sensors calibrated using recently collected summer field campaign data. As a consequence, no detailed results are available at the time of writing this abstract. However, some interesting observations can be noted. The moisture regime on the forest floor was highly sensitive to the incoming shortwave radiation, which was up to 6 times higher in the north-facing (equatorial) slopes due to slope orientation and the sparse vegetation compared to vegetation on the south-facing (polar facing) slopes. Differences in shortwave radiation resulted in peak temperatures within the litter that were up to 2 times higher on the equatorial-facing site than those on the polar-facing site. For instance, on November 2013 with maximum open air temperature of 35° C, the temperatures within the litter layer at the north-facing and south-facing sites were 54° C and 32° C, respectively, despite air temperature at the two sites differing by less than 2° C. The minimum gravimetric water content in the litter layer on the same day was 21% on the equatorial-facing slope and 85% on the polar-facing slope. A full analysis and summary of the experimental data will be available for the conference presentation. The implications for modelling spatial variability in fuel moisture will be discussed.

4. Acknowledgements

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