Soil Hydrological Properties after Wildfire

Using mini-disc infiltrometer to measure infiltration properties in burnt catchments with the aim to predict runoff response and erosion.

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Figure 1. Debris flow across Mt Timboritha Rd near Licola, Victoria, 2007 Photo: Adrian Murphy, Melbourne Water

South-eastern Australia has been affected by several regional wildfires in recent years. The burnt areas (~ 4 million hectares) encompass a range of climates, geologic units and forest types that collectively make up the Great Dividing Ranges of southeast Australia.

While the region is naturally prone to wildfire, the last ten years has seen an increase in wildfire activity due to ten consecutive years of drought with above average temperatures and below average rainfall.

The hydrological and geomorphic response of burned landscapes in the region indicate that dry Eucalypt forest environments in mountainous regions of Victoria are particularly sensitive to post-fire erosion events due to the efficient delivery of runoff and debris from long, steep and often severely burned hill slopes. High magnitude erosion events such as debris flows have been triggered by runoff and sediment entrainment processes on steep hill slopes, causing severe channel erosion and can have significant impacts on downstream water quality, aquatic habitats and infrastructure (eg. Figure 1).

My research project is designed to parameterize and develop a hill slope erosion model that focuses on the processes and conditions that trigger post-fire debris flows and which take into account the temporal changes in the key properties of the system as it recovers from the wildfire disturbance. Some of the key hydrological parameters of the system include water repellency, storage capacity of wettable ash, sorptivity and the saturated hydraulic conductivity of the infiltrating soil surface.

These properties are difficult to measure in the research catchments which are very steep (>30 degrees) and where vehicle access is limited. Rainfall simulations and other measurement techniques such as conventional ring and disc infiltrometers often require heavy equipment and large amount of water and/or are unsuitable for steep sloping terrain.

The mini disc infiltrometer (Decagon™) has proved to be a very useful device for measuring soil infiltration properties in these systems:

1)The small disc diameter means that contact material is unnecessary and level surfaces can easily be located on steep slopes.

2) The device requires small volumes of water which can be carried in a portable water bladder carried as a backpack (Figure 2).

3) Measurements are quick, cheap, and suitable for capturing spatial and temporal variability in infiltration when other methods are too time consuming or resource intensive. The parameters can be represented as probability distributions by obtaining a large number of replicate measurements.

Figure 2. Getting ready to measure infiltration properties in steep and burnt terrain near Sunday Creek, Victoria, 2009

The soils in burned forests are typically characterised by a two layered system: a wettable ash overlying highly water repellent soil. Therefore, when the mini-disc infiltrometer is placed on top of the ash, the measurement is highly influenced by lateral flow through the ash and does not represent the properties of the soil.

The measurements show that the ash results in very high initial sorptivity values (Figure 3). This is followed by a sharp reduction in infiltration rates which often approach zero due to the highly water repellent soil at depth between 2 cm and 5 cm.

Figure 2.1 & 2.2 The Decagon mini disc

A retention ring is pushed through the ash and inserted into the water repellent soil in order to overcome this problem and capture accurate information on the sorptivity and hydraulic conductivity of the ash – soil combination (Figure 2). During the measurement, the infiltrometer is held in place by a clamp attached to a metal rod which is driven into the ground. In this way, one person can operate several infiltrometers simultaneously.

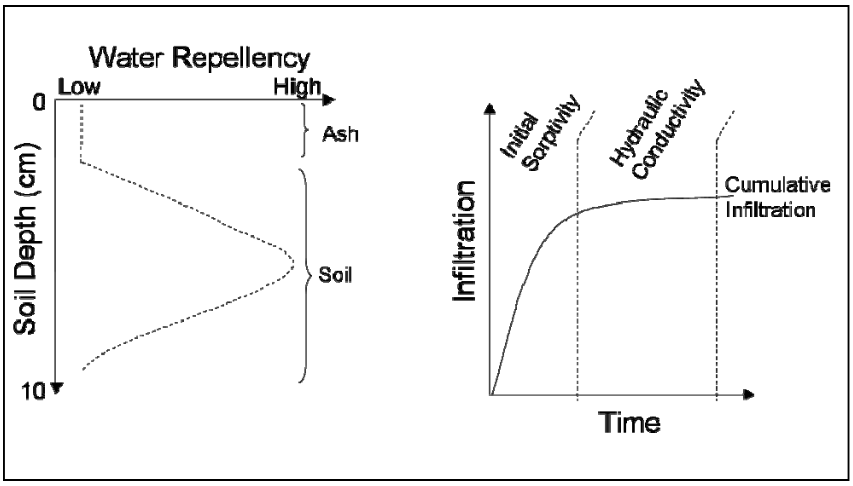

Figure 3. The distribution of water repellency in the upper soil profile results in rapid initial infiltration and very low hydraulic conductivity.

Ponding can result in large changes in infiltration rates when macropores dominate the infiltration process. Each mini-disc infiltrometer measurement was therefore followed by a ponded infiltration measurement using a custom build ponded infiltrometer with similar dimensions as the mini-disc infiltrometer from Decagon (Figure 4).

The infiltration parameters obtained from the mini-disc infiltrometers are coupled with a small set of larger scale rainfall simulations measurements (Figure 5). This is an important step which will test the representativeness of the small scale the measurements obtained using the mini-disc infiltrometer.

The field based measurements outlined here are to be followed up by lab based infiltration experiments on intact cores where initial soil moisture and water repellency can be artificially modified. In this case, the mini-disc infiltrometers will be set up to measure infiltration in a laboratory environment and aimed at untangling the complex interactions between water repellency and initial soil moisture as controls on soil infiltration properties.

Figure 4. Infiltrometers for measuring ponded infiltration rates.

Figure 5. Rainfall simulations can only be carried out in areas with easy access, they are expensive and resource intensive but act as a “reality check” for parameters obtained using the mini-disc infiltrometer.

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