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Development of an Air Permeameter for Monitoring Changes in Hydraulic Conductivity of Surface Soils due to Fire: Measurements Made Following 2003 Aspen Fire in Sabino Canyon, Az

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Background

In the summer of 2003, the Aspen Fire burned 84,750 acres of forest land north of Tucson, Arizona and resulted in the destruction of 333 buildings. The cause and severity were attributed to extreme drought conditions and high fuel loads. The semi-arid Southwest is highly vulnerable to the occurrence of wildfires and improved ability to predict the hydrologic effects of these fires is a critical component of developing effective mitigation strategies.

Prediction of the hydrologic effects of fire requires an understanding of the physical, chemical, and biological changes caused by fire and how these local changes affect the aggregate response of a watershed. Physically, the removal of organic compounds destroys soil structure and results in a disaggregation of soil structure. In addition to a decrease in total porosity and loss of macropores, the most notable physio-chemical effect of fire is the creation of a hydrophobic organic layer which reduces infiltration rates. In the southwest, the lost of vegetation and litter cover makes soils vulnerable to intense monsoon rains. Finally, loss of vegetation results in changes in evapotranspiration and soil moisture status.

As part of a larger project to study the effects of the Aspen Fire on the hydrology of Sabino Creek Basin, a Portable Mini Air Permeameter (PMAP) was developed to rapidly assess the soil air permeability in the field, both in burned and unburned soils. This instrument allows us to study the local effects of fire on soil physical conditions.

Hydrophobic Soil as a result of Fire

Air Permeameters

Air permeameters have been used successfully in agricultural settings to determine the hydraulic conductivity of soils (Blackwell et al., 1990; Iversen et al., 2001). Iverson designed a field air permeameter in which a metal 20 cm diameter cylinder is pressed into the soil. The cylinder is sealed with an inflatable rubber tube and the flowrate and pressure is read from a graduated mounted flowmeter and a water manometer. However, it was difficult to drive the metal cylinders of standard air permeameters into rocky soils typical of the arid Southwest. As a result, PMAP was developed by modifying a standard soil sampler used by soil scientists.

Iverson Permeameter

Rocky soils in Southern Arizona

Research Objectives:

- **Development of "Modified Soil Core Sampler - Air Permeameter" to measure air permeability in situ at small scales and in rocky soils**
- **Determination of air permeability measurements as a function of soil properties, vegetation type, burn severity, and slope for post-burn conditions**

PMAP - Portable Mini Air Permeameter

Cost of Equipment:	
1. Air Permeameter Cap	$ 35
2. Soil Sampler Kit	$ 612
3. Digital Flowmeter	$ 850
4. Digital Manometer	$ 130
5. Air Cylinder	$ 200
Total Cost →	**$1827**

PMAP

2 ¼" OD Soil Core Sampler

Accessories & Air Cylinder

PMAP is an air permeameter which can be applied to any standard 2¼" OD soil core sampler. A soil core sampler kit can be purchased from Soil Moisture Equipment Corp. The main component is the custom-made 3¼" OD air-space cap which consists of air inlet and pressure ports (¼" OD) based on the Iverson air permeameter design. Once the soil core sampler is pounded to a soil depth of 4", the 2" height cap is screwed on and a digital flowmeter and manometer are attached to measure the flowrate and pressure. When taking measurements, pressure is set at a constant value less than 10 cm H_20 and the corresponding flowrate is measured. In this field study, air permeability measurements were measured at 5, 7, and 9 cm of H_20. After the air permeability measurement is taken, a soil sample is extracted for laboratory measurements of gravimetric moisture content and hydraulic conductivity. These laboratory measurements will be correlated to the air permeability measurements. The total cost for all components is $1827.

I. Soil Core Sampler Pounded to a depth of 4"

II. A 2 ¼Soil Core in Soil & PMAP Air-Space Cap

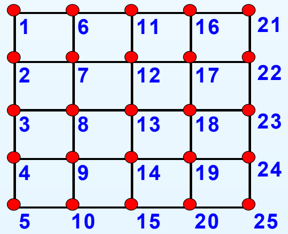
III. PMAP Field Set-Up

Conclusions:

- **Air permeability of soils is significantly reduced after a moderate to high severity burn.**
- **PMAP proved to be a useful field tool to quickly estimate soil permeability for a wide range of soils on varying slopes.**

Field Methods

One of the objectives of our study is to determine the effects of fire on soil properties as a function of vegetation-cover, fire intensity, and soil texture to develop pedotransfer functions to predict the hydrologic effects of fire at point scale. Field measurements of air permeability were collected at 16 sites for burned and unburned chaparral and coniferous forest with varying slopes and burn severities. A 32' x 32' plot was discretized into a 25-point square grid upon which air permeability and moisture content were measured.



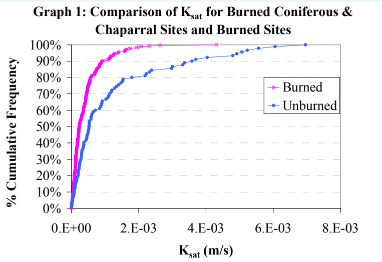
25 point grid

Soil sample at a point

Burned Chaparral Site

Preliminary Results and Ongoing Research

The figure below shows cumulative frequencies for all burned and unburned samples. Preliminary analysis of air permeability measurements indicates a reduction in air permeability following burns as demonstrated by a shift of the curve to the upper left.



Air permeability measurements will be completed for a total of 24 burned and unburned sites. Also, the water permeability of collected soil samples will be measured using Reynolds hydraulic conductivity tank. Finally, the saturated hydraulic conductivity will be correlated to air permeability values and corrected for varying moisture contents. Independently, we will compare laboratory and field measurements of air permeability using Iverson and PMAP permeameters to calibrate the PMAP measurements.

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