P2.15 SEASONAL CHANGES IN SOIL WATER REPELLENCY FOLLOWING WILDFIRE IN CHAPARRAL STEEPLANDS, SOUTHERN CALIFORNIA

Ken R. Hubbert*, Valerie Oriol
USDA, Pacific Southwest Research Station, Riverside, California

1. INTRODUCTION

In southern California, soil water repellency is particularly common in unburned chaparral communities, due in part to the dry Mediterranean climates, shallow, coarse-textured soils, and the high resin content of chaparral plants and chaparral litter (DeBano, 1981). Movement and soil deposition of hydrophobic substances from the litter and plants occur mainly when the fire is burning (Savage, 1974), and also pre-fire as a result of throughfall and leaching during rain events. At present, seasonal changes in water repellency following wildfire are not well understood. It is recognized that the degree and duration of soil water repellency under natural conditions may be strongly influenced by seasonal weather conditions (Dekker et al., 1998). Consequently, the intensity of the hydrologic response is, in part, dependent on time and the soil moisture content.

In late September 2002, the Williams Fire burned 15,426 ha including >90% of the San Dimas Experimental Forest (SDEF). Little is known about the mechanisms and speed by which hydrophilic conditions develop in periods of wet weather, nor hydrophobic conditions in periods of dry weather. The wildfire provided an opportunity to describe changes in soil water repellency over an eleven-month period (Nov 2002 to Sep 2003). Objectives were: (1) to determine the temporal variability of soil water repellency during a one-year period following wildfire, and (2) to look at the effect of precipitation on changes in soil moisture and soil water repellency during the same period.

2. MATERIALS AND METHODS

2.1. *Site description*

The ~3 ha study watershed (#0518) is located within the San Dimas Experimental Forest (SDEF) in the foothills of the San Gabriel Mountains of southern California (34° 12'45" N, 117° 45' 30" W) (Fig. 1). The climate is Mediterranean, with hot, dry summers, and cool, wet winters. Topography is rough with precipitous canyons and steep slopes (Ryan, 1991). Bedrock in the area has been subjected to intense heat and pressure resulting in a high degree of alteration, faulting, folding, and fracturing. As a result, the rocks are poorly consolidated and very unstable, (Sinclair, 1953). Slopes were generally very steep (>55%), shallow and coarse-textured, with rock-fragments throughout (Jones and Graham, 1992). The soils are coarse-loamy, mixed, thermic Typic Xerorthents, characterized by gravelly loamy sand textures in the soil A horizon (Hubbert et al., submitted). The soils are generally loose with low bulk densities.

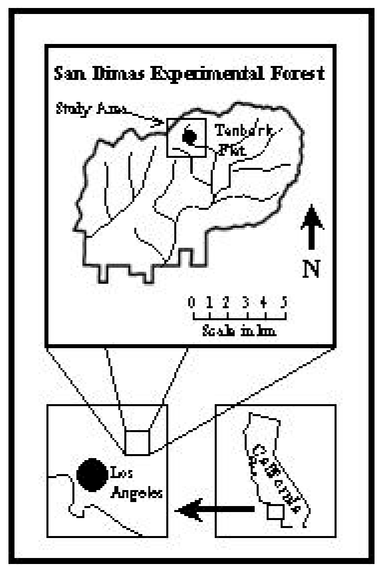

Fig. 1. Map showing general location of the study watershed.

The natural vegetation is chaparral, characterized by sclerophyllous leaves, 1 to 4 m plant height, and dense canopies. Common chaparral species include chamise (*Adenostoma fasciculatum* Hook & Arn.), hoaryleaf ceanothus (*Ceanothus crassifolius* Torr.), sugar bush (*Rhus ovata* S. Watson), Eastwood manzanita (*Arctostaphylos glandulosa* Eastw.), scrub oak

* *Corresponding author address:* Ken R. Hubbert
USDA Forest Service, Pacific Southwest Research Station, Riverside, CA 92507
e-mail khubbert@fs.fed.us

(*Quercus berberidifolia* Liebm.), black sage (*Salvia mellifera* E. Greene), and wild buckwheat (*Eriogonum fasciculatum* Benth.). The stand age of the chaparral was 42 years, with the watershed last burning during the 1960 Johnstone Fire that consumed 88% of the 6947 ha forest.

Following the Williams Fire (Fig. 2), the Burned Area Emergency Rehabilitation (BAER) team reported low burn severity of 3,322 ha, moderate burn severity as 6,015 ha, and high burn severity of 1,982 ha, with a total area of 11,347 ha (total Williams Fire = 15,426 ha) considered water repellent (Napier, 2002).

Fig. 2. View of the SDEF after the Williams Fire. Photo taken in October 2003.

2.2. *Field measurements and analysis*

We randomly chose four transects that crossed the watershed in a chevron pattern. Sampling sites along the transects were unevenly spaced at 0, 1, 2, 4, 8, 16, 32, and 50 m. At each sampling point, post-fire soil water repellency was sampled using the water drop penetration time (WDPT) method. Sampling was done at two to three-week intervals for eleven months following the fire. Twenty measurements were taken at the mineral soil surface within an area 15 x 15 cm. Another 20 measurements were taken at 2 cm depth and 10 measurements at the 4 cm depth. A squeeze bottle with attached dropper was used to place the water drops. The time of water drop penetration was determined when the droplet no longer existed on the surface in a spherical state, but had flattened and infiltrated. We have modified existing soil water repellency indexes to give us the following classification scheme: 0-1 s - not repellent, 1-5 s very low repellency, 5-30 s - low repellency, 30-180 s – moderate repellency, and >180 s - extreme repellency. This classification scheme is in agreement with Robichaud (1996), except that the time for “no repellency” is 0-1 s instead of 0-5 s.

Precipitation data was obtained from the RAWS (National Interagency Remote Automated Weather Stations) Tanbark Station located within the SDEF. Gravimetric water measurements were made gravimetrically after oven-drying (Gardner, 1986).

3. RESULTS AND DISCUSSION

In measurements conducted prior to the wildfire in a similar and adjacent watershed, 41% of the 1.28 ha watershed soil surface exhibited “very low to no repellency”, 22% “low repellency”, and 37% “moderate to extreme repellency” (Hubbert et al., submitted). Two weeks following the end of the wildfire, surface soils exhibited 25% “very low to no repellency”, 26% “low repellency”, and 49% “moderate to high repellency” (Fig. 3). The initial 12% increase in repellency at the soil surface resulted from hydrophobic organic substances moving from the burning litter and plant material into the soil (DeBano, 1981).

Following the 3-d rain event (11/8 to 11/10) of ~125 mm, “moderate to extreme repellency” decreased from 49 to 35%. Continued rain events through December amounting to ~81 mm further reduced “moderate to extreme repellency” from 35 to 4%, and increased “very low to no repellency” from 25 to 91% (Fig. 3). Robichaud (1996) noted a decrease in hydrophobicity as the soil profile became wet, and no water repellency after the third rain event, but it is still unclear at what critical soil moisture water repellency disappears in soils (Dekker and Ritsema, 2000). During and following the winter and spring rain events, “very low to no repellency” remained above 70%, only dropping to 58% on 5/2/2003. On two occasions (3/17 and 4/16), “moderate to high repellency” dropped to 0% when the sampling date immediately followed a rain event.

During drying periods, “moderate to high repellency” returned to less than half the pre-rain amount of 38% in the surface soil for all dates

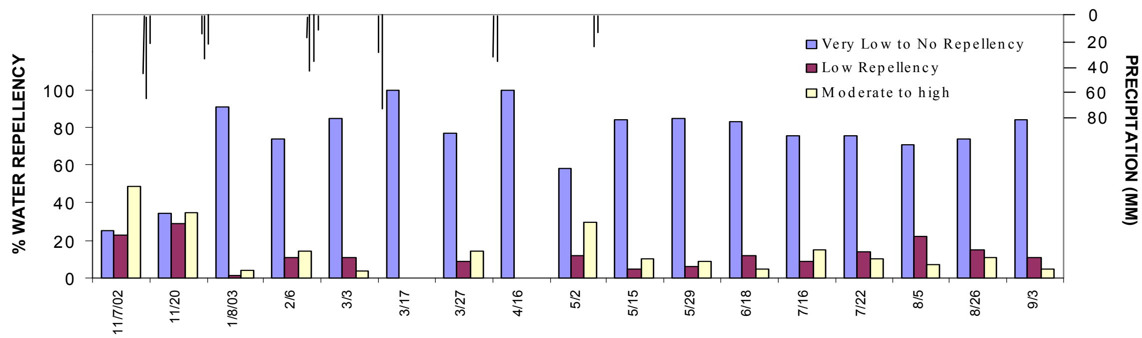

Fig. 3. Temporal variability of soil water repellency at the 0-2 cm depth in relation to precipitation during an eleven-month period following wildfire.

except 5/2/2002 (Fig. 3). And contrary to expectations, soil water repellency at the soil surface did not return during the long, summer dry season, even at very low soil moisture contents (Fig. 4). After long dry periods, Shakesby et al., (2000) reported that soils are highly non-wettable. Doerr et al. (2000) stated that little is known on breakdown of water repellency and its re-establishment in soils.

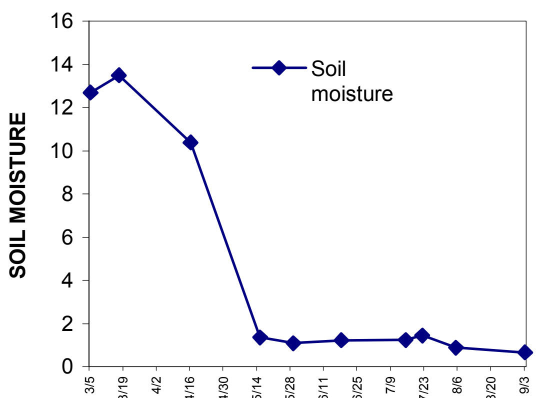

Fig. 4. Seasonal changes in soil moisture at the 0-2 cm depth during the time-period 3/5/2003 to 9/3/2003

Although not shown, water repellency during drying periods was more pronounced at the 2 and 4 cm depths, returning to levels greater than one-half pre-rain amounts. The increase in water repellency with depth was due in part to downward translocation of volatized organics during the fire and re-condensation at depth. In addition, long consistent wet periods may have leached hydrophobic substances from the soil surface into the 2 and 4 cm depths (Crockford et al., 1991).

Explanations for the lower values of "moderate to extreme repellency" during the summer dry period at the soil surface include 1) a lack of new chaparral litter and plant cover that would provide hydrophobic organic compounds, 2) the movement of the highly unstable surface soils located on very steep slopes (>55%), and 3) root growth and microfauna activity. The return of water repellency to pre-fire levels may depend on increases in litter and plant cover during the recovery of the chaparral, which would provide a source of hydrophobic substances and result in greater soil stabilization. It appeared that the initial non-chaparral species that followed the fire did not contribute to surface water repellency.

Another factor affecting soil water repellency in the surface soil was the redistribution of ash into the soil. Ash deposited on the surface following fire immediately becomes buried to ~2 cm depths as a result of movement of ravel material and soil creep. In some areas, we observed ash buried to depths of 10 cm only two months after the fire. Ash is highly wettable, and where buried it can decrease water repellency.

In many cases, areas of "moderate to extreme repellency" were associated with remnant fungal mat pieces. The wildfire resulted in the drying and weakening of the fungal mat structure, allowing it to break apart and move with the unstable soils. All of the areas with fungal mat material exhibited "moderate to extreme repellency". Savage et al. (1969) suggested that common fungal products contribute to water repellency, especially after heating.

Under field conditions, hydrophobic soils typically alternate seasonally or over shorter intervals between repellent and wettable states in response to rainfall and temperature patterns (Shakesby et al., 2000). Because erosional process may occur for a number of years following wildfire, it is important for land managers to understand the dynamic nature of soil water repellency in relation to time and weather events.

5. REFERENCES

Crockford, S., Topadilis, S., Richardson, D.P. 1991. Water repellency in a dry slerophyll forest: Measurements and processes. Hydrol. Proc. 5:405-420.

DeBano, L.F. 1981. Water repellent soils: a state-of-the-art. USDA Forest Service General Technical Report PSW-46, Pacific Southwest Forest and Range Experiment Station, Berkeley, CA.

Dekker, L.W., Ritsema, C.J., Oostindie, K., Boersma, O.H. 1998. Effect of drying temperature on the severity of soil water repellency. Soil Sci. 163:780-796.

Dekker, L.W., Ritsema, C.J. 2000. Wetting patterns and moisture variability in water repellent Dutch soils. J. Hydrology 231-232:148-164.

Doerr, S.H., Thomas, A.D. 2000. The role of soil moisture in controlling water repellency: New evidence from forest soils in Portugal. J. Hydrology 231-232:134-147.

Gardner, W.H. 1986. Water content. p.493-544. *In* A. Klute (ed.) Methods of soil analysis. Part 1, 2nd ed. Agron. Monogr. 9. ASA and SSSA, Madison, WI.

Hubbert, K.R., Wohlgemuth, P.M., Graham, R.C., Narog, M. Prescribed burning effects on soil physical properties and dry season erosion in a steep chaparral watershed, southern California, U.S.A. Geoderma (submitted).

Hubbert, K.R. Wohlgemuth, P.M., Preisler, H. Spatial distribution of soil water repellency in a mixed chaparral watershed pre- and post-fire. Geoderma (submitted).

Huffman, E.L, MacDonald, L.H., Stednick, J.D. 2001. Strength and persistence of fire-induced soil hydrophobicity under ponderosa and lodgepole pine, Colorado Front Range. Hydrol. Proc.. 15:2877-2892.

Jones, D.P., and Graham, R.C. 1993. Water-holding characteristics of weathered granitic rock in chaparral and forest ecosystems. Soil Sci. Soc. Am. J. 57:256-261.

McNabb, D.H., Gawed, A.F., Froehlich, H.A. 1989. Infiltration, water repellency, and soil moisture content after broadcast burning a forest site in southwest Oregon. J. Soil Water Conserv. 44:87-90.

Napier, C. Williams Fire Burned-Area Report- FS-2500-8, USDA Forest Service FSH 2509-13. October 10, 2002.

Robichaud, P.R.. 1996. Spatially-varied erosion potential from harvested hillslopes after prescribed fire in the interior Northwest. Ph.D. Dissertation, University of Idaho, Moscow, ID.

Ryan, T.M. 1991. Soil survey of Angeles National Forest area, California. USDA Forest Service, Pacific Southwest Research Station, San Francisco, CA.

Savage, S.M. Martin, J.P., Letey, J. 1969. Contribution of some soil fungi to natural and heat-induced water repellency in sand. Soil Sci. Soc. Amer. Proc. 33:405-409.

Savage, S.M. 1974. Mechanism of fir-induced water repellency in soil. Soil Sci. Soc. Am. Proc. 38:652-657.

Shakesby, A., Doerr, S.H., Walsh, R.P.D. 2000. The erosional impact of soil hydrophobicity: Current problems and future research directions. J. Hydrol. 231-232:178-191.

Sinclair, J.D. 1953. Erosion in the San Gabriel Mountains of California. Eos, Transactions, American Geopysical Union 35:264-268.