Soil Hydraulic Characteristics of a Small Southwest Oregon Watershed Following High-Intensity Wildfires[1]

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Abstract: The Angel Fire of September, 1987 caused extensive damage to second growth forest in the south fork drainage of Cow Creek, 55 km northeast of Grant's Pass, Oregon, USA. The fire was characterized by a high-intensity burn over areas of steep topography. The areal distribution of soil hydraulic properties in a small, tributary watershed following high-intensity wildfire is examined using tests of infiltration capacity, saturated hydraulic conductivity, and soil moisture characteristics. Also, measures of soil water-repellency are determined. Soil hydraulic properties are evaluated for logged and forested slopes up to 30 degrees. Results indicate a relatively small effect of high-intensity wildfire on the generation of water-repellent soils and the hydrologic response of this watershed.

This study characterized the soil hydraulic properties of a small watershed in southwest Oregon that experienced high intensity wildfire. Of particular interest is the degree to which the wildfire produced water-repellent soils.

STUDY SITE

The study site (fig. 1) is in southwest Oregon, 55 km northeast of Grant's Pass. It consists of a 1.3 km^2, first and second-order drainage on the south fork of Cow Creek. The site ranges in elevation between 975 and 1340 m with maximum slope angles approaching 30 degrees.

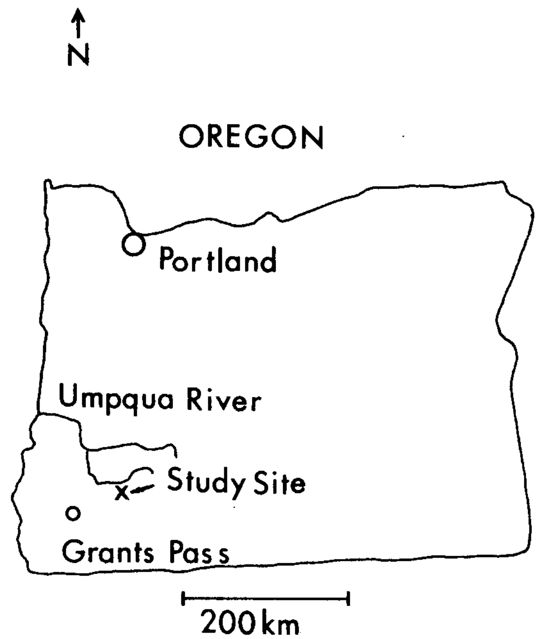

Figure 1--Study Site Location

Vegetation within the study area is Douglas fir and mixed pine forest with an understory of grasses, ferns, forbs, and shrubs. Vegetation on the study site has been largely removed by road building, logging, and wildfire.

Soils in the study basin can generally be described as stony clay-loam, derived from moderately competent serpentine bedrock. In forested areas, the soil is covered with an organic litterlayer of 1.5 to 7.5 cm.

SAMPLING PLAN

Soil samples were taken from four areas (Fig. 2), consisting of a forested erosion pin plot, a logged erosion pin plot, an undisturbed forested control area and an area of mixed landcover types. All sites except the control site were burned by wildfire in September 1987; fieldwork was conducted February 25-28, 1988.

Field inspection of the soils showed no obvious hydrophobic layer; accordingly, sampling was confined to the upper 10 cm of the soil profile.

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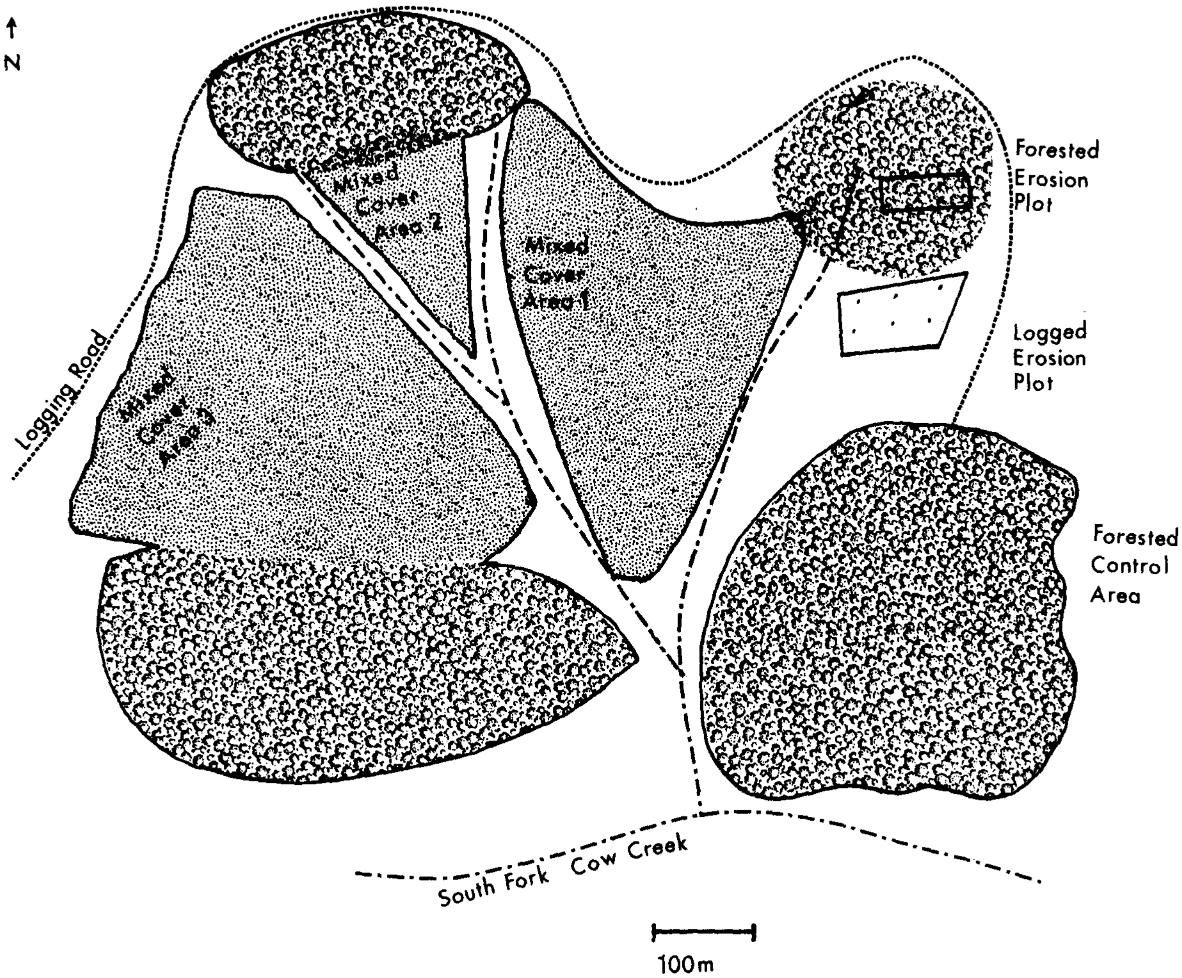

Figure 2--Study basin diagram showing sampling areas.

The two erosion pin plots were sampled on their perimeter at 10-m intervals. The control site was randomly sampled, as was the mixed landcover area.

The soil sampling procedure used a gravity soil corer that retrieves a soil cylinder of 68.7 cm^3 (5.4 cm diameter x 3 cm height). Infiltrometer measurements were limited to the two erosion pin plots.

METHODS OF ANALYSIS

Field Measurements

Infiltration capacity was measured using a single-ring ponding infiltrometer (Hills 1970). The ring was 10.2 cm in diameter and a constant head of 1.27 cm of water was used. Field data consist of time (t) versus cumulative infiltration (F) in cm.

Laboratory Measurements

Parameters measured by laboratory experiment included bulk density, saturated water content, saturated hydraulic conductivity, water drop penetration, and soil moisture-capillary pressure changes.

Bulk density (gm/cm^3) was determined by drying the cores at 105° C for 24 hours and weighing. Bulk soil volume of the samples was 68.7 cm^3.

Saturated water content was determined by saturating the soil cores with water for 24 hours. The cores were then removed from the water, allowed to drain for 30 minutes, and weighed. Moisture contents are reported as volume of water per bulk volume of soil.

Saturated hydraulic conductivity (cm/hr) was determined using a constant head device with 3 cm of water depth.

The desorption soil moisture-capillary pressure curves were determined with a pressure plate. Soil water content at 0, 0.1, 0.2, 0.3, 0.5, 1, 3, 10 and 15 bars were determined by progressively weighing and drying the cores. Data (fig.3) are reported as volume of water per volume of bulk soil versus pressure.

Water drop penetration is a test of the water repellency of soils. Letey (1968) describes the test, which consists of applying a small quantity of water to the soil and measuring the time until the water is absorbed. We conducted the test using oven-dried soils and applying 1 cm^3 of water. Absorption times are reported in seconds.

RESULTS AND CONCLUSIONS

Results of the laboratory analyses are shown in table 1. Values for all areas and transects sampled were compared statistically to those from the control plot, using a two-sample t-test for means and an F-test for variances (Snedecor and Cochran 1967). As can be seen from table 1, there are few statistically significant differences. The majority of the significant differences are in variances and seem to reflect an overall homogenization of burned sites compared to the unburned control; in nearly all cases the variance of properties measured in the burned sites was less than that measured on the control.

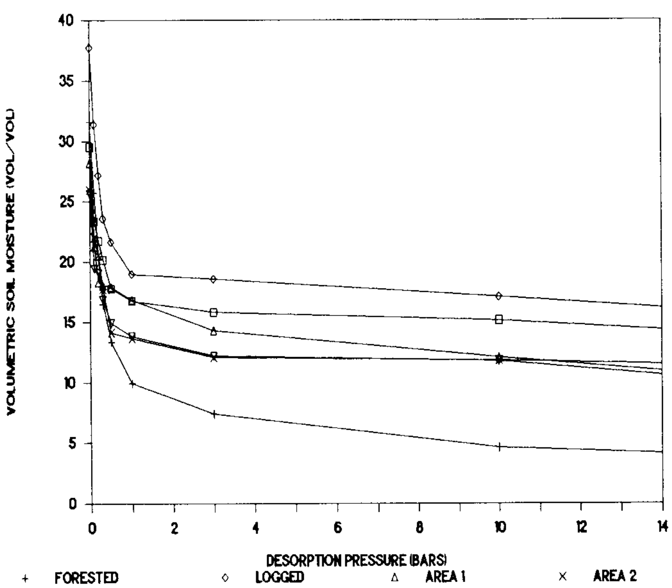

Figure 3-- Median capillary pressure changes by location

Control Area

Saturated hydraulic conductivities measured in this area are the highest measured in the study basin with a mean of 78.9 cm/hr. These data also point out the extreme variation characteristic of this property; the coefficent of variation is near unity.

Bulk density values for the control area are the highest measured in the basin with an average of 1.04 gm/cm^3, though only slightly larger than the other areas sampled. Saturated water contents for the control area had a mean value of 41.4, near the middle of the values for the other areas, and a standard deviation of 8.65, the second highest value overall.

Soil water-capillary pressure curve data measured for the control area show a relatively strong ability of the soil to hold water under tension, and may be a result of the high clay content of the soil underlying the surface organic layer in this area. Statistics of water drop penetration times for the control area are found in table 1. While these values are not high when compared to those for extremely water-repellent soils, they do indicate a moderate degree of water repellency (DeBano 1981).
The infiltration capacity of the control area exceeds rainfall intensities and should yield little surface runoff.

Surface erosion on the control area should be minimal and most likely be a result of windthrow and resulting soil disturbance. Landsliding may contribute sediment to streams if the subsurface flow of water is sufficient to cause saturation of the soil mass.

<u>Forested Erosion Plot</u>

Results of the field infiltration tests are given in table 1. The infiltration rates are generally quite high (150+ cm/hr for the short times tested) and quite variable between runs (infiltration capacities at different points for the same time vary by a factor of 2 to 5). Excavation around the infiltrometers following the test showed the flow from the infiltrometer was largely downhill and occurred above a clayey horizon found at an approximated depth of 3 to 9 cm.

Hydraulic conductivity is high and extremely variable (nearly two orders of magnitude); this is consistent with the ring infiltration measurements made on the site and the hydraulic conductivities from the control site. While the hydraulic conductivities are approximately one-third less on this plot than the control plot, they are not statistically different than

Table 1--Summary statistics by sample location

Sample sites	[1]N	[2]Ks	[3]Bd	[4]SWC	[5]IR	[6]WDPT
		cm/hr	gm/cm^3	pct.vol	cm/hr	sec
Control	10	[7]78.9	1.04	41.4	N.A.	164
		[8]78.8	.177	8.65	N.A.	290
Forested	26	55.2	.921*	50.0*	209	2
		45.5*	.137*	6.90	166	.385*
Logged	25	33.7	1.03	51.1*	205	80
		34.3*	.102*	9.21	126	180
Area #1	15	37.7	.925	36.6	N.A.	300
		23.4*	.074*	8.27	N.A.	953*
Area #2	7	34.1	1.03	35.3	N.A.	7
		16.0*	.030*	4.66	N.A.	12*
Area #3	9	31.4	1.02	34.0	N.A.	405
		11.8*	.027*	7.00	N.A.	1200*

[1]Number of samples measured
[2]Saturated Hydraulic Conductivity
[3]Bulk Density
[4]Saturated Water Content
[5]Infiltration Rate
[6]Water Drop Penetration Time
[7]Sample Average,
[8]Standard Deviation
* = indicates significant difference than control value at alpha = 0.05

the control plot, and still larger than rainfall intensities.

Bulk densities are low, and saturated moisture contents are high, reflecting the open structure typical of forest soils. The saturated moisture content values are significantly different from the control plot values.

Statistics of water drop penetration are shown in table 1. Penetration times are nearly instantaneous, indicating the absence of water repellency.

The results above indicate that the runoff processes on the forested plot will probably not be significantly altered by the fire. Infiltration capacities and hydraulic conductivities are high, leading to the conclusion that the system is dominated by subsurface flow; this is typical of forested sites and identical to the conclusion for the control site. Overland flow, if it occurs, would be by saturation of the soil.

Erosion on this plot should occur as some surface wash and shallow piping if saturation overland flow occurs. Since this plot still had significant organic cover we expect raindrop splash and surface sealing to be unimportant.

<u>Loaned Erosion Plot</u>

Results of the field infiltration tests for the logged erosion plot (table 1) are almost identical to the results for the forested plot discussed above, indicating that little surface runoff is to be expected.

Saturated hydraulic conductivities measured on the logged plot (table 1) are lower than the control plot, though not statistically significant. While these conductivities are well above expected rainfall intensities, they possibly indicate an effect of log skidding. Bulk density of the logged plot falls between the forested plot and the control area. Saturated water contents for the logged plot are significantly higher than the control plot.

Soil moisture-capillary pressure curve data for the logged plot show the highest water retention of all areas. This may be a result of the surface disturbance by log skidding and the exposure of the clayey subsoil.

Water drop penetration times for the logged erosion plot are higher than the forested erosion plot but lower than the control area. According to DeBano (1981) this soil would be classified as moderately water repellent, like that of the control area.

Results obtained for the logged erosion plot indicate that this area has been moderately affected by logging and fire. The expected runoff response of this plot is likely to be subsurface although some surface runoff may occur where the clayey subsoil is exposed. No organic horizon is found in this area, and erosion from raindrop splash is expected. This may in turn cause surface sealing and further surface runoff.

Area Transects

The soils data for the three transects are very similar to those for the other plots; as part of the overall logged and burned area they exhibit mean saturated hydraulic conductivity values nearly identical to those for the logged erosion pin plot.

The saturated water contents are the lowest reported. The water penetration time data show significant variation both within and between transects. The within-transect variation might be explained by the disturbance associated with logging and the removal and redistribution of organic matter. The between-area variation may reflect the differences in fire intensity over the watershed. For example, area 2, which has the smallest penetration times, appears to have been only lightly burned. Area 1 appeared in the field to have been heavily burned. Area 3 appeared to have areas of both heavy and light burning.

Again using the classification scheme of DeBano (1981), soils in areas 1 and 3 would be considered moderately water repellent, while those in area 2 would be considered slightly repellent.

The results above indicate that soils in areas 1 and 3 are somewhat water repellent. This condition, with the removal of surface organic matter, may lead to some Horton overland flow in response to high-intensity storms falling on dry soils. The hydraulic conductivities are still high compared to rainfall rates, indicating that when the soils are wet, subsurface flow paths will dominate.

Erosion on the area areas will likely be a mix of raindrop splash and sheetwash during the summer. Landsliding may still be important during winter on steeper parts of the watershed.

SUMMARY

A study of soil hydraulic properties was conducted on a small watershed in southwest Oregon to evaluate the effects of wildfire on hydrologic response and erosion.

Results of the analyses indicate a small effect of high intensity fire in causing some moderately water repellent soils over some areas of the watershed. This effect will most likely be seen as some sheetwash during summer periods of high intensity rain on dry soils. Runoff response during wet periods will likely be dominated by subsurface flow paths.

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REFERENCES

DeBano, L.F. 1968. Water Movement in Water Repellant Soils. In: Water Repellent Soils, Proceedings of the Symposium on Water Repellent Soils. May 6-10, 1968, University of California, Riverside.

DeBano, L.F. 1981. Water Repellent Soils: A State of the Art. Gen. Tech. Rep. PSW-46, Pacific Southwest Forest and Range Experimental Station., Forest Service, U.S. Department of Agriculture, Berkeley, Ca.

Hills, Rodney C. 1970. The Determination of the Infiltration Capacity of Field Soils Using the Cylinder Infiltrometer. British Geomorphological Research Group Technical Bulletin 3.

Letey, J. 1968. Measurement of the Contact Angle, Waterdrop Penetration Time, and Critical Surface Tension. In: Water Repellent Soils, Proceedings of the Symposium on Water Repellent Soils. May 6-10, 1968, University of California, Riverside.

Snedecor, George W. and Cochran, William G. 1967. Statistical Methods. Iowa State University Press, Ames, Iowa.