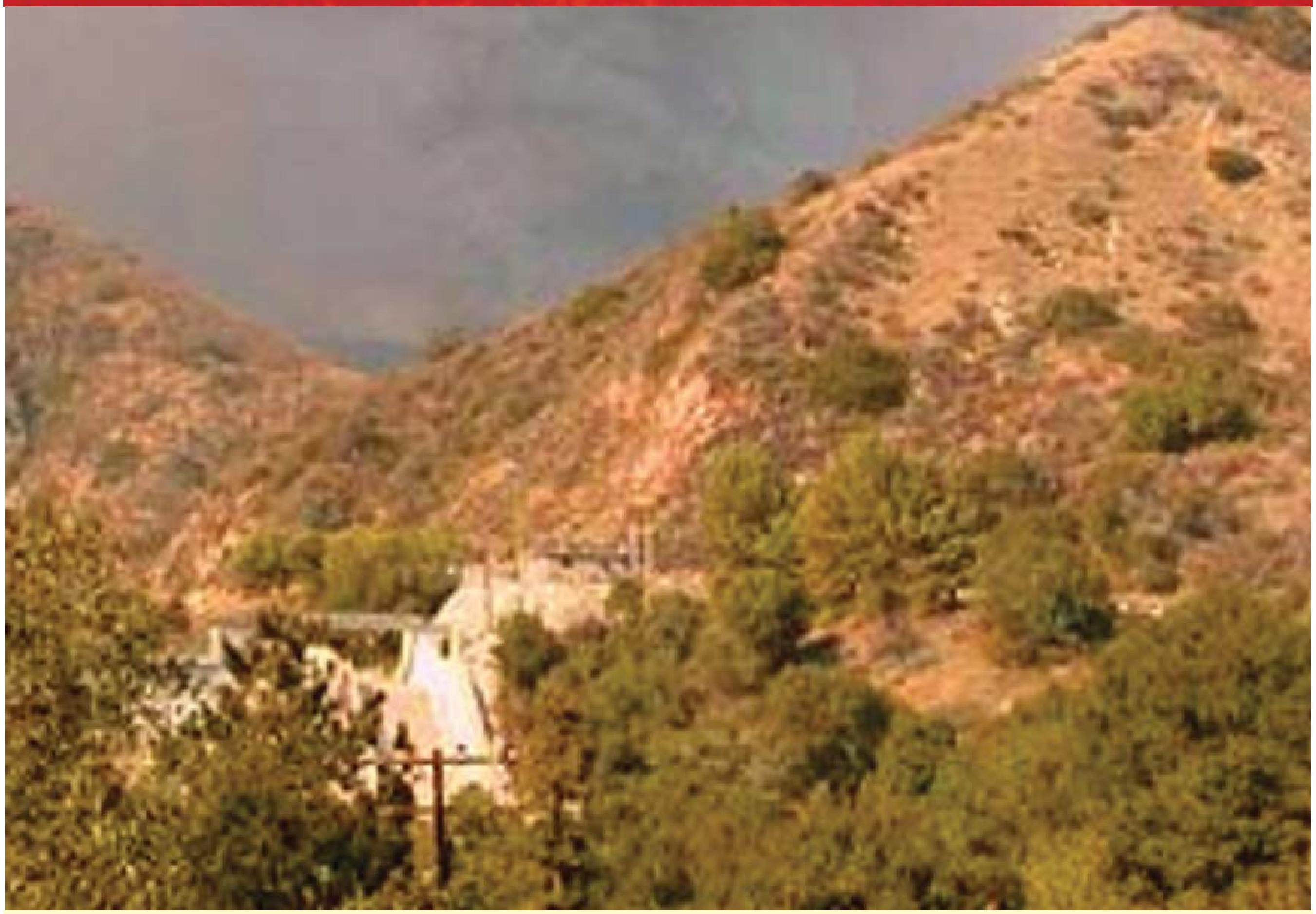
Joint Fire Science Program

Fire Science Brief

RESEARCH SUPPORTING SOUND DECISIONS



The 2002 Williams Fire burned through native chaparral and grass-converted watersheds in the San Dimas Experimental Forest. Credit: Rich Hawkins.

The Good Earth: Run-off, Erosion, and Recovery in the Post-fire Chaparral Steeplands of Southern California

Summary

In September 2002, the Williams Fire burned 38,184 acres of chaparral steeplands, including more than 90 percent of the San Dimas Experimental Forest. The 1960 Johnstone Fire had burned many of the same watersheds some forty years earlier, thus providing opportunities to compare post-fire watershed response coupled with management efforts that had converted some native chaparral areas to grassland. With scant studies on soil water repellency, plant recovery, and their effects on watershed hydrology, managers face difficulties in planning for erosion/run-off problems. The researchers delivered quantified data on changing soil properties, the character and structure of regenerating plants, and the factors that produced sediment movement and run-off in the post-fire landscape.

Key Findings

- Soils commonly repel water in unburned chaparral due to hydrophobic compounds leaching from the plants—the amount and duration of repellency increasing in dry soils, and decreasing after rain.
- After wildfire, soil water repellency declines with time, with no difference between areas converted to grassland and native chaparral areas.
- Following the Williams Fire, herbaceous plants known as “fire followers” dominated the vegetation, with fewer plant species and more bare ground occurring in grass converted areas than in native chaparral areas which have greater diversity and more robust regrowth.
- Sediment yield was high during the first winter after fire, negligible in the second year, and minor during the third year despite record rains.

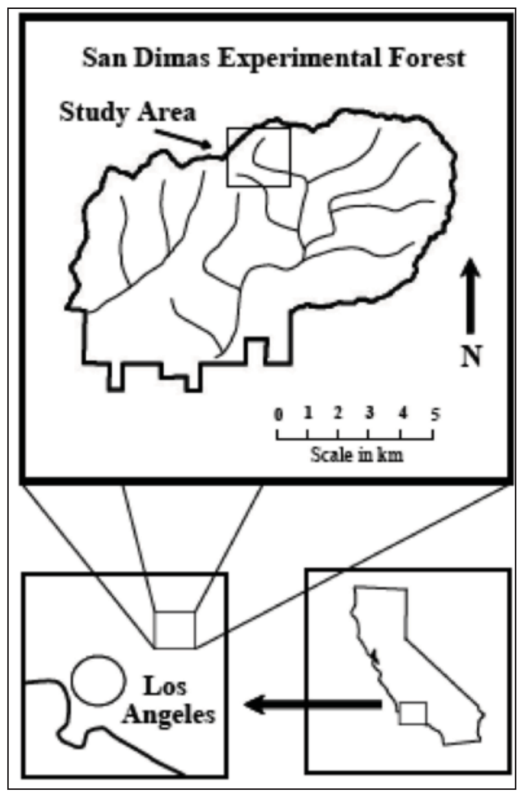
Introduction

Dirt. It’s what we’re made of. So says a creation story of the Oneida Indian nation. Their Good Spirit used it to fashion humanity. So did the ancient Chinese goddess Nuwa. And the creator in the Judeo-Christian and Islamic faiths. A compelling force in the psyche of humankind keeps producing this archetype. In the English language, the name for our planet is synonymous with soil, and land, rather than with water, though water covers the majority of its surface. Out of earth are we. While the primacy of soil is buried in our consciousness, often we know too little about it. What happens to earth—dirt—land when it is hit with a major disturbance such as fire? What changes do the characteristics of soil undergo after burning? What happens as water passes through, or over it? And what of the plants that grow in that post-fire medium?

Three questions, two fires, one experimental forest

Wildfire, then rains that lead to water racing down scorched soils, carrying sediments, and the scouring blasts of Santa Ana winds blowing across the southland toward the Pacific are a part of the infamous fire/erosion cycle that garners so much attention in the news. At times like these, it seems the entire geography of southern California is at risk of destruction on an epic scale. The concern, of course, is the consequence to lives, property, and developments, in a place where it is no revelation that the wildland-urban edge continues to grow in this country’s most populous state.

In California, as is the case elsewhere in the nation, and around the world, developments are often sited for aesthetic values, though a look at topography with a land navigator’s eye reveals floodplains, sloping drainages, collecting basins, or eroding cliffs. The problems for land managers who try to develop effective plans that cater to a multiplicity of concerns and goals are often made more complex by a lack of detailed information on natural processes affecting the lands under their stewardship. Without having solid numbers to work with, managers have difficulty predicting how much water and sediment will be generated from a burned chaparral-covered area compared to one that has been converted, by disturbance and prior management efforts, to grassland, for example. Pete Wohlgemuth, hydrologist with the Pacific Southwest Research Station, and team members including Marcia Narog, an ecologist with the Pacific Southwest Research Station; Jane Beyers, a plant ecologist with the Pacific Southwest Research Station; and Ken Hubbert, a Forest Service wildland soil scientist believe quantifying the moisture-carrying capacity and repellency of soils after a wildfire, determining the character of regenerating plant communities and their roles in affecting the water cycle, and knowing the amount of sediment produced are critical components to understand, and plan for run-off and erosion in the post-fire landscape.



Study data yielded critical information for developing post-fire management plans in southern California.

The San Dimas Experimental Forest is part of the Forest Service and is managed cooperatively by the Pacific Southwest Research Station and the Angeles National Forest. The San Dimas Experimental Forest sits in the foothills of the San Gabriel Mountains, thirty-six miles northeast of Los Angeles. Like much of the Mediterraneantype climate in the area, slopes and basins in the forest scorch in the summer heat, are blasted by the Santa Ana winds, and green up when the winter rains come. Chaparral and coastal sage, with some oak woodlands, make it a forest more of shrubs than of timber. Some areas of formerly native chaparral have converted to grasslands following earlier disturbances—natural and man-made. When the Williams Fire burned 38,184 acres of chaparral steeplands in September of 2002, including more than 90 percent of the San Dimas Experimental Forest, Wohlgemuth and his team had an opportunity to compare the effects of this fire with an earlier fire that in 1960 burned through many of the same watersheds. Looking at this one location and these two fires, the scientists had three questions they wanted to explore: How did soil characteristics after the fire affect the hydrology (water cycle) in these lands? How did regenerating plants respond after the fire? And taken together, how did soils and plants influence run-off and erosion in the watershed?

Soils

Hydrophilic, hydrophobic. Water-loving. Water-fearing. What causes soils to attract or repel water? In the chaparral woodlands of southern California, a number of factors contribute to soil's changeable nature. Weather plays a role—dry soils repel water while rain decreases repellency. The coarse texture of the soils allows water to drain more than a clay type of soil would. And in the world of livings things, plants, insects and microorganisms secrete waxes, oils, resiny compounds that make soil resist saturation. In the study area, the scientists unearthed big fungal mats—entities that make soil repellent to water both before and after fire, and whether the soil is wet or dry.

Between fires, water-repellent compounds can increase on the soil surface, and leach into lower layers. The researchers wanted to determine what fluctuations in soil water repellency would occur after fire. Following the Williams Fire, the Forest Service Burned Area Emergency Response Team (BAER) determined that of the 34,019 acres burned, 28,039 acres were water repellent. Because wind had not been blowing at the time of this end-of-summer burn, the fire was fuel driven, with the rate of fire spread relatively slow, and the duration of smoldering relatively long. The fire consumed most of the organic litter—leaves, twigs—reducing it to a thin layer of ash. One week after the fire, the Santa Ana winds kicked into play, and drove small pieces of rock downslope, and redistributed ash over the landscape.

Fifteen months before the Williams Fire, researchers had collected data on soil water repellency in an adjacent watershed and found 41 percent of the surface soil showed very low to no repellency, 22 percent of the surface soil showed low repellency, and 37 percent showed moderate to extreme repellency to water. After the fire, the scientists took samples from the crest, upper, middle, lower, and foot of the hillsides for twelve months, at 1–4 week intervals at the soil's surface, and at 2 centimeters (roughly ¾ inch) and 4 centimeters (roughly, 1½ inch) below the surface to determine if the soil was "wettable," or slightly, moderately, or highly repellent to water. Using data from the Remote Automated Weather Station (RAWS) situated in the forest, the scientists had numbers on precipitation, relative humidity, and air temperature to figure into their analyses.

Fungal mats make soils repellent to water—before and after fire. Credit: Matt Trappe, Oregon State University.

The picture of surface water repellency changed. Two weeks after the Williams Fire, very low to no repellency areas dropped to 25 percent, and moderate to high repellency areas increased to 49 percent. "This 12 percent increase in water repellency at the soil surface likely resulted from hydrophobic compounds moving from the burning litter and plant material into the soil," the team explains. Summer gave way to the cooler seasons, and after the third rain that delivered water to the burned land, moderate to extreme water repellent soils decreased from 49 to 35 percent of the soil surface. Additional winter rains that watered the landscape reduced the area of moderate to extreme repellency further from 35 percent all the way down to 4 percent, and areas of low to no repellency increased dramatically from 25 to 91 percent. On two sampling dates following rain in the spring, areas of moderate to high repellency dropped to zero.

Researchers found a different situation underneath the soil surface. At the 2 centimeters and 4 centimeters depths, the areas of moderate to high repellency stayed higher than on the surface of the soil, and only after spring rains did they drop below 10 percent. When summer once again returned, the scientists found areas of moderate to extreme repellency at 4 centimeters reached higher levels than those they found just after the wildfire. This, they explain, was probably owing to water repellent compounds, released from plants as they burned, leaching downward through rainwater.

Winter rains played a big role in breaking down water repellent soil conditions, but the rate of breakdown is still not clear, the team explains, nor how much moisture is required to begin the breakdown of repellency. After rains, it may be, the researchers think soil wetness must stay above

10 percent before repellency is diminished, or disappears altogether. At the two lower sampling depths, the scientists found repellency returning when soil wetness fell below 2 percent.

Water repellency at the surface did not return to the levels the team observed just after the fire, possibly due to the lack of new chaparral litter and plants that would create hydrophobic compounds that would then leach into the soil. The details of soil characteristics are critically important to management planning. "Because erosional processes 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," the scientists urge.

Santa Ana winds, as shown in this National Aeronautics and Space Administration satellite image, are powerful enough to contribute to erosion by blowing sand, grit, rock, soil and ash.

Plants

With the Williams Fire burning many of the areas that the 1960 Johnstone Fire burned, Wohlgemuth and his team had an opportunity to compare watersheds with different management histories in the San Dimas Experimental Forest. After the 1960 fire, three watersheds of native chaparral were seeded with grass and treated with herbicide, three regenerated naturally. In 1999, narrow bands at the top of one chaparral and one grass-converted watershed were burned in a prescribed fire. In the narrow, "black line" areas where fire treatment had been applied, the researchers observed yet another age class of plants growing.

Beginning in 2003, the team measured plant composition and structure in each watershed, and evaluated reconstructed pre-fire shrub density, post-fire ground cover, post-fire shrub density, post-fire sprouting shrub density, and post-fire seedling density. In lands where the native chaparral of chamise, hoaryleaf ceanothus, sugar bush, Eastwood manzanita, scrub oak, black sage and wild buckwheat grew in thick densities and canopies, nineteen species of shrubs and bushes recovered differently in the various treatment or no treatment areas.

In the areas where herbicide had been used, the researchers found fewer species than in the untreated areas. The area that had been treated with prescribed fire in 1999 showed plant recovery level midway between the herbicide treated and untreated sites. On untreated sites, shrub cover was greater, as was plant diversity and numbers. Immediately after the fire, seedlings popped up all over, but most shrub seedlings did not survive because too little moisture was available to help them past their beginnings. Areas that had been treated with prescribed fire or converted to grassland lost tree and shrub species. Both native chaparral and grassland watersheds burgeoned in herbaceous plants after the fire, what the scientists term "fire followers," but after three years, the herbaceous plants diminished and watersheds appeared to be returning to the plant communities present before the Williams Fire. Areas that burned as a "black line" in 1999 for prescribed fire were almost entirely covered with native deerweed, a sub-shrub, and non-native mustard, the team documented, which they say illustrates the negative consequences of chaparral burning in too rapid an interval between fire events. "Once chaparral is lost from an area, it will not easily re-establish naturally."

Watershed

Just as they checked into the stationary situations, the scientists also took at look at movement. In the study area, most sediment traveling downhill occurred during the first winter after the Williams Fire, even though 2003 had only moderate amounts of rainfall. This mirrored the timing of sediment movement following the 1960 Johnstone Fire. With plants growing well over the next few years, soils and sediments stabilized, and sediment movement was minimal, even in 2005 which experienced a record deluge. The flow of water, however, was tied to rainfall, and the greatest amount of run-off the scientists observed was during that record rainy season of 2005. Sediment that had rolled down steep, burned slopes and filled channels during the first winter after the Williams Fire was scoured clear by those drenching rains—and ended up in reservoirs and basins.

A fire that causes unstable soils by removing anchoring plants, weather that desiccates, oily and waxy compounds that inhibit water from soaking into soils can cause problems for areas downhill after rains.

Soil characteristics, plant characteristics. Cycles that burn. Cycles that moisten. Factors that play a big role in how water and sediments will move over a landscape. A fire that causes unstable soils by removing anchoring plants, weather that desiccates, oily and waxy compounds that inhibit water from soaking into soils can cause problems for areas downhill after rains.

Loose soil and water can produce anything from small trickling streams and showers of rock and grit, to fast-moving concrete-like slurries that become hazardous debris flows. As we continue our walk on the land, a fundamental urge drives us to know what dirt is doing. It's in our nature.

Management Implications

Modeling for planning and risk assessment at the wildland urban interface is critical for land managers following wildfires which can, with subsequent weather, lead to erosion, moving sediments, flooding, and debris flows. The researchers are continuing to provide hard numbers on post-fire soil and plant properties that affect run-off and erosion after wildfire. A detailed synthesis of data has been sent to the *International Journal of Wildland Fire* for publication.

Further Information: Publications and Web Resources

Hubbert, Ken R. and V. Oriol. 2003. Seasonal changes in soil water repellency following wildfire in chaparral steeplands, southern California. Extended abstract, 5th Symposium on Fire and Forest Meteorology Joint with 2nd International Wildland Fire Ecology and Fire Management Congress. Available online at http://ams.confex.com/ams/FIRE2003/techprogram/paper_67224.htm

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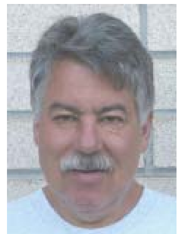
Scientist Profiles



Pete Wohlgemuth is a Hydrologist with the Pacific Southwest Research Station. His research includes post-fire erosion and sedimentation as well as evaluating the effectiveness and consequences of post-fire erosion control techniques.

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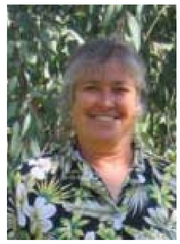

Marcia Narog is an Ecologist with the Pacific Southwest Research Station. Her research includes fire effects studies on common and endangered plants and animals found in oak forests, chaparral, deserts, and riparian zones.

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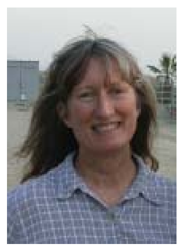

Jan Beyers is a Plant Ecologist with the Pacific Southwest Research Station. Her research includes fire effects studies, especially in chaparral and coastal sage scrub ecosystems, and evaluating the effectiveness and vegetation effects of emergency postfire stabilization treatments.

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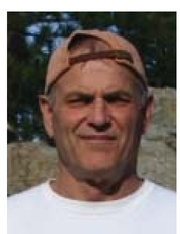

Ken Hubbert is a Soil Scientist with the Pacific Southwest Research Station. His research includes studies on the effects of fire and forest management activities on soil properties, including water repellency (hydrophobicity) and nutrient content.

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Results presented in JFSP Final Reports may not have been peer-reviewed and should be interpreted as tentative until published in a peer-reviewed source.

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