1B.8 HILLSLOPE EROSION FOLLOWING THE WILLIAMS FIRE ON THE SAN DIMAS EXPERIMENTAL FOREST, SOUTHERN CALIFORNIA

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1. INTRODUCTION

In chaparral environments, the climatic patterns that produce highly flammable brush vegetation also generate weather conditions that promote high-severity wildfires. In these fire-prone ecosystems, wildfire is a significant disturbance event. Fire incinerates vegetation, alters soil properties, and renders the landscape susceptible to the forces of sediment transport. Under these conditions, accelerated erosion in upland watersheds is inevitable.

Accelerated post-fire erosion is accentuated in the mountains of southern California because of steep topography, non-cohesive soils, and intense rainfall events. This accelerated erosion can cause environmental site degradation and can seriously harm downstream human communities at the wildland/urban interface. Lives are threatened, property is jeopardized, and corporate infrastructure (roads, bridges, pipelines, utility lines) is placed at risk.

Although the patterns of post-fire erosion on chaparral hillslopes in southern California are generally understood, uncertainty about the magnitude of destruction associated with post-fire erosion events stems from our limited ability to predict specific post-fire watershed responses. Unfortunately, prediction, usually in the form of risk assessment and planning that involves numerical modeling, can only derive from a sufficient understanding of the erosion problem and the quantification of fire effects and erosion processes.

A wildfire on the San Dimas Experimental Forest that burned over an ongoing sediment flux study provided an opportunity to document and quantify the effects of fire on hillslope erosion in small watershed units in a semiarid, chaparral-covered, steepland environment. Results of this research could serve as a benchmark against which to test existing models of post-fire erosion for the southern California area.

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1.1 *Study Area*

The San Dimas Experimental Forest (SDEF) is a 6945 ha research preserve administered and operated by the USDA Forest Service, Pacific Southwest Research Station (Figure 1). With its headquarters at Tanbark Flat (34^o 12' N latitude, 117^o 46' W longitude), the SDEF is located in a front range of the San Gabriel Mountains about 45 km northeast of Los Angeles, California.

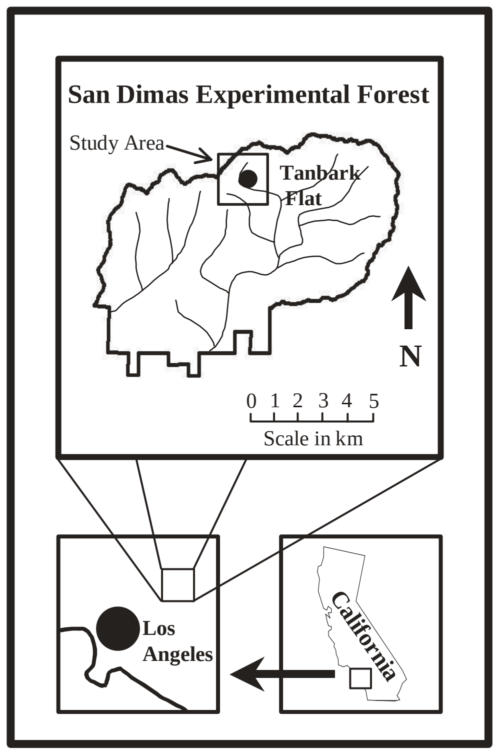

Figure 1. Location map of the San Dimas Experimental Forest.

Topography in the SDEF consists of a highly dissected mountain block with narrow, steep-walled canyons (slope angles average 68 percent) and steep channel gradients (average of 15 percent). Elevations in the study area range from 750 m to 1050 m. Slope profiles exhibit both summit and basal convexities, as the hillslopes meet the channels in an inner gorge (Wohlgemuth, 1996). Bedrock geology is dominated by Precambrian metamorphics and Mesozoic granitics that produce shallow, azonal, coarse-textured soils (Dunn et al., 1988).

The SDEF experiences a Mediterranean climate, characterized by cool, moist winters and hot, dry summers. Mean annual precipitation, falling almost exclusively as rain, is 714 mm (62-year record), but rain during individual years can range from 258 to 1595 mm. Over 90 percent of the average annual precipitation falls between the months of November and April, with 10 percent of the storms producing over 50 percent of the total rain (Wohlgemuth, 1996).

Native vegetation in the SDEF consists primarily of mixed chaparral. Plant cover on south-facing slopes ranges from dense stands of chamise (*Adenostoma fasciculatum*) and ceanothus (*Ceanothus* spp.) to more open stands of chamise and sage (*Salvia* spp.). North-facing hillsides are dominated by scrub oak (*Quercus berberidifolia*) and ceanothus, with occasional hardwood trees – live oak (*Quercus agrifolia*) and California laurel (*Umbellularia californica*) – occurring on moister shaded slopes and along the riparian corridors (Wohlgemuth, 1996).

1.2 *Background*

Semiarid geomorphic systems are characterized by high rates of sediment production (Langbein and Schumm, 1958). The steep San Gabriel Mountains of southern California are an extreme example in which the high natural erosion rates are accentuated by management practices and wildfire (Sinclair, 1954). Weathered rock debris combines with organic litter to form thin, colluvial soils (DeBano, 1974). This sediment, stored on the hillslopes, is shed quasi-continuously by the gravitational process of dry ravel and the hydrologic processes of rainsplash and overland flow (Rice, 1974).

Fire magnifies the erosion hazard in the southern California mountains by reducing the resistances to the agents of erosion. The removal of the vegetation canopy and surface organic material decreases rainfall interception (Hamilton and Rowe, 1949), and the denuded hillsides are subjected to unimpeded raindrop impacts (Wells, 1981). In addition, the combustion of soil organic matter can create a subsurface water-repellent layer that restricts infiltration and promotes overland flow (DeBano, 1981).

The SDEF was established in the early 1930s to document and quantify wildland hydrology in the semiarid chaparral-covered steeplands of southern California. Concomitantly, the nearly seventy years of accumulated watershed research – that has included both wildfires and prescribed burning – has produced invaluable information on post-fire erosion (Dunn et al., 1988).

Management treatments following a wildfire in 1960 involved the vegetation type conversion of some native chaparral watersheds to a mixture of perennial grasses. Accompanied by herbicide spraying of the re-growing brush vegetation to assist in their establishment, these perennials included a variety of wheatgrass species (*Agropyron* spp.), Harding grass (*Phalaris tuberosa* var. *stenoptera*), big bluegrass (*Poa ampla*), smilo grass (*Oryzopsis miliacea*), and blando brome (*Bromus mollis*) (Corbett and Green, 1965).

In 1994, a study was initiated to quantify sediment fluxes through several small (1-3 ha) headwater catchments in the SDEF that last burned in the 1960 wildfire (Wohlgemuth, 1996). Because of differences in the nature of the ground surface vegetation, hillslope erosion was an order of magnitude less in type-converted grass watersheds compared to chaparral catchments. One of these chaparral watersheds was burned in a prescribed fire in 2001. First year post-fire hillslope erosion was twice as great as pre-burn levels during the dry season and increased by 5-fold in the wet season, despite a record drought year (Wohlgemuth and Hubbert, in press).

In September 2002 virtually the entire SDEF burned in the Williams Fire, a high severity wildfire that consumed the vegetation on nearly 15,000 ha across the San Gabriel Mountains and threatened several foothill communities. The fire burned over the aforementioned sediment flux study, providing a unique opportunity to quantify hillslope erosion following a wildfire on the same sites for which there was an extensive pre-fire dataset. The areas that burned in the 2001 prescribed fire did not re-burn in the 2002 wildfire.

2. METHODS

In the sediment flux study, four small watersheds were selected to measure hillslope erosion: three in native chaparral vegetation and one in type-converted grass (Wohlgemuth, 1996). Hillslope erosion was sampled using 75 sheet metal collector traps with a 30 cm aperture (Wells and Wohlgemuth, 1987) on unbounded plots scattered throughout each watershed (Figure 2, Figure 3). The traps were installed in summer 1994, and then sediment was collected for 8 years

Figure 2. Post-fire dry season erosion captured in a 30-cm aperture sediment collector.

prior to the Williams Fire and through the first post-fire winter. Hillslope erosion is expressed as a flux: the air-dried mass of collected debris per unit width of slope contour (kg/m) per collection period. Although 23 sediment collections have been made to date at irregular intervals over the life of the project, the data are aggregated here into erosion periods of four-month wet seasons and eight-month dry seasons.

Figure 3. Post-fire wet season erosion in a burned chaparral watershed. Note collector trap with cover for scale and scour from overland flow.

3. RESULTS AND DISCUSSION

Hillslope erosion is extremely variable in the SDEF, both before and after the fire. Within the statistical distributions, dispersion often equals or exceeds the measure of central tendency (Table 1). In the pre-fire environment, dry season erosion and wet season erosion are roughly equal, although the erosion rates are greater in the wet season, as the same amount of sediment is delivered in half the time (Table 1). Immediately following the fire, wet season erosion greatly exceeds dry season erosion in both rate and magnitude (Table 1).

	Hillslope Erosion	
Watershed ID	Pre-Fire	Post-Fire
	kg/m	
0507 (Grass)		
Dry Season[a]	0.1 ± 0.1[b]	0.7 ± 1.0
Wet Season	<0.1 ± 0.1	15.1 ± 11.3
0508 (Chaparral)		
Dry Season	1.2 ± 1.2	3.9 ± 4.5
Wet Season	0.8 ± 0.7	14.1 ± 18.0
0542 (Chaparral)		
Dry Season	1.3 ± 0.7	3.1 ± 2.1
Wet Season	0.9 ± 0.6	8.3 ± 6.9
0560[c] (Chaparral)		
Dry Season	1.3 ± 0.9	2.3 ± 3.5
Wet Season	1.3 ± 0.7	6.8 ± 12.0

[a] Data aggregated to an 8-month dry season and a 4-month wet season
[b] Median and semi-interquartile range (n=75)
[c] Burned in a prescribed fire in 2001

Table 1. Hillslope erosion before and after burning.

In the unburned environment, the order of magnitude disparity in hillslope erosion between vegetation types (Table 1) confirms previously published data (Wohlgemuth 1996). Mature chaparral often produces a complete canopy cover, but usually exhibits plant densities of about one per square meter. Moreover, the deep tap roots do little to bind the surface soil. This allows for the largely unrestricted movement of sediment and litter, especially on steep slopes. In contrast, grasses can have tens to hundreds of plants per square meter and have extensive, shallow root systems that hold the surface soil in place. This accounts for the lower pre-fire erosion levels in grass vegetation by both gravitational and hydrologic transport processes.

In chaparral watersheds, post-fire dry season erosion was 2-3 times greater than unburned levels (Table 1). Combustion of organic matter in the surface horizons disrupts soil structure, and may trigger dry ravel events (Wohlgemuth and Hubbert, in press). Furthermore, as organic barriers to surface sediment transport are incinerated, sediment trapped behind stems and downed limbs are liberated in a flush of ravel during and immediately after the fire. The burned landscape remains extremely sensitive to any disturbance, until re-growing vegetation can stabilize the site.

Post-fire dry season erosion increased by 7 times over unburned levels in the grass watershed (Table 1). Most of the roots remained intact, but the standing grass and thatch were completely consumed, liberating trapped sediment. Although the dry season post-fire/pre-fire erosion ratio was much greater in the grass vegetation type, the magnitude of the erosion was only about one-fifth the amount experienced in chaparral watersheds (Table 1).

Post-fire wet season erosion in chaparral catchments was 9-18 times greater than prior to the fire (Table 1). With the loss of the protective brush canopy and the increase in surface soil water repellency (Hubbert et al., in press), hydrologic processes are accentuated, resulting in accelerated erosion. Surface runoff often attacks sediment deposits initially mobilized by dry ravel. Concentrated overland flow can carve a network of rills into the hillside that rapidly convey water and sediment to the stream channels at the toe of the slopes.

In the grass watershed, post-fire wet season erosion was more than 300 times greater than comparable unburned values (Table 1). This dramatic increase attests to the watershed protection provided by the grass vegetation prior to the fire. Moreover, this increase in post-fire erosion may also reflect an additional supply of sediment previously caught up in the thatch but now available for transport. Not only was the wet season post-fire/pre-fire erosion ratio much greater in the grass vegetation, but the magnitude of the erosion was the largest of any watershed (Table 1).

The 2001 prescribed burn in chaparral vegetation produced post-fire/pre-fire ratios for dry season erosion that were one-fourth to one-third less than the wildfire (Table 1). Presumably, the wildfire produced greater fire severities, and hence a greater degree of watershed disturbance necessary to generate dry ravel, than the prescribed burn. The same catchment generated one-fourth to one-half less wet season erosion during the first winter after burning compared to the wildfire (Table 1). While this relationship may also result from the lower fire severities, more probably this response reflects the record low rainfall following the prescribed burn (Wohlgemuth and Hubbert, in press). However, both dry season and wet season hillslope erosion were less after a prescribed fire than a wildfire. This supports the contention that prescribed burning could be used as a sediment management tool (Wohlgemuth, 2001).

4. SUMMARY AND CONCLUSIONS

A high severity wildfire that burned over an ongoing sediment flux study provided a unique opportunity to document and quantify post-fire hillslope erosion for the same sites that had eight years of pre-fire data. Post-fire dry season erosion was 2-3 times greater than pre-burn levels in chaparral catchments and 7 times greater in a type-converted grass watershed. Post-fire wet season erosion was 9-18 times greater than pre-burn levels in chaparral and over 300 times greater in grass. A prescribed burn produced less erosion in both the dry season and the wet season compared to the wildfire. Results of this study indicate that wildfire can dramatically alter the erosion response of upland landscapes, but that prescribed burning can reduce these impacts and may thus be useful as a sediment management tool.

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