# SOIL LOSS FOLLOWING THE RODEO-CHEDISKI WILDFIRE: AN INITIAL ASSESSMENT

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The Rodeo-Chediski wildfire, the largest fire in Arizona's history, damaged, destroyed, or disrupted the hydrologic and ecological functionings of all the ecosystems impacted. The extent to which these functionings will return to pre-fire conditions, if they ever will, is open to conjuncture. It is therefore very important that the impacts of this wildfire be documented to establish a reference for the time-trend responses of impacts from future wildfires of comparable magnitudes. To that end an initial assessment was made of soil loss on two watersheds in the ponderosa pine forests at the headwaters of the Little Colorado River after the Rodeo-Chediski wildfire. One of the watersheds experienced a high-severity burn and the other a low- to medium-severity burn. Soil loss is continuing to be monitored to obtain a longer, more comprehensive picture of the impacts of this catastrophic wildfire event.

## WATERSHEDS STUDIED

Two nearly homogeneous watersheds, 60 acres (24 hectares) each, were established in 1972 by the University of Arizona and the USDA Forest Service, Rocky Mountain Research Station, along Stermer Ridge, about 9 miles (15 km) south of Overgaard, Arizona, at the headwaters of the Little Colorado River. The watersheds were located in the previously cut-over, mostly uneven-aged ponderosa pine forests of the Colorado Plateau physiographic province. The most recent harvest of the pre-fire timber removed 45 percent of the sawtimber by group selection in the early 1960s. The objective of establishing these watersheds was to obtain baseline information on the hydrologic and ecological functioning of ponderosa pine forests situated on sedimentary soils (Ffolliott and Baker 1977). Most of the information about the ponderosa pine forests in the region before 1972 had been obtained on volcanic soils, with only limited work on sedimentary soils.

The watersheds exhibit the relatively flat topography (most of the slopes are less than 10%) that is common on the Colorado Plateau. Elevations range from 6800 to 7000 ft (2073–2134 m). Cretaceous undivided material that is similar to the Coconino sandstone formation lies beneath the watersheds. McVickers soils in the Soldier-Hogg-McVickers Association characterize the two watersheds. Hendricks (1985) described these moderately well to well drained soils as having a fine, sandy loam texture. Sixty-five percent of the annual precipitation of 20–25 inches (508–635 mm) falls from October to April, much of it as snow, and most of the remainder falls in rainstorms from July to early September. More than 90 percent of the intermittent pre-fire streamflow from the watersheds occurred as a result of snowmelt-runoff or winter rains prior to the Rodeo-Chediski wildfire. Before the wildfire, summer storms, while often intense, rarely produced significant stormflows.

The watersheds had been "moth-balled" in 1977 after completion of the baseline studies. However, the 3 ft (0.9 m) H-flumes were left in place in anticipation of future monitoring needs. After the Rodeo-Chediski wildfire, these control sections were refurbished and reinstrumented with water-level recorders, and a weather station on the site was reestablished. The set of 30 permanently located sample points (plots) that had originally been placed on each watershed to sample on-site hydrologic and ecological parameters were relocated to provide a basis to study the impacts of varying fire severities on hydrologic and ecological processes (Ffolliott and Neary 2003).

A fire severity classification system that related fire severity to the soil-resource response (Hungerford 1996; DeBano et al. 1998) on the sample plots was extended to the area of each watershed to determine the relative portions of the respective

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watersheds that were burned at low, moderate, and high severity (Wells et al. 1979). This extrapolation of the classification indicated that one of the Stermer Ridge watersheds had experienced the impacts of a high-severity, stand-replacing fire, and the other watershed had been exposed to a low- to medium-severity, stand-modifying fire.

## METHODS

Estimates of soil loss were initially obtained from measurements of 23 soil pedestals on the severely burned watershed and 18 soil pedestals on the lightly to moderately burned watershed at the end of the summer monsoonal rains 2 months after the wildfire. These soil pedestals were randomly located on the watersheds but they were not distributed in a manner that provided an unbiased sample of the watershed conditions; most of the pedestals were found on the upper and middle slopes of the watersheds. Three erosion pins were then installed around each of the sample points on the two watersheds to obtain unbiased estimates of post-fire soil loss. Two pins were placed 6 ft (1.8 m) upslope and one pin the same distance downslope of the point. Measurements of soil loss were made 10 and 16 months after the wildfire. The erosion pins were reset after measurement to estimate soil loss in the intervening period. Soil loss for the 10-month period represented that associated with the first post-fire winter precipitation and snowmelt-runoff events, whereas soil loss for the 16-month period, that is the intervening 6-month period, represented loss from the summer monsoonal rains occurring in the second year after the wildfire. A bulk density value obtained from soil samples collected from unburned sites on Stermer Ridge was used as a basis to convert measurements of average soil loss to corresponding erosion rates in terms of tons per acre (metric tons/hectare).

Analyses of variance were used to compare the averages of soil loss relative to watershed condition and hillslope position, slope percent, and aspect within a watershed. Tukey-Kramer multiple comparison tests were made to evaluate the differences among respective means. When heterocedasticity was detected by the Bartlett's test for homogeneity of variances, nonparametric Tukey-type multiple comparison tests were used to assess differences among means (Zar 1999). All statistical inferences were made at the 0.10 alpha level.

## RESULTS AND DISCUSSION

### Watershed Differences

Soil loss estimated by the measurements of soil pedestals after the first summer monsoonal rains following the Rodeo-Chediski wildlife is shown in Figure 1. More soil was lost on the two Stermer Ridge watersheds in this period than that reported by Rich (1962) for a comparable time period (that is, following the first post-fire summer monsoonal rains) after a "hot wildfire" burned 60 acres (24 hectares) of ponderosa pine–Douglas-fir forest vegetation on the upper part of the 381 ac (154 ha) South Fork of Workman Creek in 1957. In comparison to Stermer Ridge, the soils on the Workman Creek watersheds are underlain by Dripping Springs quartzite rock that has been intruded by diabase and basalt plugs and sills. Troy sandstone outcrops on the upper portion of these watersheds, including the area burned.

Figure 1 shows the average soil loss following the first winter precipitation and snowmelt-runoff period and second summer monsoonal rains after the Rodeo-Chediski wildfire based on measurements of the erosion pins. There was greater soil loss during the former than the latter, a difference attributed largely to a "breaking down" of the extensive post-fire hydrophobic conditions of the soils on the severely burned watershed. Soil loss on the lightly to moderately burned watersheds was similar in these two post-fire periods, presumably because of the comparatively small change in the less extensive hydrophobicity of the soils on this watershed.

The measurements of soil pedestals suggest that 25–30 tons per acre (56–67 metric tons/hectare) of soil were eroded on the severely burned watershed in response to the first summer monsoonal rains, and 15–20 tons per acre (34–45 metric tons/hectare) of soil were lost on the lightly to moderately burned watershed (Figure 2). Soil erosion rates on the severely burned and lightly to moderately burned watersheds after the first winter precipitation and snowmelt-runoff period following the wildfire were 22 and 12 tons per acre (49 to 27 metric tons/hectare), respectively. Erosion rates after the second summer monsoonal rains were statistically similar, averaging 11 tons per acre (25 metric tons/hectare) for both watersheds.

Sediment transport was used as a proxy for soil loss by Campbell et al. (1977) in their evaluation of the effects of a wildfire (the Rattle Burn) on a pon-

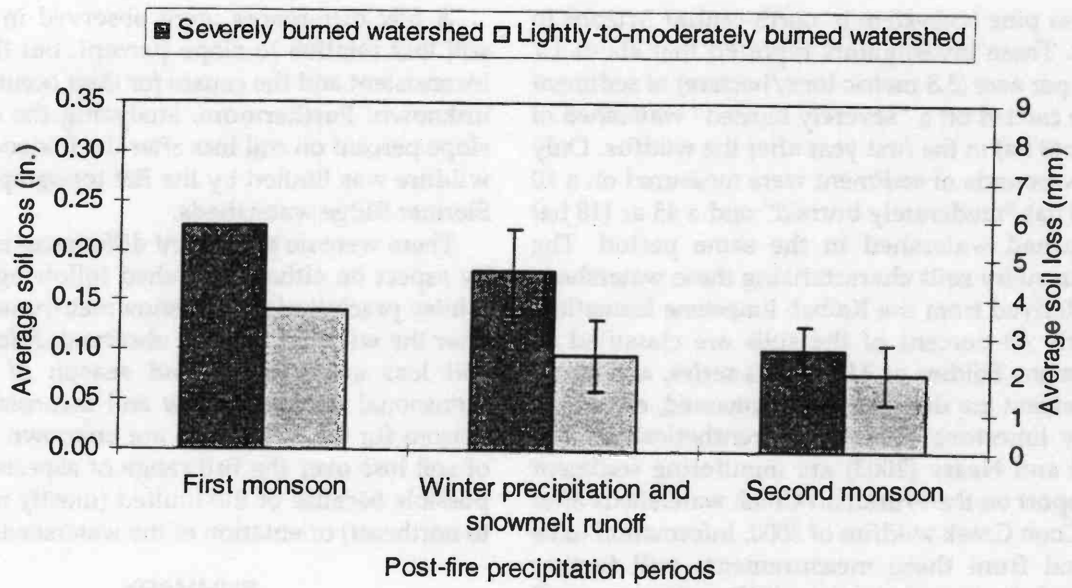


Figure 1. Averages and 90% confidence intervals for soil loss on the Stermer Ridge watersheds for three post-fire precipitation periods after the Rodeo-Chediski wildfire. (Confidence intervals were not calculated for soil loss after the first post-fire summer monsoonal rains because the soil pedestals measured were not distributed in a manner that provided an unbiased sample of the watershed conditions.)

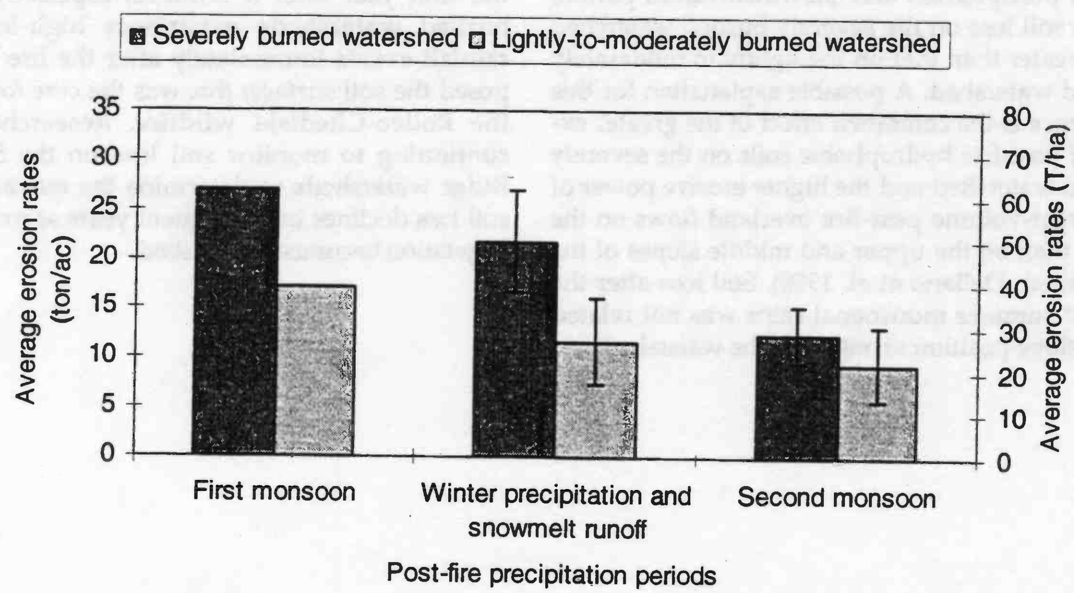


Figure 2. Averages and 90% confidence intervals for erosion rates on the Stermer Ridge watersheds for three post-fire precipitation periods after the Rodeo-Chediski wildfire. (Confidence intervals were not calculated for the erosion rates after the first post-fire summer monsoonal rains because the soil pedestals measured were not distributed in a manner that provided an unbiased sample of the watershed conditions.)

derosa pine ecosystem in north-central Arizona in 1972. These investigators reported that about 1.7 tons per acre (3.8 metric tons/hectare) of sediment were carried off a "severely burned" watershed of 20 ac (8 ha) in the first year after the wildfire. Only a few pounds of sediment were measured on a 10 ac (4 ha) "moderately burned" and a 45 ac (18 ha) unburned watershed in the same period. The sedimentary soils characterizing these watersheds are derived from the Kaibab limestone formation. Nearly 40 percent of the soils are classified as either the Soldier or McVickers series, and about 50 percent are designated as unnamed, extremely stony limestone outcrops. Parenthetically, Gottfried and Neary (2003) are monitoring sediment transport on the Workman Creek watersheds after the Coon Creek wildfire of 2000. Information to be gained from these measurements will further expand the knowledge of wildfire effects on soil loss and sedimentation on watersheds in Arizona's montane forests.

### Hillslope Position, Slope Percent, Aspect

Soil loss on upper, middle, and lower hillslope positions of the Stermer Ridge watersheds is shown in Figure 3 for the first winter precipitation and snowmelt-runoff period and the second summer monsoonal rains after the wildfire. The only difference occurred on the lower slopes after the winter precipitation and snowmelt-runoff period, where soil loss on the severely burned watershed was greater than that on the lightly to moderately burned watershed. A possible explanation for this difference is the combined effect of the greater extent of post-fire hydrophobic soils on the severely burned watershed and the higher erosive power of the larger-volume post-fire overland flows on the lower than on the upper and middle slopes of the watershed (DeBano et al. 1998). Soil loss after the second summer monsoonal rains was not related to hillslope position on either of the watersheds.

A few differences were observed in post-fire soil loss relative to slope percent, but they were inconsistent and the causes for their occurrence are unknown. Furthermore, analyzing the effects of slope percent on soil loss after the Rodeo-Chediski wildfire was limited by the flat topography of the Stermer Ridge watersheds.

There were no significant differences in soil loss by aspect on either watershed following the first winter precipitation and snowmelt-runoff period after the wildfire, and the observed differences in soil loss after the second season of summer monsoonal rains were few and inconsistent, and reasons for the differences are unknown. Analysis of soil loss over the full range of aspects was not possible because of the limited (mostly northwest to northeast) orientation of the watersheds.

## SUMMARY

Watersheds denuded by devastating wildfire are vulnerable to a high rate of soil loss and, as a consequence, can yield large amounts of post-fire sediment. While the magnitude of soil loss on the Stermer Ridge watersheds following the Rodeo-Chediski wildfire is site-specific, it reflects the response that might be expected from catastrophic wildfire of varying severities on watersheds with similar conditions to those on the Stermer Ridge watersheds. Soil loss will generally be highest in the first year after a wildfire, especially if the burned watersheds experience high-intensity rainfall events immediately after the fire has exposed the soil surface; this was the case following the Rodeo-Chediski wildfire. Researchers are continuing to monitor soil loss on the Stermer Ridge watersheds to determine the rate at which soil loss declines in subsequent years as protective vegetation becomes established.

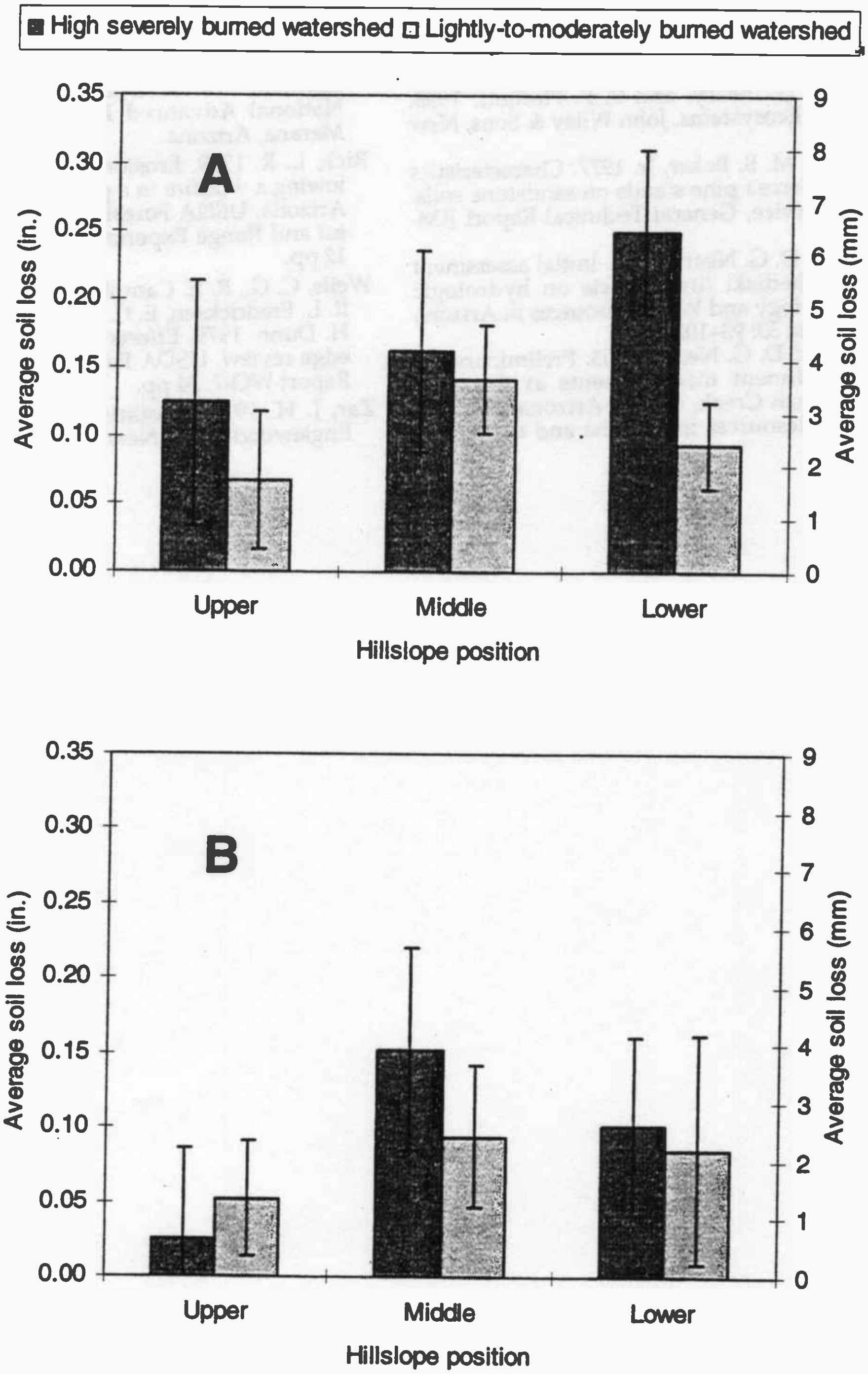


Figure 3. Averages and 90% confidence intervals for soil loss on the Stermer Ridge watersheds for different hillslope positions after (A) the first winter precipitation and snowmelt-runoff period and (B) the second summer monsoonal rains after the Rodeo-Chediski wildfire.

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