

Post-fire rill and gully formation, Schultz Fire 2010, Arizona, USA

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Introduction

The Schultz Fire burned 6,100 ha on the eastern slopes of the San Francisco Peaks, a dormant Middle Pliocene to Holocene aged stratovolcano in northern Arizona (Figure 1). The fire burned in the Coconino National Forest between June 20th and 30th, 2010, across moderate to very steep ponderosa pine and mixed conifer watersheds. About 40% of the fire area was classified as high-severity, mostly on mountain slopes greater than 30% and in places exceeding 100%. The upper slopes rise to over 3,300 m and are the source for high energy water, coarse sediments, and woody material. A steep gradient of nearly 1,000 m exists from the upper slopes to the base of the lower fans. Summer thunderstorms tend to develop over the mountain due to orographic lifting. Over the course of an active 2010 Monsoon, ranking the fourth highest in rainfall on record, the burned area received numerous precipitation events. The largest event occurred on July 20th and was characterized by a peak rainfall of 25 mm in fifteen minutes, resulting in numerous debris flows, historic floods and substantial hillslope erosion. Flood flows were one to two orders of magnitude larger than those produced by similar pre-fire rainfall events.



Figure 1. Schultz Fire burned area on the east flank of the San Francisco Peaks, July 2010.

Objectives

The upper slopes of the San Francisco Peak have gradients range from 60 to >100%. These areas developed unprecedented erosion after the intense July 20th storm. The objective of this study was to evaluate the extent and degree of new rill and gully formation, reactivation of old gullies, and how this network contributes to the substantially altered hydrologic response of the upper mountain slopes.

Methodology

New rill and gully formation were assessed along the Waterline Road using visual and photographic surveys. Long-term measurements are being done by on-the-ground measurements, terrestrial LIDAR, and repeat aerial photography. The first set of photos was taken on October, 27, 2010, at a scale of 1:12,000 by Kenney Aerial Mapping, Phoenix, Arizona. Repeat photography will be done in late September of each year to follow.

Results and Conclusions

Substantial amounts of soil were eroded out of a newly developed rill and gully system, removing the A horizon and much of the B horizon. Prior to the fire there was a minimal presence of rills or gullies as the soil was protected by a thick O horizon. This protective organic layer burned off during the fire leaving the soil exposed to raindrop impact and erosion. There was widespread occurrence of high severity fire, with some watersheds classified as 70% high severity wildfire. This left most of the soils with moderate to severe water repellency, so surface runoff was extensive. Peakflows from the July 20th storm contained high concentrations of ash and topsoil material. Mineral soil loss is estimated to be >10 cm on 2,000 ha of the upper watersheds.

The development of an extensive rill and gully network fundamentally changed the hydrologic response of the upper portions of every catchment (Figure 2). Rills are self-organizing erosion systems characterized by numerous and randomly occurring small channels of only several centimetres in depth and centimetres to tens of metres long.



Figure 2. Large rill systems developing on a steep slope (right) and small gully development beginning (left). Schultz Fire, 2010, above the Waterline Road, Coconino National Forest, USA.

Sediment yields increase with increasing slope, rill spacing decreases as slope angle increases, rill patterns show an increased elongation and parallelism on steeper slopes, and hillslope rills tend to be evenly spaced on bare, straight slopes (Favis-Mortlock et al. 2000). Rills on the upper slopes of the San Francisco Peaks within the Schultz Fire perimeter are now 10-20 cm deep into the B and C horizons running the entire length of

slopes. Parallel rills in the right photo of Figure 2 demonstrate the transition from sheet erosion to rill erosion. The rills are 30 to 40 cm apart crossing entire slopes. They are up to 5 cm deep and beginning to coalesce. The rills shown on the left are transitioning to small gullies 20 to 30 cm deep. They are cutting below the ponderosa pine surface root systems and into fragmented and weathered C horizon andesite and dacite. Small lateral gullies that are 50–100 cm deep (Figure 3) merge into now deeply incised main drainage gullies (3–5 m deep) that occupy previous swales in the upper mountain slopes (Figure 4). Despite the elevation and precipitation regime there are no perennial stream channels.



Figure 3. Rapidly deepening gullies on the upper mountain slopes of the San Francisco Peaks within the high-severity portion of the Schultz Fire of 2010.

Flood flows in July and August of 2010 incised deeply into the slopes consisting of volcanic colluvial material and ash and tephra deposits. In many places the gullies have cut down to bedrock, thus allowing subsequent flood flows to scour out fresh, unweathered material. The pre-fire slope surface was about 1 m above the individual on the left in Figure 4. The deep incisions of these main drainage gullies has lowered the base level of the smaller lateral gullies, leading to additional headward cutting of the gully system.



Figure 4. Deeply incised (3 m) main drainage gully within the Schultz Fire along the Waterline Road, Coconino National Forest, Arizona.

Wildfires often produce severe watershed impacts, especially in steep terrain (DeBano et al. 1998, Neary et al. 2008). Interruption of watershed processes results in significantly increased runoff (Ice et al. 2004). The intense, short duration rainfall of the 2010 Monsoon in northern Arizona interacted with slope, water repellency and extensive areas of bare soil to produce flood flows orders of magnitude in excess of flows produced by similar pre-fire rainfall events. These events eroded significant amounts of soil and led to the development of large rill and gully networks. The networks now cover much of the upper mountain. Sediment delivery to the channels is likely to taper off after 3 -5 years, but could increase due and future slope failures.

Crown-replacing wildfires like the Schultz Fire of 2010 have major impacts on the forest ecosystem and hydrology of the Mogollon Rim and the people that inhabit the region. Research will continue on the Schultz Fire for many years to document changes in the landscape and post-fire ecosystem recovery.

References

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