Scaling Post-fire Effects from Hillslopes to Watersheds: Processes, Problems, and Implications

Lee H. MacDonald[1], Dan Brogan[2], Peter A. Nelson[2], Stephanie Kampf[1], and Joe W. Wagenbrenner[3]
[1]NREL and Department of Ecosystem Science and Sustainability, Colorado State University
[2]Department of Civil and Environmental Engineering, Colorado State University
[3]Pacific Southwest Research Station, USDA Forest Service

Abstract. Over the last two decades we have made considerable progress on understanding and predicting the effects of wildfires on runoff and erosion at the hillslope scale. One cannot, however, sum up the hillslope-scale effects to predict what happens downstream because of the scale-dependent changes in driving variables and controlling processes; yet resource managers need an understanding and some predictive capability to assess post-fire risks and guide post-fire treatments. Our objectives are to: 1) show how scaling varies even at the hillslope to sub-watershed scales (<1 km^2); 2) summarize the results of our four-year study on post-fire erosion and deposition at different spatial scales in two 15 km^2 watersheds after the High Park Fire in Colorado; and 3) discuss the implications of this and other studies for predicting post-fire sediment deposition and delivery at the watershed scale for different site conditions and storm events.

At scales of up to about 1 km^2 unit-area sediment yields typically decline with increasing area and especially with increasing slope lengths, but the magnitude of these declines varies with soils, topography, vegetative recovery, and the dominant runoff and erosion processes. Intensive field surveys and lidar differencing in two 15 km^2 watersheds after the 2012 High Park Fire showed a predominance of sediment deposition in the valley bottoms. In contrast, channel incision was dominant during snowmelt due to the limited overland flow and surface erosion at the hillslope scale. Similar depositional trends have been observed at the watershed scale in other studies, but the September 2013 flood in our study area reversed this depositional pattern with the sustained high flows removing nearly all of the post-fire sediment and extensively expanding and coarsening the downstream channels. Volume changes for 50-m channel segments over four different time periods were only weakly correlated with channel width, slope, confinement, maximum 30-minute rainfall intensity, and burn severity. Nevertheless, we believe that a process-based understanding--when combined with morphometric data, burn severity, and a specified rainstorm--can crudely assess post-fire flooding, erosion, and deposition risks at scales of perhaps 20-50 km^2. At larger scales post-fire risks should diminish based on observed decreases in unit area peak flows and sediment delivery in unburned watersheds, but this has yet to be clearly documented for burned conditions. More explicit assessments of changing effects over different spatial scales are essential to better evaluate risks to life, property, and water quality as well as guide post-fire hillslope rehabilitation treatments.