Post-Fire Sediment Flux of the Day Fire, California

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Hillslope transport rates in steeplands often increase dramatically following wildfires. Hillslope material transported by post-fire ravel processes is the primary source for sediment entrained in hazardous debris flows, which tend to initiate during intense rainfall. We used sediment traps to assess post-fire hillslope transport rates in steeplands burned by the 2006 Day fire in the Transverse Ranges of southern California. We installed seven sediment traps flush with the ground surface on relatively planar hillslopes ranging in gradient from 0.3 to 0.76 within two geologic parent materials: Mesozoic plutonic rocks and Miocene conglomerate and sandstone. Traps were installed within 2 to 4 weeks of fire containment while ravel was on-going. In the first month following fire containment, we observed widespread dry ravel and grain flows of cohesionless granular material occurring in response to localized turbulent wind bursts and solar-driven thermal variations. We collected sediment at <1 month intervals between October 2006 and July 2007, air dried samples, and then manually sieved and weighed them for particle size determination. The sediment mass acquired from each trap emptying interval was converted to a sediment flux per unit contour width. A nearby anemometer provided estimates of wind direction and speed.

Particle size distribution of sediment accumulated in the traps remained relatively uniform throughout the monitoring period with no apparent immediate spike in post-fire, fine-grained ashy material. Ravel from the Miocene sediment is largely gravelly sand, while that derived from Mesozoic plutonic rocks is a sandy gravel grus. Sediment flux from all seven traps ranges over 2 orders of magnitude from 0.002 to 0.5 $m^3m^{-1}yr^{-1}$, lower on gentle slopes and higher on steeper slopes, independent of parent material. Plots show an exponential relation between cumulative sediment flux and local hillslope gradient, consistent with a non-linear relation between flux and gradient found by others. The departure from a flux law that is linear with slope occurs at ~0.8. Four of seven sediment traps recorded the highest sediment fluxes per trap-emptying interval prior to the onset of rain, with 6 to 32% of their total mass for the entire monitoring period accumulating during dry conditions. Sediment accumulation at these four traps correlates closely with both average wind speed and time-integrated wind speed. The remaining three traps record their highest fluxes in response to the first post-fire storms, despite their minimal precipitation, representing only 11% of seasonal precipitation. For all the sediment traps, these relatively small early-season rainstorms generated between 20 and 55% of the total accumulated sediment mass. In contrast, the largest rainfall event, producing 50% of the total seasonal rainfall, generated only moderate sediment fluxes, and late-season rain and wind events, albeit larger, did not have commensurately high sediment fluxes.

These observations indicate that large volumes of sediment were transported under dry conditions and in response to the first rain storms. As a result, many slopes >0.65-0.7 were stripped to bedrock during the course of monitoring. Soil pits downslope in valley bottoms indicate aggradation of 0.25 m with a maximum fill exceeding 0.5 m. The combination of observed bedrock emergence and decreases in sediment flux recorded by the traps through the high rain and wind events indicates that these hillslopes converted from transport-limited to supply-limited conditions within months following the fire. Much of the sediment transported off the steep hillslopes aggraded the low-order channel network, which provides ample material for potential entrainment in future debris flows or floods.