Geophysical Research Abstracts
Vol. 16, EGU2014-15748, 2014
EGU General Assembly 2014

Predicting the delivery of sediment and associated nutrients from post-fire debris flows in small upland catchments

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Post-fire debris flows are extreme erosion events that can dominate the long term supply of sediment from headwaters to streams in upland catchments. Predicting the location, frequency and magnitude of debris flows is therefore important for understanding sediment dynamics in upland catchments and providing a basis on which to manage hydro-geomorphic risk in burned areas. In this study we survey 10 post-fire debris flow events in southeast Australia with aims to i) identify rainfall conditions underlying the debris flow response, ii) quantify erosion rates in hillslope and channel source areas, and iii) estimate the delivery of sediment and water quality constituents to receiving waterways. Rainfall events that triggered debris flows had an annual exceedance probability ranging from 0.1 to 0.6, and 30-minute intensities, I_{30}, ranging from 17-60 mm h^{-1}. Sediment delivery by debris flows (100-200 t ha^{-1}) is similar to that which has been reported for similar events in the western US and Spain. In terms of eroded volume, there was on average an equal contribution from hillslopes and channels to debris flows, which is in agreement with the calculations of surface and subsurface source contributions obtained from radionuclide concentrations. In terms of the potential water quality impacts from post-fire debris flows, the hillslopes had much higher concentration of constituents such as fine clay and silt, plant available phosphorous and total carbon. The data on debris flow magnitude was used to evaluate two different approaches for predicting sediment delivery from debris flows. A statistical debris flow model developed by the US Geological Surveys and parameterized for catchments in western US performed well (R^2 = 0.92) in terms of predicting the overall volume of material delivered at the catchment outlet. An alternative modeling approach, using local slope and contributing area as predictors of erosion, also produced good results, and could be used to obtain more detailed predictions of sediment entrainment, deposition, the overall source contribution and the associated constituents. Future work will aim to link models of debris flow magnitude with models of initiation and debris flow frequency after fire.