A probabilistic approach for channel initiation

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Abstract. The channel head represents an important transition point in hillslope erosion processes. There is a nonlinear threshold transition across the channel head with soil loss much larger in channels than on hillslopes. This has stimulated considerable research into the location of channel heads in the landscape. Recently this research has used digital elevation models (DEMs) and quantities derived from DEMs, most notable slope, S, and specific catchment area, a. Deterministic specific catchment area thresholds for channel initiation sometimes dependent on slope have been suggested, for example $aS^{\alpha}>C$. In this paper we suggest that the channel initiation problem be viewed probabilistically with a spatially variable probability of channel initiation that depends on slope and specific catchment area and the probability distributions of median grain size (d_{50}), surface roughness and excess rainfall rate. A probabilistic approach is important because it can quantify the likelihood of enhanced erosion due to channelization from areas where a deterministic approach may have indicated unchanneled terrain. In our study areas in the Idaho Batholith we measured slope, specific catchment area and d_{50} at field located channel heads. We show that a channel initiation threshold based on our d_{50} measurements explains a significant part of the observed variability in the threshold function involving specific catchment area and slope (aS^{α}) at channel heads. We then characterize the variability of model inputs (d_{50}, roughness and excess precipitation rate) using probability distributions and show that the probability distribution of area slope threshold derived from these inputs matches the probability distribution of area slope thresholds measured at field channel head locations. A gamma probability distribution provides a reasonable match to the distributions of area-slope threshold measured and modeled at channel heads. We also show that a similar gamma probability distribution matches the distribution of area slope thresholds in other published channel head data.

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