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Inter-replicate and duration-related systematic variability: does enrichment of soil organic carbon last forever?

Yaxian Hu, Wolfgang Fister, and Nikolaus Kuhn
Basel University, Basel, Switzerland (yaxian.hu@unibas.ch)

Sediment generated by interrill erosion processes is often reported to be enriched in soil organic carbon (SOC). To assess SOC loss by erosion, the amount of eroded sediment is often multiplied with the average organic carbon content in the eroding soil and the average enrichment ratio of SOC in sediment. However, the complex interaction between rainfall, runoff and soil crusting renders SOC erosion to be highly variable over time. Apart from the inherent variability of crust formation and soil erosion that may affect SOC enrichment, conservation of mass dictates that the enrichment ratio of SOC in sediment must be balanced over time by a decline of SOC in the source area material. The use of average enrichment values, or values obtained from short erosion measurements, is therefore likely to generate a high uncertainty in estimating SOC loss over longer events. Similar errors are also likely to occur as a consequence of applying SOC erosion data generated based on current rainfall characteristics to estimate SOC loss in the future with changing rainfall magnitudes. This study is designed to measure and quantify the effects of two types of variability onto SOC erosion: 1) inter-replicate variability under laboratory conditions caused by the non-eliminable variations of rainfall characteristics, soil properties, erosion and crusting, as well as 2) the systematic variability related to event duration.

Two silty loams were subjected to a simulated rainfall of 30 mm h-1 intensity for 360 min. Runoff and soil erosion rates were recorded every 30 min. The whole rainfall event was repeated 10 times to enable the variability of the erosional response to be statistically determined. Two-step erosion models were developed based on the infiltration, runoff and soil erosion data obtained from six selected event durations of 60, 120, 180, 240, 300 and 360 minutes, all of which aimed to systematically quantify the crust formation induced changes of SOC erosion.

The results show that: 1) the enrichment ratios of SOC dropped to unity or even below 1 during prolonged crusting, confirming that preferential erosion is limited by depletion of SOC on the eroding soil surface; 2) the inter-replicate variability of runoff and soil erosion rates declined considerably over rainfall time. Yet, even after maximum runoff and erosion rates were reached, the inter-replicate variability still remained between 15 and 39%, indicating the existence of significant inherent variability; and 3) the increasingly improved predictions with extending event durations suggested that observations from short events cannot be directly extrapolated to predict soil and SOC loss over prolonged events, and vice versa. Apart from identifying significant inter-replicate variability, the results demonstrate the need to place SOC erosion data used for modeling past and future events into the proper context of rainfall characteristics and soil surface conditions.