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Using semi-variogram analysis for providing spatially distributed information on soil surface condition for land surface modeling

Holly Croft (1), Karen Anderson (1), and Nikolaus J. Kuhn (2)
(1) University of Exeter, United Kingdom (H.Croft@exeter.ac.uk), (2) University of Basel, Switzerland

The ability to quantitatively and spatially assess soil surface roughness is important in geomorphology and land degradation studies. Soils can experience rapid structural degradation in response to land cover changes, resulting in increased susceptibility to erosion and a loss of Soil Organic Matter (SOM). Changes in soil surface condition can also alter sediment detachment, transport and deposition processes, infiltration rates and surface runoff characteristics. Deriving spatially distributed quantitative information on soil surface condition for inclusion in hydrological and soil erosion models is therefore paramount. However, due to the time and resources involved in using traditional field sampling techniques, there is a lack of spatially distributed information on soil surface condition. Laser techniques can provide data for a rapid three dimensional representation of the soil surface at a fine spatial resolution. This provides the ability to capture changes at the soil surface associated with aggregate breakdown, flow routing, erosion and sediment re-distribution. Semi-variogram analysis of the laser data can be used to represent spatial dependence within the dataset; providing information about the spatial character of soil surface structure.

This experiment details the ability of semi-variogram analysis to spatially describe changes in soil surface condition. Soil for three soil types (silt, silt loam and silty clay) was sieved to produce aggregates between 1 mm and 16 mm in size and placed evenly in sample trays (25 x 20 x 2 cm). Soil samples for each soil type were exposed to five different durations of artificial rainfall, to produce progressively structurally degraded soil states. A calibrated laser profiling instrument was used to measure surface roughness over a central 10 x 10 cm plot of each soil state, at 2 mm sample spacing. The laser data were analysed within a geostatistical framework, where semi-variogram analysis quantitatively represented the change in soil surface structure during crusting. The laser data were also used to create digital surface models (DSM) of the soil states for visual comparison.

This research has shown that aggregate breakdown and soil crusting can be shown quantitatively by a decrease in sill variance (silt soil: 11.67 (control) to 1.08 (after 90 mins rainfall)). Features present within semi-variograms were spatially linked to features at the soil surface, such as soil cracks, tillage lines and areas of deposition. Directional semi-variograms were used to provide a spatially orientated component, where the directional sill variance associated with a soil crack was shown to increase from 7.95 to 19.33. Periodicity within semi-variogram was also shown to quantify the spatial scale of soil cracking networks and potentially surface flowpaths; an average distance between soil cracks of 37 mm closely corresponded to the distance of 38 mm shown in the semi-variogram. The results provide a strong basis for the future retrieval of spatio-temporal variations in soil surface condition. Furthermore, the presence of process-based information on hydrological pathways within semi-variograms may work towards an inclusion of geostatisically-derived information in land surface models and the understanding of complex surface processes at different spatial scales.