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Soil erosion monitoring at small scales: Using close range photogrammetry and laser scanning to evaluate initial sediment delivery

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Soil erosion represents one of the most significant environmental problems of the 21st century with severe impacts on terrestrial ecosystems. Traditionally, soil losses by water are determined by runoff plots in situ. Micro-scale devices (<1 m length) are commonly used to monitor soil erosion rates in comparative field studies. This is especially the case in ecological-pedological experiments, investigating e.g. the effect of plant characteristics on erosion processes. The small plot size allows to focus precisely on interrill processes with the smallest possible set of confounding factors and a high number of replications. However, the runoff plot method is labour- and time-intensive, sediment handling can be challenging and the measurement accuracy varies importantly with the applied control of the measurement setup.

To optimize the acquisition of small-scale erosion data from splash and interrill processes, digital methods become more and more of interest. Therefore, we compared the use of photogrammetry with a) terrestrial and b) airborne (UAV) single lens reflex (SLR) cameras as well as c) a terrestrial laser scanner (Leica Scanstation P40) to determine event-based initial erosion rates. Rainfall simulations with the Tübingen rainfall simulator and micro-scale runoff plots (0.4 m × 0.4 m) were conducted on two substrates: a Hortic Anthrosol and sieved sand (0.10-0.45 mm). Runoff plots were exposed to rainfall events with an intensity of 60 mm h^{-1}. The measurements were repeated 5 times per substrate for each method and images of the runoff plot surfaces were captured before and after every event. The overlapping SLR images were processed in Agisoft PhotoScan (Structure from Motion - SfM) to process digital surface models (DSMs) with sub-millimetre resolution (a + b). Laser scans were processed with Leica Cyclone and ESRI ArcGIS (c). We assessed the volume of detached sediment by calculating the differences between multi-temporal DSMs or point clouds. After every rainfall simulation, the discharged sediment was weighed to derive the ground-truth for validation.

The results showed that photogrammetry with digital cameras as well as the use of laser scanners are principally suitable methods to create small-scale 3D point clouds and to map topography differences necessary for initial erosion rate calculation. The processing with common software systems, however, proves to be challenging and high precision is required for recording in the

field. All methods overestimated the erosion rates with differences to the weighed sediment delivery from 14 to 45 %. The accuracy was higher for uniform sand than for the Anthrosol treatment. The SfM approach with digital cameras derived better results than the laser scanner used in this study. The terrestrial use of cameras was superior to the airborne use in this small-scale setup, because of the necessary flight altitude to avoid air turbulences on the soil surface. Further development of the measuring techniques and their precise application in the field as well as adapted software processing are still needed. Nevertheless, the methods tested show promising possibilities even for small-scale erosion measurements. Ideas and further suggestions on improvements will be presented at the EGU 2020.