Experimental investigation of particle detachment by raindrop impact: three-dimensional measurements of particle trajectory and velocity

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The detachment of soil by raindrop impact is an important transport mechanism within the process of soil erosion. Not only is the energy available for raindrop detachment several orders of magnitude greater than that available for interrill and rill erosion, but also much of the sediment transported through runoff processes is initially detached by raindrop impact. Consequently, further understanding of the raindrop-detachment process is fundamental to the development of soil-erosion models and their predictive capabilities. Recent investigations using high-speed imaging have been carried out by Furbish and colleagues, and this work has contributed important information about splash travel distances from dry surfaces and has provided insight into the mechanism of grain movement. However, these imaging studies have been two-dimensional in nature, with results limited in the range of conditions examined. Also, no information has been provided on the specific particle trajectories, which is needed to provide a mechanistic understanding of the role of this process in soil erosion.

In the present study, the detachment of sand particles by raindrop impact is investigated using multiple, high-speed cameras. This experimental arrangement and subsequent analysis provides data on particle trajectory and velocity, in all three dimensions of space, during the impact, detachment, transport and deposition processes. In addition to these ballistic measurements, photogrammetry is utilised to analyse the change in surface morphology caused by a single droplet impact. Through these measurements, both particle-travel distance and the total amount of detachment are investigated, providing valuable insight into raindrop-erosion processes. Results demonstrate the influence of the interactions of particle size and droplet characteristics on detachment and transport on different slope angles.

The results from this work (1) provide a first evaluation of the link between rates of splash and raindrop detachment thereby overcoming a major limitation in existing understanding of the dynamics of erosion processes; (2) suggest that the mechanics of splash are more complex than hitherto suspected; and (3) enable the dynamics of raindrop interactions with dry and wet surfaces to be evaluated. These methodological advances underpin the development of more realistic characterizations of the dynamics of raindrop, flow and erosion processes.