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CONFERENCE PAPER · APRIL 2013

DOI: 10.13140/2.1.2874.9124

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Geophysical Research Abstracts
Vol. 15, EGU2013-11427-1, 2013
EGU General Assembly 2013

Integrating Novel Field, Laboratory and Modelling Techniques to Upscale Estimates of Soil Erosion

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Erosion is a particle-based phenomenon, yet most of current understanding and modelling of this process is based on bulk measurements rather than the movement of individual particles. Difficulties with measuring particle motions in dynamically changing conditions are being overcome with the application of two new technologies – particle imaging velocimetry (PIV) and radio frequency identification (RFID). It is thus possible to evaluate the entrainment, transport and deposition of individual particles and these data can be used to parameterize and to test particle-based modelling of the particle-based process.

Both PIV and RFID tagging have been used in laboratory experiments to evaluate the detachment process by raindrops on bare surfaces and in shallow flows using rainfall simulation. The results suggest that the processes are more complex than hitherto thought with multiple detachment and transfer mechanisms. Because both mechanisms affect travel distance, they affect the ways in which estimates of soil erosion can be scaled from plot to hillslope and catchment scales. To evaluate movements at larger scales, we have also used RFID-tagged particles in field settings to look at sediment transfers following the Fukushima accident in Japan, 2011.

A marker-in-cell model (MAHLERAN-MiC) has been developed to enable the laboratory results to be up-scaled and tested in a field setting. Markers (representing sediment particles), containing sediment-property information, are initially distributed on a cellular grid. A cellular model is used to set up the boundary conditions and determine the hydrology and hydraulics on the hillslope. The markers are then moved through the grid according to these properties. This technique combines the advantages of Eulerian and Lagrangian methods while avoiding the shortcomings of each (computational efficiency vs. accuracy). The model simulates all the processes of detachment and transport; raindrop detachment and transport, interrill erosion, concentrated erosion (bedload transport) and suspended sediment transport. We demonstrate how distributions of travel distances change as spatial and temporal scales of application change, and thereby how the laboratory and field experiments can be best used to develop more robust approaches to the upscaling of estimates of erosion rates.