Towards Quantitative Real Time Tracing of Soils and Sediment: Using Fluorescent Soil Particles and Image Analysis

J.N. Quinton[1], R.A. Hardy[2], J.M. Pates[3], M.R. James[4]

Soil and sediment are important vectors for the transport of pollutants in the environment, including nutrients, pesticides and metals; therefore, the fate of many chemicals in soil systems is closely linked to that of sediment. Understanding the mechanisms responsible for sediment transport and linking sources to sinks has been hampered by the lack of suitable tracers. In this paper we report on two developments.

1. Development of a clay tracer. Producing a tracer that accurately mimics clay transport is challenging, due to the small size of the particles and their unique physical properties. Here we describe the design and synthesis of a tracer using natural clay particles as a foundation, exploiting the natural ability of clay to sorb molecules to coat the clay with a thin layer of fluorophore. Application of the tracer has been demonstrated through the collection of real-time images of the tracer moving over the surface of a small soil box during a simulated rainfall event (Figure 1). These images allow, for the first time, clay to be tracked spatially and temporally without the need to remove soil for analysis, thus resulting in minimal experimental artifacts. Custom written software has been used to extract high resolution data describing tracer movement and extent throughout the experiment.

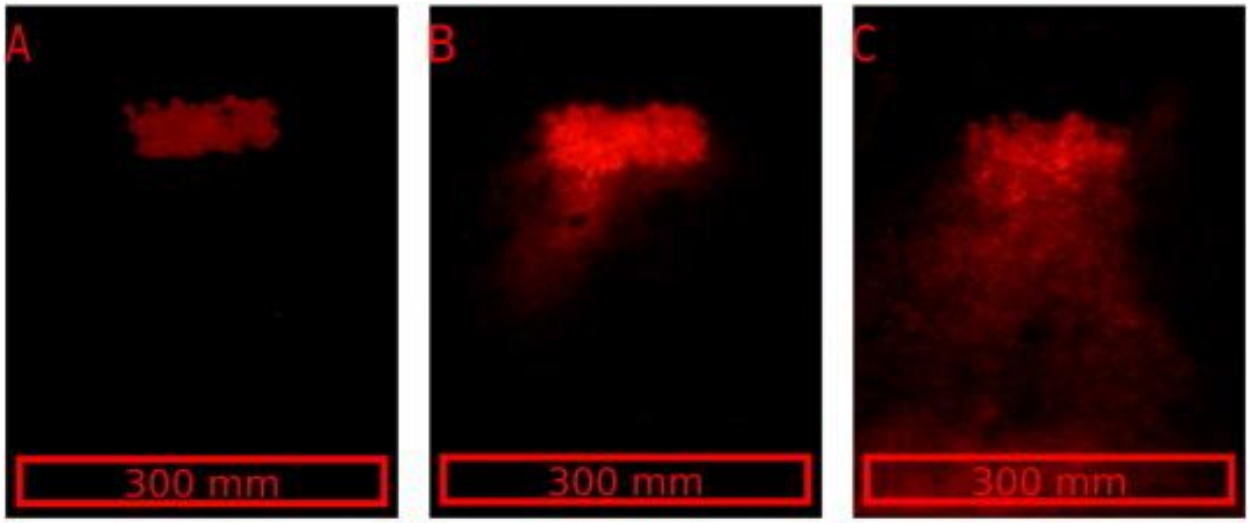

Figure 1. True color images of soil box (top of box at top of image) showing tracer location at various times. A was before exposure to rain, B after 262 s of rain, and C after 2252 s. After 0 s the tracer was constrained to the area where it was applied. After 262 s the tracer had moved down the box and spread laterally, further movement and lateral spreading continued until the experiment was ended at 2252 s. Transport pathways of clay from the top of the box to the bottom can be observed together with a depositional area which formed at the bottom edge of the box (from Hardy et al., 2016).

[1]John N. Quinton, Professor, Lancaster Environment Centre, Lancaster University, Lancaster, United Kingdom; [2]Robert A. Hardy, Ph.D. Candidate, Lancaster Environment Centre, Lancaster University, Lancaster, United Kingdom; [3]Jacqueline M. Pates, Senior Lecturer, Lancaster Environment Centre, Lancaster University, Lancaster, United Kingdom; [4]Michael R. James, Senior Lecturer, Lancaster Environment Centre, Lancaster University, Lancaster, United Kingdom. Corresponding author: J.N. Quinton, email: J.Quinton@lancaster.ac.uk.

2. Quantitative tracing of sand sized particles. Here we present a novel technique which can give insight into the movement of individual soil particles. By combining novel fluorescent videography techniques with custom image processing and a fluorescent soil tracer we have been able to trace the motion of multiple individual soil particles under rainfall. The system is able to track multiple sub-millimeter particles simultaneously, establishing their position 50 times a second with sub-millimeter precision (Figure 2) and to calculate a range of metrics including average (Figure 3) and instantaneous velocities.

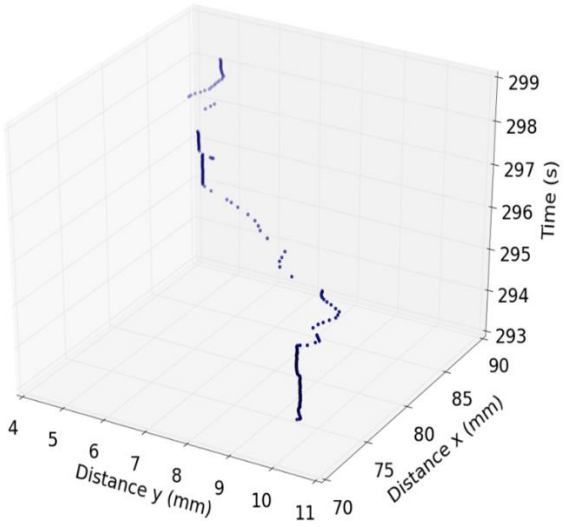

Figure 2. Positions of a single sand grain during a simulated rainstorm.

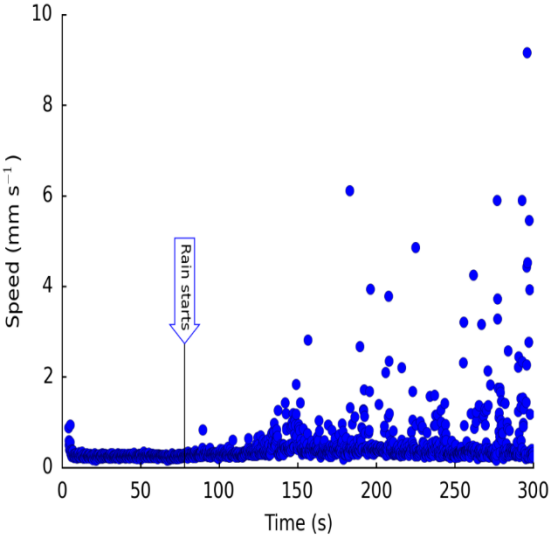

Figure 3. Average speed of each particle detected at time intervals within the simulated rainfall event.

It is hoped that these approaches will allow us to better understand and track the movement of sediment through the environment and open up new opportunities to create, parameterize and evaluate soil erosion models, as the motion of individual soil particles can now be tracked.

References

Hardy, R.A., J.M. Pates, J.N. Quinton, and M.P. Coogan. 2016. A novel fluorescent tracer for real-time tracing of clay transport over soil surfaces. Catena 141: 39-45.