High precision laboratory rainfall experiments on particle transport distance using fluorescent tracers

COST Action: ES 1306 "Connecteur"

STSM Reference Number: COST-STSM-ES1306-35738

STSM Beneficiary: Dr. Wolfgang Fister, Physical Geography and Environmental Change Research Group, Department of Environmental Sciences, University of Basel, Basel Switzerland.

Host Institution: Prof. Dr. John Quinton, Lancaster Environment Centre, Lancaster University, Lancaster, United Kingdom.

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1. Introduction

The connectivity of sediment transport through the landscape is controlled by many different factors. Besides environmental factors such as soil surface properties, land management and vegetation cover, the most dominant ones being rainfall and surface flow characteristics as well as their interactions. So far, very little is known about the specific transport modes and transport velocities of sediment particles in interrill areas. A conceptual model of particle detachment and movement in raindrop impacted thin surface flows exists (*Kinnell* 2005), however, the experimental proof of this theory is still lacking. This is especially relevant for very thin surface flows, particularly below depths of 3-4 mm, our physical understanding of basic soil detachment and transport processes is not good enough to improve the precision of present physical soil erosion models.

2. Purpose of the STSM

At the high precision rainfall laboratory at the University of Basel, we are currently trying to tackle this problem experimentally. With our current setup we are able to very precisely control and monitor rainfall and surface flow characteristics, i.e. depth of surface flow and flow velocity. Thus we are able to obtain very valuable data on the physical interaction between raindrop kinetic energy, water depth and flow velocity with regards to total particle detachment (*Greenwood et al.* 2013). However, with the current setup we are only able to acquire average transport distances for the bulk material, which is not precise enough to further improve our understanding of individual particle movement in raindrop induced thin surface flows. At the host institution, a new soil tracing technique using fluorescent tracers in combination with videography analysis has recently been developed for sand (*Hardy et al.* 2017) and clay sized particles (*Hardy et al.* 2016). In future, this method will hopefully be able to deliver the high resolution data on individual particle travel pathways that are necessary to further improve our process-based understanding. With these factors in mind, the main aim of this STSM was, therefore, to create an opportunity to exchange knowledge of each other's highly specialized experimental methods through joint experiments and extensive discussions. Through this knowledge transfer, the research team in Basel should be able to integrate this method into their existing experimental setup, in order to further test this newly developed tracer technique under very precise conditions, including thin surface flows. Furthermore, the STSM will allow both parties to foster cooperation and to link the teams from both departments closer together, to start an initiative consisting of common research projects and concomitant publications.

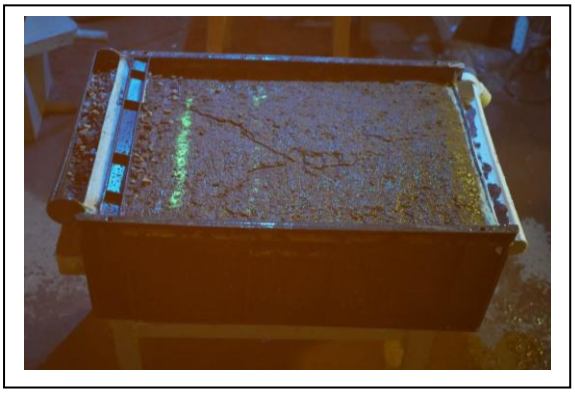
3. Description of the Work

During the first few days, the applicant was introduced to the rainfall laboratory facilities and the experimental setup at the Environmental Centre at Lancaster University. A special focus was put on the specifications of the camera and video recording as well as the optical filter that was used to detect the fluorescent tracer. Two PhD-students from the host institution supported the applicant during this familiarization process, which, in-turn created the opportunity for them to learn more about the basic concepts and the calibration techniques of rainfall simulators from the applicant. This mutual transfer of knowledge about the use of rainfall simulations was further facilitated through a joint doctoral seminar involving the whole research group of the host institution, plus a visit to the project field site of the students.

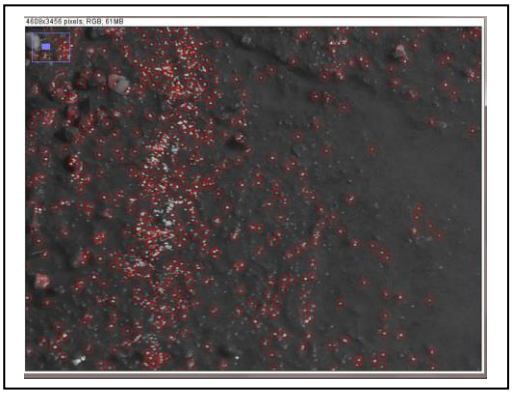
After the initial calibration of the rainfall simulator had been accomplished, initial test experiments on a soil plot were executed. A few experiments were enough to show clear evidence of the advantages of the tracer method over the method presently used at the University of Basel. Most importantly, the detection of individual particle pathways over time proved to be very promising. However, as soon as the surface flow reached certain turbidity, a major problem of the new method became apparent. The individual tracer particle could not be detected during the experiment anymore, because of the high particle content in the surface

flow. After the surface flow drained away, some of the tracer particles were covered under a thin soil layer. Until now, we have not been able to quantify the amount of the hidden/submerged tracer, but we think this could create some problems, especially when working with soils under controlled surface flows and not just on sand particles. Not necessarily a solution to this problem, but an improvement on the technique could also include factoring in the magnetic signature of the tracer applied. By using a Magnetometer, it could perhaps be possible to quantify the covered tracer particles. But in the absence of a Magnetometer, this idea needs to be tested in future experiments as well.

A major part of the available work time was used to find and test a freeware particle tracing software that could substitute the presently used Python codes. By using freely available and continually maintained windows based software, it would be possible to analyze the obtained images without in-depth knowledge of programing. A software that seemed to work reasonably well is ImageJ, including the "Mosaic Particle Tracer 2D/3D" plugin (*Sbalzarini and Koumoutsakos*, 2005), which was tested among the best algorithms for particle tracking under various test configurations (*Chenouard et al.* 2014).



Soil plot with fluorescent tracer



Screenshot of particle detection using ImageJ

In conclusion, we can say that although this STSM is not at present data-rich, it was a great success in terms of laying foundations and paving the way for our two departments to collaborate together in the future. A lot of information could be shared, initial thoughts about joint future research ideas could be exchanged and most importantly, both institutions have learned a great deal about each other's methods, so that the adaptation of the methods at the applicant's home institution should be feasible. In addition, a short return visit from the host, John Quinton, to the University of Basel was scheduled for the end of this year.

4. Contribution to the Aims of the COST Action ES 1306

This STSM contributes to the main aim of the COST Action ES 1306, which is to share and transfer knowledge between scientists to enable them to use and/or improve the facilities at their respective institutions. The outcome of the future collaboration between the host and the applicant, and the expected outcome of the planed experiments, will most probably refine our conceptual understanding of the different particle transport modes in shallow overland flows (Working Group 1). In addition, the improvements to the varying experimental setups in Basel and Lancaster could create a common template on how to measure particle movement in the future (WG 2). Finally, the obtained high resolution and precision data could be used to parameterize and validate a new generation of soil erosion models that describe particle movement more specifically (WG 3).

5. Confirmation by the host institution of the successful execution of the STSM

A letter confirming the successful execution of the STSM by the host, Prof. Dr. John Quinton, is attached in a separate file.

6. Authorization to post the report at the Action website

Herewith I give my authorization to post this report on the COST Action ES 1306 website.

Dr. Wolfgang Fister

Basel, Switzerland

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