Different tools to characterise rainfall events at the laboratory scale

S. Jomaa[1], J. Jaffrain[2], B.C.P. Heng[3], D.A. Barry[1], A. Berne[2], G.C. Sander[3]

[1] Laboratoire de technologie écologique, École Polytechnique Fédérale de Lausanne (EPFL), Switzerland (seifeddine.jomaa@epfl.ch, andrew.barry@epfl.ch))
[2] Laboratoire de télédétection environnementale, École Polytechnique Fédérale de Lausanne (EPFL), Switzerland (joel.jaffrain@epfl.ch,alexis.berne@epfl.ch)
[3] Department of Civil and Building Engineering, Loughborough University, United Kingdom (b.c.p.heng@lboro.ac.uk, g.sander@lboro.ac.uk)

1. Motivation and objectives

Rainfall simulators are beneficial tools for studying soil erosion processes and sediment transport for different circumstances and scales. They are useful to better understand soil erosion mechanisms and to develop and validate process-based erosion models. Simulators permit experimental replicates for both simple and complex configurations. The 2-m × 6-m EPFL erosion flume is equipped with a hydraulic slope control and a sprinkling system located on oscillating bars 3 m above the surface. It provides a near-uniform spatial rainfall distribution. The intensity of the precipitation can be adjusted by changing the oscillation interval. The flume is filled to a depth of 0.32 m with an agricultural loamy soil. Raindrop detachment is an important process in interrill erosion, the latter varying with the soil properties as well as the raindrop size distribution and drop velocity. For better prediction of the raindrop detachment, an accurate characterization of the rainfall event can potentially support erosion calculations and sediment transport predictions. In order to achieve this and to better characterize the simulated rain, different techniques were used: (i) Digital terrain model (DTM), (ii) drop size distribution (DSD) and (iii) splash cups.

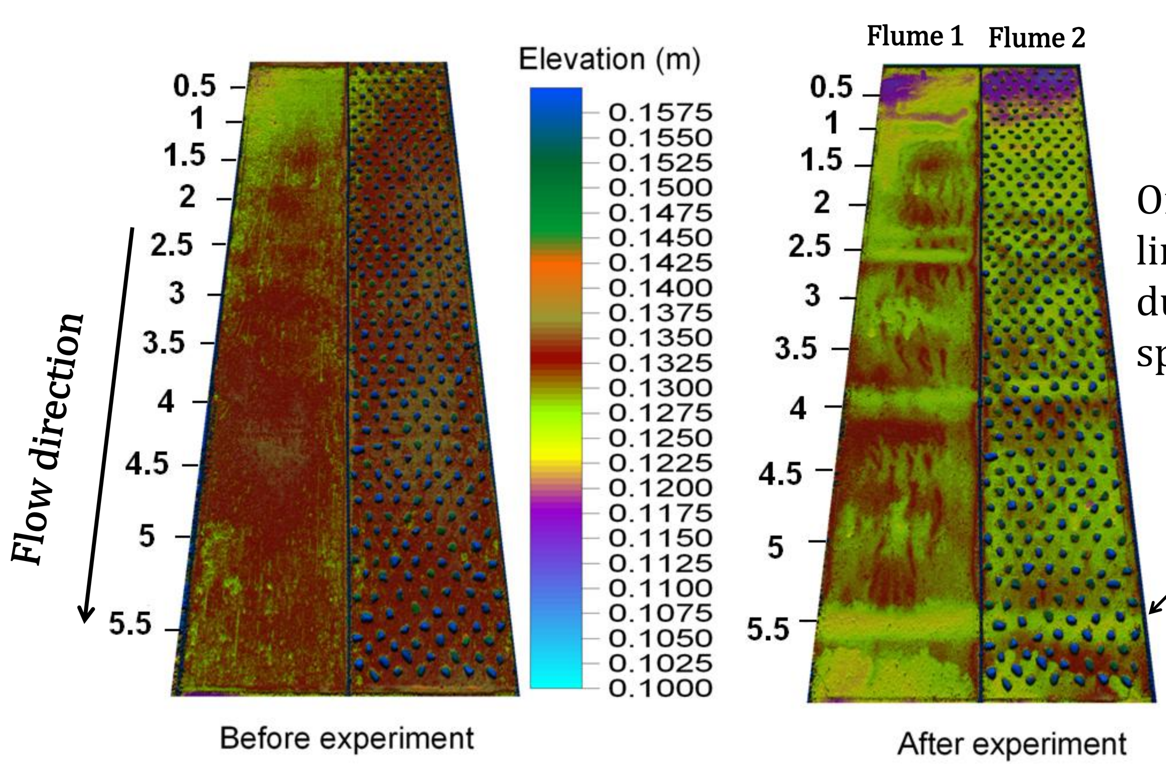
2. Digital Terrain Model Investigation

Laser scanning of the soil surface was carried out before and after the experiment and digital terrain models (DTM) were generated and compared, in order:

- to understand better the spatial distribution of the rainfall event;
- to identify whether surface non-uniformity has had in impact on sediment transport;
- to determine whether sediment transport during the erosive event should be modelled as 1D or 2D process.

1 - The DTM after the experiment shows four lines transversal to the flow direction. These roughly parallel depressions are at distances 1, 2.5, 4 and 5 m from the top of the flume. As these four regions occurred exactly half way between the five pairs of sprinklers, it follows that the zone with greater erosion are due to the increased precipitation rate - and detachment rate - resulting from the overlapping sprinklers.

2 - DTM shows, in the flume 2 (20% covered by surface stones), that the sediment transport is 1D and interrill erosion is the dominant process (Fig. 1). However, in flume 1 the soil erosion is not homogenous over the flume, suggesting that the sediment transport is more 2D than 1D. In addition, rills occurred in flume 1 and the overlapping behavior is more clear than in flume 2 in which the stones provide an additional protection of the original soil against rill erosion.



One of the four transversal lines due to the increased due to the overlapping sprinklers.

Figure 1. The soil surface DTM measured before and after the experiment. Data were collected using a FARO Laser Scanner (http://laser-scanner.faro.com). The effect of the flume slope was removed from the images and the same reference point was set for both scans using a known location in the flume support.

3. Drop Size Distribution Technique

Figure 2. The 2-m × 6-m EPFL erosion flume (design of experiment)

Simulated rain was characterized using two types of instruments:

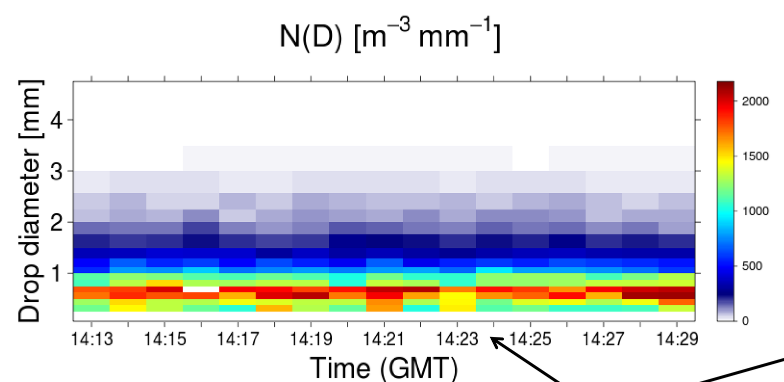
Tipping-bucket rain gauge (TB): (2)
- Précis Mécanique, France
- 400 cm^2 sampling area
- Tip resolution = 0.1 mm
- Records tipping times (0.1 s)

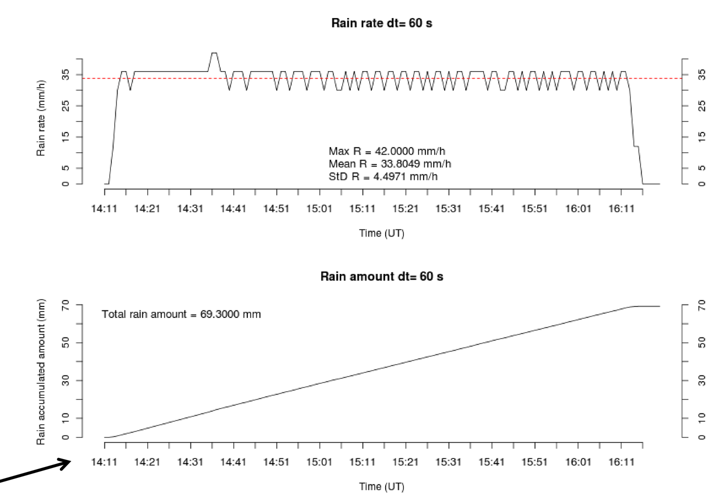
Optical disdrometer Parsivel: (1)
- OTT, Germany
- 54 cm^2 sampling area
- Based on laser attenuation
- Size and speed of drops

Experiment conducted for different rain intensities (30 to 100 mm h^{-1}).

Example of results: $R_{sim} \sim 30$ mm h^{-1}.

$R_{TB} = 33$ mm h^{-1}.
$R_{Par} = 29$ mm h^{-1}.





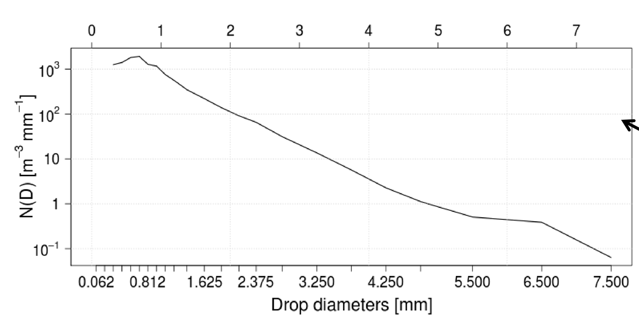
Rain rate fluctuations appear to be negligible during the experiment

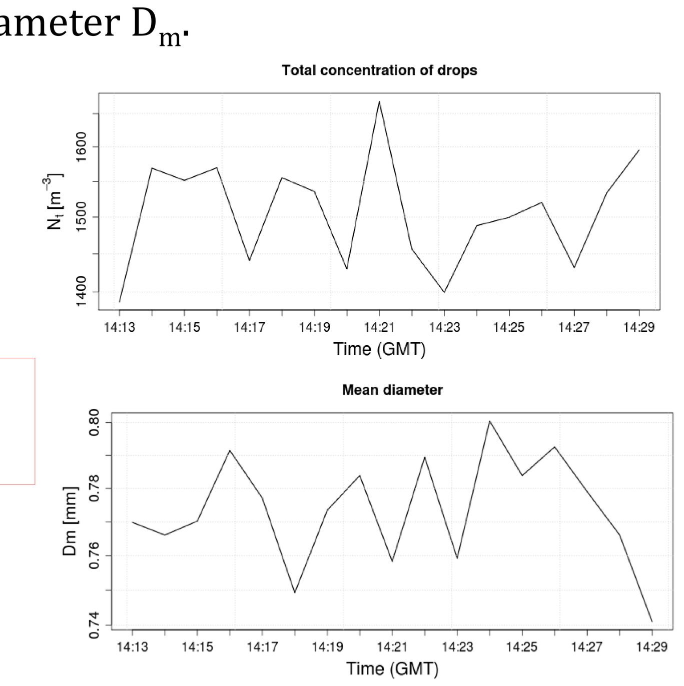
To characterize raindrop size distribution (DSD):

$$N(D) = N_t f(D).$$

- Total concentration of drops N_t.
- Mean diameter D_m.

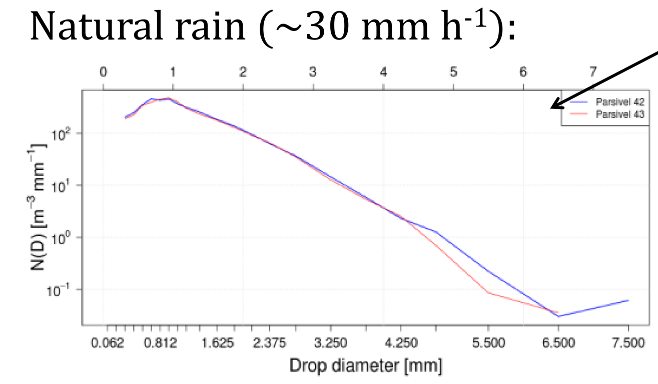
Simulated rain (30 mm h^{-1})





Simulated rain seems realistic

Natural rain (~30 mm h^{-1}):



Limitations:
Splashing affects Parsivel measurements?
Drops do not reach their terminal fall speed?

4. Splash Cups

Soil particle motion was measured locally using splash cups. These cups measured the detached material rates at different locations; one was in region where the rainfall distribution is uniform and the other one in the overlapping rainfall rate (Figs. 1 and 2). In contrast to previously reported splash cup experiments, the cups used in this study were equipped at the top with upside-down funnels, the upper part having the same diameter as the soil sampled at the bottom. This ensured that the soil detached and captured by the device was not re-exposed to rainfall.

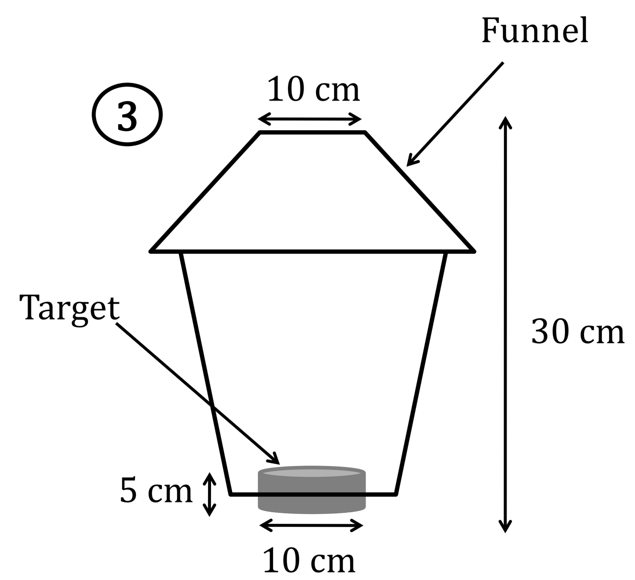


Figure 3. Schematic overview of the splash cup used in the experiment

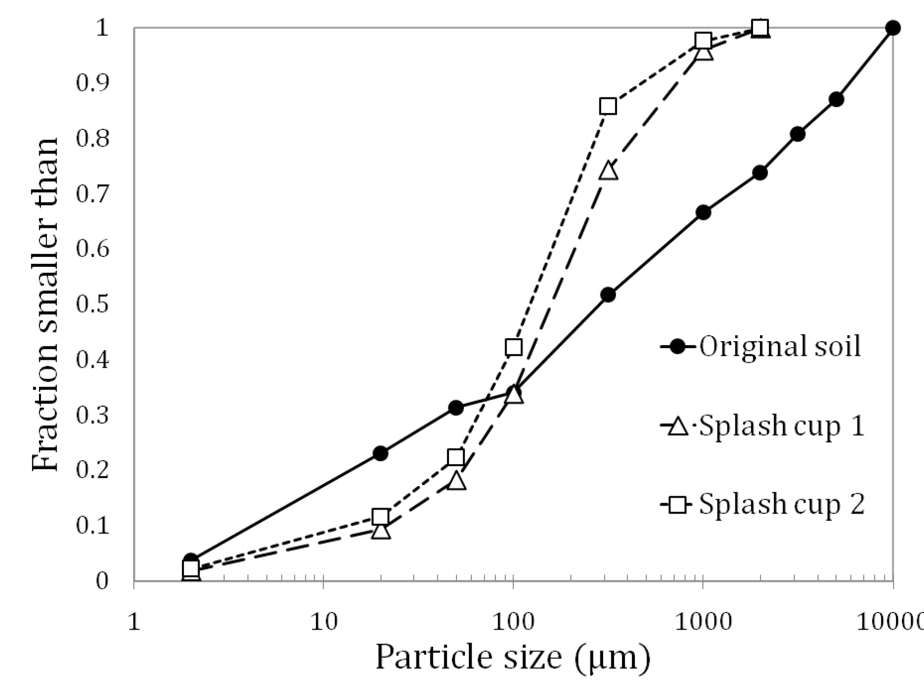


Figure 4. Comparison between the size distribution of the splashed materials in both cups against the original soil

The results show that soil particles/fragments up to a size of 2000 µm can be splashed by raindrop impact. Fig. 4 shows that the mid-size fractions (50-100, 100-315 and 315-1000 µm) were transported by the raindrop splash. However, the finer (< 2, 2-20 and 20-50 µm) and the larger particles (> 1000 µm) were less splashed.

5. Conclusions

Different tools were used to characterize the simulated rain of the 2-m × 6-m EPFL rainfall simulator. The results have shown:

- The laser scanner shows that the rainfall event is near-uniform over the flume except the five lines generated by the overlapping of the sprinklers.
- The DSD technique confirms that the simulated rain seems realistic when we compared it with an natural intensity rain (30 mm h^{-1})
- The splash-cups technique confirmed that the raindrop splash process is a selective particle size process, however, this technique could be improved more in order to define better the detachment mechanisms in soil erosion modeling.

This study was supported by the Swiss Natural Science Foundation (grants: 200021-113815 and 200021-118057/1).