Experimental setup for precise investigation of raindrop impacted thin water flows

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Background:
Small scale processes, such as splash, sheet, and interrill erosion mechanisms, can be studied with a high degree of precision and accuracy by using experimental setups with rainfall simulators over soil flumes. However, in many investigations on raindrop impacted thin water flows, difficult to measure key erosion variables are not obtained, but inferred from easier to determine parameters. For example, rainfall intensity and flow discharge are recorded to rather crudely estimate flow velocity and depth. Since flow depth and velocity vary spatially and temporally during experiments with non-controlled flow conditions, this lack of measurement accuracy clearly reduces the explanatory power of the experimental data.

Aim:
Development of an experimental setup and procedure in order to be able to control and manipulate the key factors of the processes of raindrop impacted thin surface flows, i.e. flow depth, flow velocity, and rainfall kinetic energy.

Objectives:
1. Development of a very precise rainfall simulator (drop former) to produce homogenous and constant rainfall.
2. Development of an erosion flume with controllable water depth and flow conditions.
3. Development of a measurement method to verify actual flow depth.

Experimental setup:

Fig. 1: a) Overview of experimental setup, including erosion flume and rainfall simulator mounted on hydraulic lift. b) Setup of flow meters to control water discharge and rainfall intensity. c) Frontal view of erosion flume with coated weir, ripple guard, and depth gauge.

Table 1: List of key factors that were kept constant throughout all experiments.

<table>
<thead>
<tr>
<th>Factors</th>
<th>Values</th>
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<tbody>
<tr>
<td>Rainfall intensity</td>
<td>100 mm h⁻¹</td>
</tr>
<tr>
<td>Drop fall height</td>
<td>6 m</td>
</tr>
<tr>
<td>Drop size</td>
<td>2.6 mm</td>
</tr>
<tr>
<td>Flow velocity</td>
<td>40 mm h⁻¹</td>
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Table 2: Experimental protocol.

Preparations:
1. Preparation of sandbed and measurement of sandbed depth
2. Flow calibration measurements (see fig. 2)
3. Weir adjustment to specified height
4. Discharge measurement
5. Rainfall intensity calibration
6. Measurement of water depth

Run experiment for 10 mins.

Post-experimental work:
1. Re-measurement of flow depth and flow discharge
2. Re-calibration of rainfall intensity
3. Re-measurement of sandbed depth
4. Sampling of eroded sediment from trap

Exemplary results:

Fig. 2: Results of an exemplary calibration run to determine optimum flow rate necessary to ensure chosen flow velocity of 40 mms⁻¹.

Fig. 3: Relationships between sediment concentrations per unit rainfall and flow depth, for rainfall heights of 3 m and 6 m.

Conclusions:
1. Average rainfall intensity on erosion plot proved to be within +/- 5%.
2. Ability to control key factors, i.e. flow depth and flow velocity through the weir worked reliable by using calibration routines and depth measurements with the profile bridge (see fig. 1c, 2).
3. Experiments show differences in sediment concentration between 3 m and 6 m fall heights (kinetic energy) and produces replicable results (see fig. 3).

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