Effect of antecedent conditions on soil dynamics in a laboratory flume

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1. Motivation and objectives

It is well known that the presence of rock fragments on the soil surface and the soil's initial characteristics (moisture content, surface roughness, bulk density, etc.) are key factors influencing soil erosion dynamics and sediment delivery. In addition, the interaction of these factors increases the complexity of soil erosion patterns and makes predictions more difficult.

The objectives of this study were to:

(i) investigate the effect of soil initial conditions on soil erosion yields and effluent particle size distribution and (ii) evaluate this effect on the time scales associated to the erosive event.

2. Design of the experiment

Experiments: Details of the experimental design, precipitations rate and soil initial conditions are reported in Fig. 1(a) and Table 1. These experiments were performed using the EPFL erosion flume (see Jomaa et al. (2010) for more details)

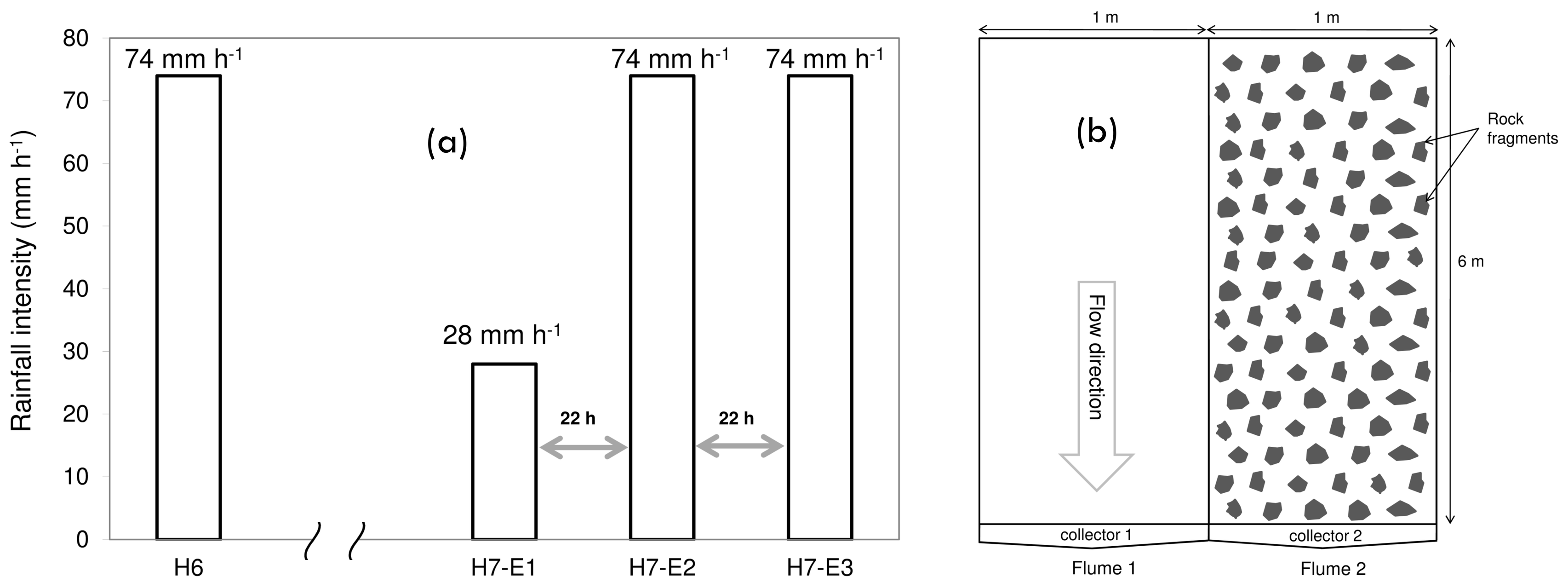

Figure 1. Panel (a) shows an overview of the experiments. Experiment H6 is a single erosion, while H7- E1-E3 are multiple rainfall events. Panel (b) illustrates an overview of flumes 1and 2.

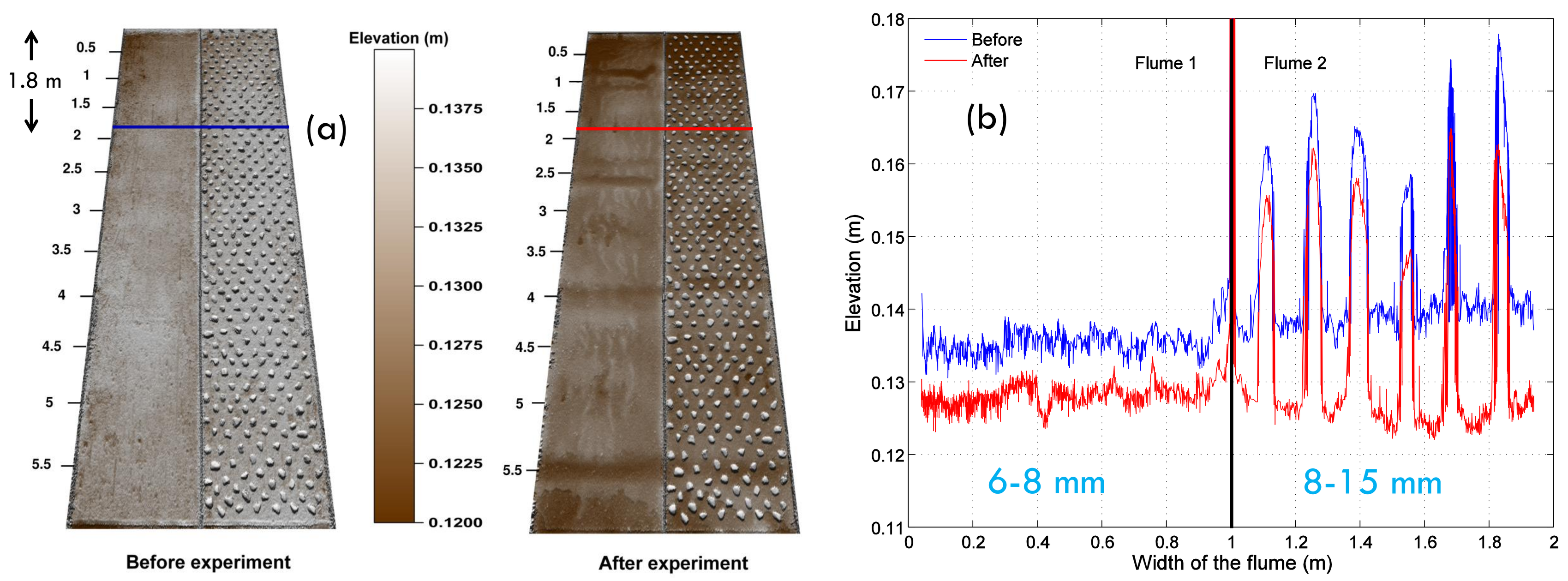

Figure 2. Panel (a) shows the digital terrain models (DTM) conducted before and after the experiment H6 using laser scanner. Panel (b) illustrates soil surface elevation along the transect 1.8 m shown in panel (a), before (blue line) and after (red) experiment H6. With uniform precipitation, soil compaction and surface sealing varies between 6 and 8 mm for the bare soil to 8 and 15 mm with rock fragment coverage. This reflects that the presence of rock fragments on the soil surface increases the infiltration rate beneath them, reducing the internal friction of the particles.

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3. Results

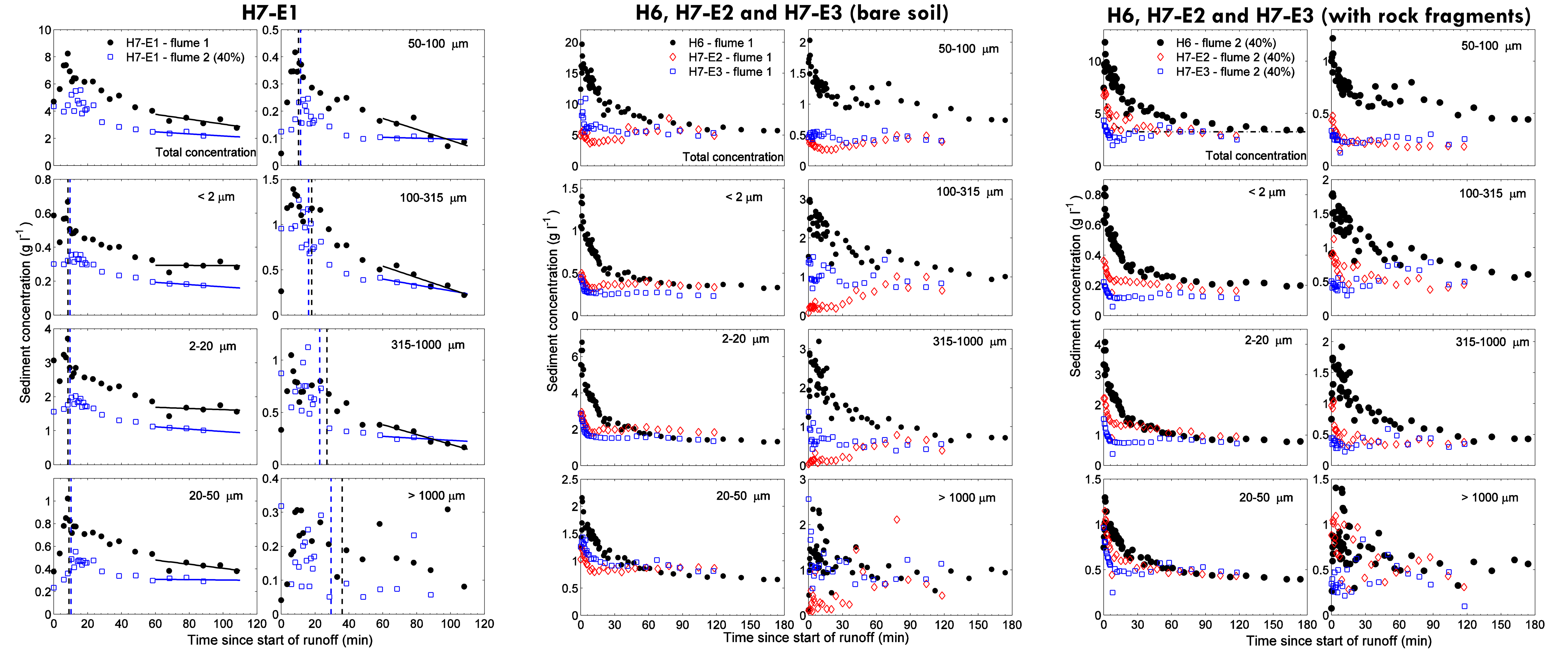

Figure 4. Results of the experiments. The vertical lines show the minimum time scale needed to reach steady state (Table 2). Comparison of the eroded concentrations with and without rock fragments show a decrease proportional to the area exposed.

Table 1. Summary of the rainfall events characteristics. The duration of each experiment was 2h, except for H6 (duration was 3h)

Event	Flume	Precipitation (mm h^{-1})	Moisture content (%) initial	Moisture content (%) final	Steady-state (mm h^{-1}) discharge	Steady-state (mm h^{-1}) infiltration	$t_{to\ runoff}$ (min)	Initial soil condition
H6	Bare	74	6.81	19.15	68.70	5.30	6.07	Hand cultivated and smoothed
	Cover (20%)		6.52	21.88	54.30	19.70	8.28	
H7-E1	Bare	28	7.74	18.28	20.46	7.54	14.32	Hand cultivated, smoothed and slightly pre-wetted
	Cover (40%)		8.84	30.91	14.56	13.44	27.13	
H7-E2	Bare	74	19.15	21.96	71.40	2.60	1.34	The soil was not altered and left to air dry
	Cover (40%)		24.79	29.53	63.84	10.16	2.06	
H7-E3	Bare	74	20.42	22.03	72.04	1.96	1.23	The soil was not altered and left to air dry
	Cover (40%)		25.20	29.77	67.92	6.08	2.09	

Table 2. Minimum time needed to achieve steady-state for each size class, calculated as

$$t >> t_0 = \eta \frac{D}{R} + \frac{\eta^2 v_i}{R^2} \frac{m_t^*}{a_d}$$ (Jomaa et al., 2012b)

Size Class	Measured v_i (m s^{-1})	Characteristic time t_0 (h) H6 Flume 1	H6 Flume 2	H7-E1 Flume 1	H7-E1 Flume 2	H7-E2 Flume 1	H7-E2 Flume 2	H7-E3 Flume 1	H7-E3 Flume 2
1	5×10^{-7}	0.13	0.16	0.14	0.16	0.12	0.10	0.12	0.08
2	1.5×10^{-5}	0.13	0.16	0.14	0.16	0.12	0.10	0.12	0.08
3	7×10^{-4}	0.14	0.17	0.15	0.17	0.12	0.10	0.12	0.08
4	4×10^{-3}	0.17	0.20	0.17	0.19	0.13	0.11	0.14	0.08
5	2×10^{-2}	0.34	0.37	0.30	0.27	0.16	0.13	0.19	0.10
6	4×10^{-2}	0.55	0.60	0.45	0.38	0.19	0.16	0.26	0.13
7	6×10^{-2}	0.76	0.80	0.60	0.49	0.23	0.20	0.33	0.16

4. Conclusions

- Surface rock fragments retard runoff generation, decrease soil erosion delivery, and increase considerably the infiltration rate (Table 1)
- Short-time soil erosion behavior is more sensitive to the antecedent conditions than the long-time equilibrium, which instead appears only to be controlled by the rainfall intensity;
- The effect of rock fragments on the soil erosion and hydrological response is controlled by the initial soil state (surface roughness, moisture content and bulk density) and rainfall intensity
- The presence of rock fragments affects the transition to steady state erosion, especially for larger sized sediment particles
- The short-time soil erosion is sensitive to the erosion history, in particular to whether steady-state conditions were reached in the preceding erosion event (Fig. 4)
- The presence of rock fragments on the topsoil surface reduced the time needed to reach steady state compared with bare soil (Table 2). This reflects the reduction in rain splash erosion caused by rapid development of the overland flow depth (which results from the reduction of the flow cross-sectional area by rock fragments)

References

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