Pumped Rainfall Simulators: The Impact of Rain Pulses on Sediment Concentration and Size

A. Armstrong[1], P. Heng[2], J. Quinton[1], G. Sander[2] & C. F. Scott[2]

1. Introduction

Rainfall simulation is used to study controls over soil erosion processes, nutrient and contaminant transfer, and the impact of management options on soil loss. Many pumped rainfall simulators used in soil erosion studies use pulsed rain to control the rainfall intensity. We examined the effect of the rain pulsing on sediment concentration and size using three different pulse cycles with the same rainfall intensity, both experimentally and with a physically-based soil erosion model.

2. Laboratory Experimentation

Methods: Three rain pulse cycles with the same intensity were investigated: (A) on for two seconds on and off for six seconds, (B) on for three seconds and off for nine seconds, and (C) on for four seconds and off for twelve seconds. The experiments were undertaken in triplicate and samples were taken over three seconds at one second intervals. The first sample was taken when the rain pulse started (zero seconds), the second sample one second after the rain pulse started (one second) and so forth. The samples were analyzed for the effective particle size distribution and sediment concentration.

Results:
Sediment concentration peaked towards the end of the rain pulse and then gradually declined (Figure 1).

The particle size distribution of the sediment coarsened from zero to four seconds and then fined from four seconds to the start of the next pulse (Figure 1).

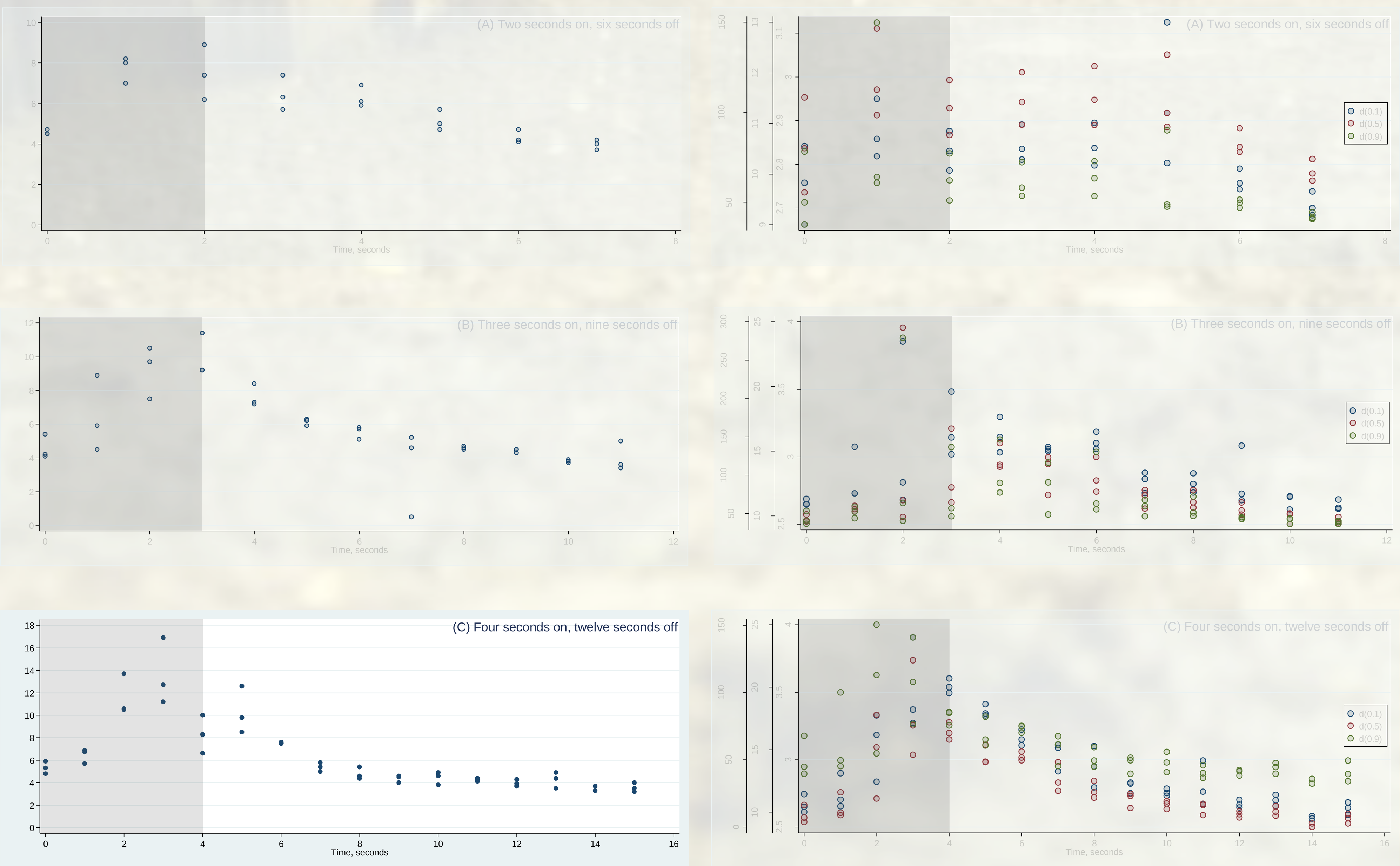

Figure 1. Changes in sediment concentration and particle size through time. Each point represents a measurement and the grey area represents rainfall. Note variable *y*-axis.

3. Modelling

Methods: The Hairsine-Rose (H-R) soil erosion model adopted in this study has two important features:

- Erosion and deposition processes are considered separately, so rainfall-driven erosion can be switched on and off in accordance with rainfall pulsing while deposition continues.
- Differential deposition rates can be modelled as particles are classified by their settling velocities.

Thus the rainfall pulsing experiments are a critical test of model theory. A numerical solution was obtained for each scenario examined in this study using a finite volume implementation of the H-R model coupled with the St. Venant equations.

Results: The model successfully reproduced the observed trends in sediment concentration and particle size distribution (Figure 2).

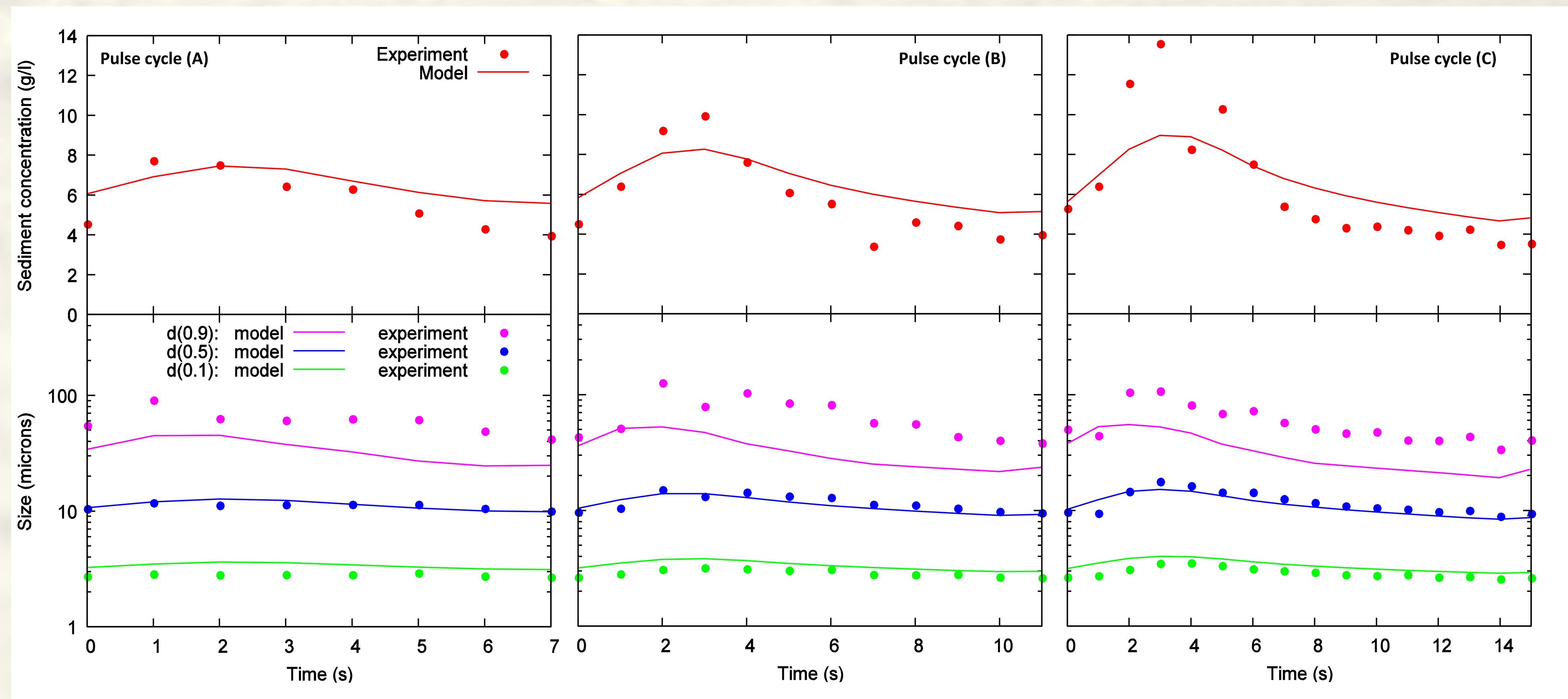

Figure 2. Model output and averaged observed data for sediment concentration and size for each rain pulse cycle.

4. Discussion

Pulsing rain has an impact on both sediment concentration and sediment size, with greater impacts evident for longer pulse cycles. Sediment concentration and particle size peaked towards the end of the rain pulse. This can be attributed to the dominance of splash detachment over flow entrainment of sediment: high sediment concentrations occur during the pulse and then decline and the particle size peaks during the pulse and then fines as coarser material is deposited. The model under-predicts the proportion of coarse particles, as shown by the d(0.9) curve. This could be because rainfall detachment is size-selective whereas the H-R model assumes no selectivity. The under-prediction of coarser particles explains the discrepancy in the magnitude of the oscillation in sediment concentration: a higher proportion of coarse particles in the flow results in a more rapid drop-off in sediment concentration during the lull period.

5. Conclusion

Consequently, the impact of rain pulse cycles on fine-scale sediment dynamics is highly significant and could impact the results of rainfall simulation studies. The implications for studies examining the chemical properties of the eroded material or modeling the data using a size class approach could be considerable. The magnitude of difference will vary between simulators, soil flumes, soil types and rainfall intensities. Therefore we suggest (1) the period the rain is off for is minimized, and (2) that samples should be taken for multiples of the rain pulse cycle. This work also shows that the H-R model is capable of modeling such complex scenarios of soil erosion and is a further validation of the model with respect to its essential features.

[1]Department of Environmental Science, Lancaster University, UK. [2]Department of Civil and Building Engineering, Loughborough University, UK. alona.armstrong@lancaster.ac.uk http://multisem.lboro.ac.uk

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