Celerity, velocity and length of near-surface flow pathways: insights from tracer experiments

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HESS pre-print on this study | *EGU25-10388 abstract* | *More information on the project*

Introduction

Overland flow and interflow through the topsoil provide fast transport routes for water and solutes from hillslopes to streams, and are particularly important for runoff generation in humid catchments with low permeability soils. We conducted tracer and sprinkling experiments on trenched runoff plots to investigate water and solute transport by these near-surface flow pathways.

Study area

The study was conducted on two plots in a small (20 ha) pre-Alpine headwater catchment in Switzerland. The climate is humid temperate. The mean annual precipitation is 2300 mm y^{-1}. The hillslopes are steep (0-69°) and covered by open forests, pastures, and wetlands. Soil depth ranges from 0.5 to 2.5 m. A conductive, organic topsoil overlays the low permeability Gleysols and Flysch bedrock.

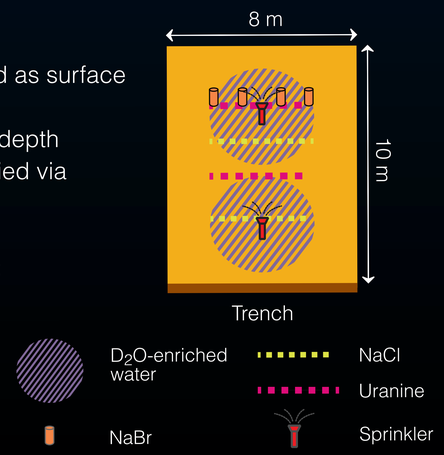
Methods

- two large trenched plots (8 m wide, >10 m long)
- one in a natural clearing in the open forest; one in a grassland
- sprinkling rate: 24-39 mm h^{-1}
- steady state conditions during all experiments
- continuous measurements of overland flow and topsoil interflow

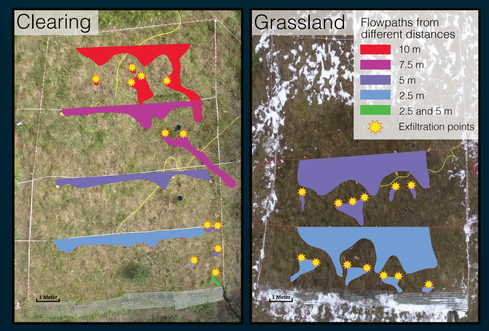
Celerity experiments:
- additional water pulses applied at various distances from the trench

Tracer experiments:
- Uranine and NaCl applied as surface line tracers
- NaBr injected at ~20 cm depth
- D_2O-enriched water applied via sprinklers

Brilliant blue dye experiment:
- blue dye applied to visualize and quantify overland flow path lengths

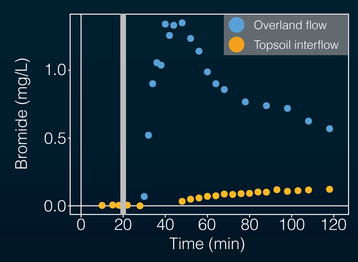


Results



Clearing
- short overland flow paths, but individual flow paths can be longer
- exfiltration from soil pipes (mouse burrows)

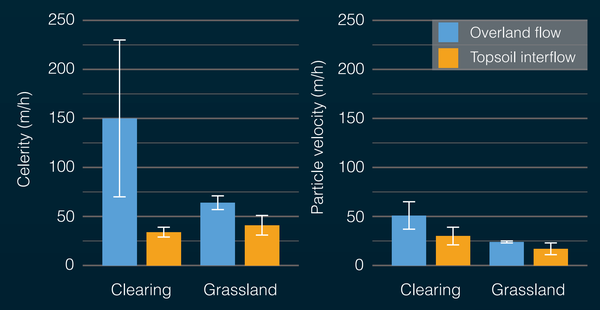
Grassland
- longer overland flow paths
- exfiltration points at bottom of microtopography



Breakthrough curves of bromide (applied to the subsurface) in overland flow and topsoil interflow for the plot in the clearing. Bromide mainly left the plot via overland flow.

Tracer recovery (% applied mass) within the first 100 minutes

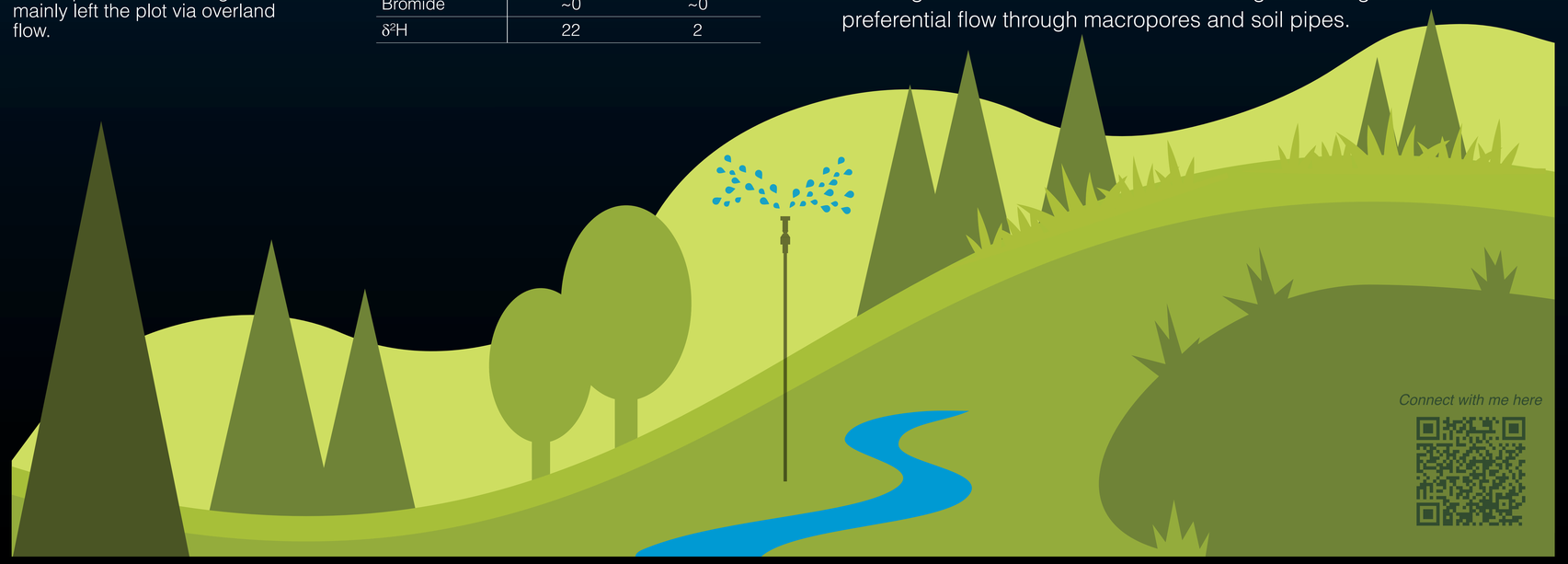
	Overland flow	Topsoil interflow
Clearing		
NaCl	1	13
Uranine	25	2
Bromide	<1	<1
δ^2H	8	4
Grassland		
NaCl	94	13
Uranine	97	7
Bromide	~0	~0
δ^2H	22	2



Celerity and maximum particle velocity (based on the first arrival of water pulses and tracers) for overland flow and topsoil interflow. Bars show means ± standard deviation.

Conclusions

- Celerities and particle velocities were high for both flow pathways, but higher for overland flow than topsoil interflow.
- There was considerable mixing of overland flow and topsoil interflow, with subsurface-applied NaBr mainly leaving the plot in the clearing as overland flow. This was further supported by the infiltration and exfiltration of blue dye at both plots.
- Runoff generation was faster in the clearing than the grassland due to preferential flow through macropores and soil pipes.



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