A-08542

Subsurface storm flow - the crucial role of interaction

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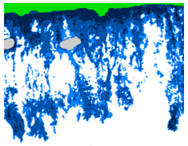
Introduction

Subsurface storm flow in lateral preferential flow paths in the vadose zone can contribute substantially to storm flow and lead to unexpected fast drainage of the soil. Our study adresses the following questions:

What are the reasons for different rates of lateral preferential flow?

How do spatially variable site characteristics and temporally variable moisture conditions influence the initiation of lateral preferential flow?

The degree of interaction is one parameter influencing subsurface storm flow. The term "interaction" describes the water transfer between preferential flow paths and the surrounding soil matrix. It cannot be directly quantified. Visualisations of infiltration patterns with dyes (see figure on the right), tracer experiments and measurements of the soil water regime help to estimate the degree of interaction.



Weiler & Naef, JH 273, 139-154

Methods

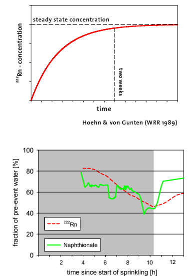
Sprinkling experiments were made and natural rainfall events were monitored on hill slopes in four different catchments in Switzerland. Fig. **A** shows the two sprinkling setups used (40 mm/h and 10 mm/h, 100 m^2). Highly resolved measurements of soil moisture and suction, piezometric heads and surface and subsurface runoff in different depths were made. Instantaneous tracer injections during steady state conditions were used to estimate flow velocities.

Event and pre-event water fractions were determined in the different flow components using artificially traced sprinkling water and ^{222}Rn as natural tracer. There is no ^{222}Rn in the precipitation and a site-specific steady state is reached after about two weeks (**B**). During sprinkling experiments we compared pre-event water fractions determined with radon and determined with an artificial tracer (**B** below).

In detailed analysis of soil profiles we investigated hydromorphic features, the thickness and texture of different soil layers, depth to bedrock, grain size distribution, packing density and macropore density (**C**). Ground penetrating radar measurements were used to scale up the observed soil structures (**D**). (for details on the last point please visit our poster presentation on Friday: A-03135 „How geophysical methods can contribute to subsurface storm flow investigations")

A

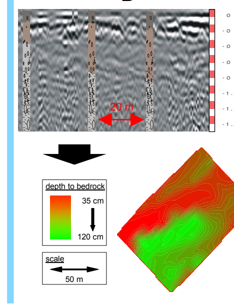
B



C

Site	Soil classification			Geological parent material			
Depth [cm] / Horizon	Sand [%]	Silt [%]	Clay [%]	[%] coarse fragments	packing density	macropore density [m^{-2}]	pH
Schlüssberg — Calcaric Cambisol — ground moraine							
0- 10 Ah	34	34	32	3	1.5	224	5
11- 24 A / B	34	34	32	5	2	136	5
24- 80 Bw	31	35	34	10	3	111	5
> 80 C	31	35	34	15	4	35	8
Koblenz — Eutric Cambisol — Loess / Moraine							
0- 15 A	26	51	23	< 1	1.5	162	6
15- 45 B	26	53	21	< 1	2	168	7
45- 90 B / C	20	50	30	2 - 5	3	214	7
Im Sertel — Cambisol — Sandstone of "Helvetien" Molasse							
0- 20 A	41	29	30	< 1	2	284	5
20- 80 B	47	29	24	< 1	2	216	5
80-160 B / Cv	51	27	22	< 1	2	344	5
160-270 Cv					4	126	8
>270 C					5	0	8
Lutertal — Cambisol — Siltstone of "Oeningien" Molasse							
0- 10 A	26	51	23	< 1	2	184	5
10- 25 B	26	51	23	< 1	2	248	6
25- 40 B / Cv	26	51	23	2 - 5	3	132	6
> 42 C					5	0	7

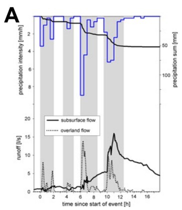
D



Koblenz

Subsurface flow responded quickly to rainfall events (**A**). Tracer injections evidenced subsurface flow with high flow velocities over more than 115 m (**B**). Subsurface flow had a low fraction of pre-event water. Such a response requires long and well-connected lateral flow paths. In fact, preferential flow was located with ground penetrating radar (GPR), when highly concentrated NaCl-solution was injected as a line source into the soil to enhance the radar reflections (**C**). Obviously, the lateral flow in soil pipes was directly fed from precipitation and only a very low interaction with the soil matrix occurred, which was mostly bypassed (**D**).

A



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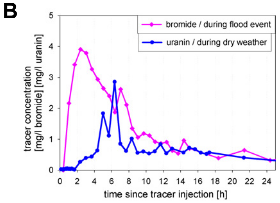

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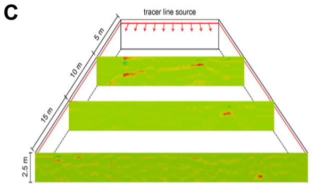

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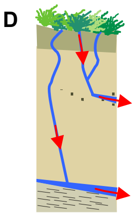
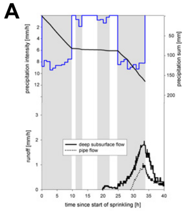


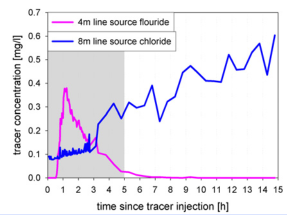
Im Sertel

Subsurface flow in a thin weathered layer above the bedrock and in a soil pipe responded strongly delayed to precipitation (**A**) and contained nearly no event water. Large differences between SSF velocities over 4 m distance and 8 m distance were observed (**B**), which indicate short and weakly connected lateral flow paths. As nearly 70 % of the sprinkled water was stored in the soil during the experiment, a high degree of interaction occurred. Comparisons of soil suction and subsurface flow intensity show a strong relation between subsoil saturation and subsurface flow (**C**). Apparently, lateral subsurface storm flow was initiated and fed indirectly from the saturated subsoil (**D**).

A



B



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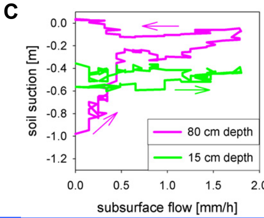

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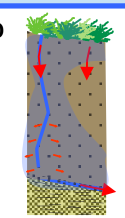
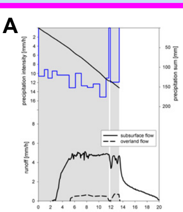


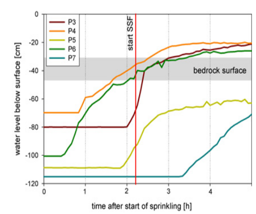
Lutertal

Subsurface flow in small lateral soil pipes directly above the bedrock responded quickly to precipitation (**A**). A patchy saturation built up above the bedrock and initiated this flow (**B**). Individual lateral pipes started to flow with substantial time differences. Pipes with high lag times had higher concentrations of pre-event water as pipes starting quickly (**C**). Evidently, some of these pipes were closely connected to vertical preferential infiltration, showed a low interaction with the surrounding soil matrix and were directly fed from precipitation. In contrast, other pipes were disconnected from vertical preferential infiltration, showed a high interaction with the surrounding soil matrix and were indirectly fed (**D**).

A



B



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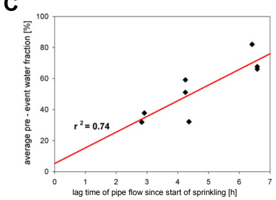

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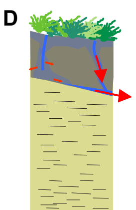
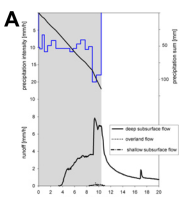


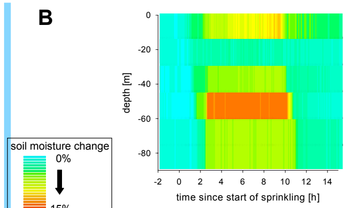
Schlüssberg

Subsurface flow in a system of macropores embedded in the subsoil responded slightly delayed to precipitation (**A**). A high change of soil moisture and saturated conditions were observed in the subsoil (**B**). Subsurface flow contained about 50% of pre-event water (**C**). Obviously, there was a intermediate degree of interaction between preferential flow and the soil matrix and subsurface flow was initiated from the saturated subsoil (**D**).

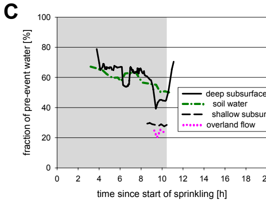
A



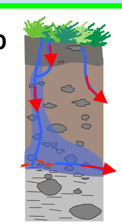
B



C



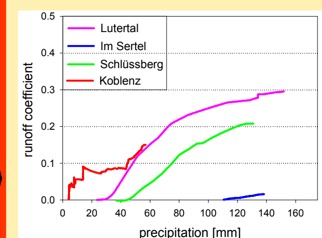
D

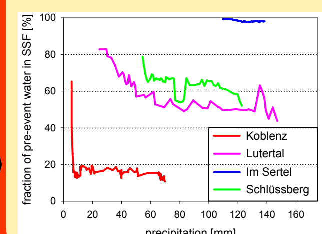


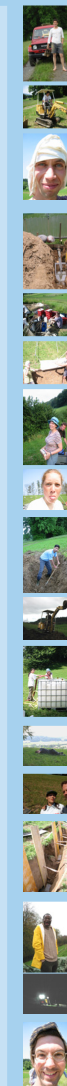
The crucial role of interaction

The subsurface flow intensity varied substantially depending on how the flow was initiated. When the soil characteristics favoured a low degree of interaction between preferential flow and the soil matrix, subsurface flow was mainly fed by bypass flow resulting in a quick subsurface flow response. In contrast, when high interaction occurred, subsurface flow was fed from saturated parts of the soil and the intensity was much lower.

The rate of pre-event water in subsurface flow responded extremely sensitive to the degree of interaction and the rate of direct or indirect feeding of lateral preferential flow. Fast subsurface flow in the soil consists therefore of event water flowing through preferential flow paths and of pre-event water mobilised in saturated zones in the soil matrix. The extent of these saturated zones and the degree of interaction between the saturated soil matrix and preferential flow paths determine the amount of pre-event water in the subsurface flow as well as the intensity of the flow.







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