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Subsurface flow dynamics and nutrient transport in forest stands – results from a large-scale sprinkling experiment

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Phosphorus (P) is an essential element of primary productivity of an ecosystem. Natural forests are known to be limited in P supply and therefore develop tight P-recycling strategies. The P availability is, however, significantly affected by P-losses of hydrological fluxes in the subsurface during rainfall events. We present the results from a large-scale sprinkling experiment on a highly instrumented experimental hillslope in the Black Forest, Germany where we simulated a large rainfall event with moderate intensities. The aim of this experiment was to quantify the lateral and vertical fluxes and time delays in subsurface flow, the transit times and the associated transport of nutrients. Secondly, we were interested in the dynamics of water and nutrient uptake by beech trees during and after such extreme rainfall events.

We sprinkled a 200 m2, relative steep hillslope in a beech forest with 60,000 l of isotopically (deuterium) labeled water for 11 h with a mean intensity of 12 to 15 mm/h. Lateral subsurface flow was measured at three depths (10cm, 240cm, 300cm) at a 10 m wide trench at the bottom of the hillslope and with zero-tension lysimeters (ca. 0.6 m2) installed at four depths into the undisturbed soil profile down to the soil-bedrock interface. This setup allowed us to quantify the lateral and vertical fluxes of subsurface flow during the experiment and to sample the water for stable water isotopes and all major ions and cations in high (up to 10 min) temporal resolution. The results from this artificial sprinkling experiment capture the P-flashing at the beginning of the sprinkling event, the immobilization of P in the upper organic rich horizon and the high lateral and vertical losses at the system boundary in 3 m depth. In addition, isotope composition in tree xylem was measured with a laser-based isotope analyzer directly in the field and showed a first signal of spiked water in the tree xylem two days after the sprinkling experiment and peaked 12-14 days after the sprinkling. The microdialysis method was used to measure P-concentration in tree xylem and allowed to capture parts of the daily variability in P concentration in the tree xylem. Additional sprinkling tests are planned at this site and two other sites in Germany that differ in their nutrient availability. High frequency sampling of the inputs, outputs and fluxes during these sprinkling experiments and one or two consecutive natural rainfall events will allow an even better quantification and explanation of the within event variability and the recovery of the ecosystem after the artificial sprinkling. By quantifying not only the lateral but also the vertical water and nutrient losses from the plots we aim at closing the water and P-mass balance for the three contrasting forest ecosystems.