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DOC mobilization from forest soils governed by intermittent hydrological connectivity of subsurface water pools

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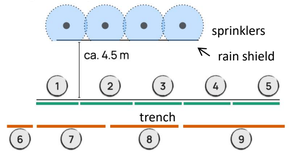
Background

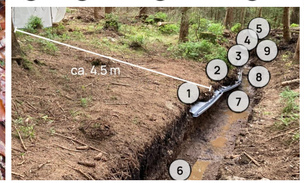
Overall increasing DOC loadings with spiking concentrations after strong precipitation events challenge drinking water production in the western Ore Mountains. To gain a better understanding of mechanisms leading to increased DOC mobilization, spatial and temporal release patterns are studied in the Sosa reservoir catchment since 2020. Several disturbed bogs are suspected to be the main DOC sources in the catchment. In the presented study (2022-present), we focus on the mobilization patterns of two small catchments (1 ha) located on:

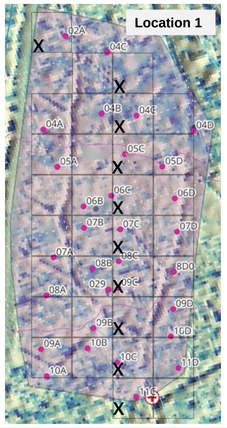
Location 1) a disturbed bog (shallow histosol with a highly compacted mineral subsoil)
- Extremely heterogenic organic topsoil layer (0,2 m to > 1 m)
- High DOC loadings suspected
- Fir forest

Location 2) a mineral soil (regolithic cambisol)
- Control catchment (“non-bog”)
- Mixed deciduous and coniferous beech forest

Irrigation experiment at location 1







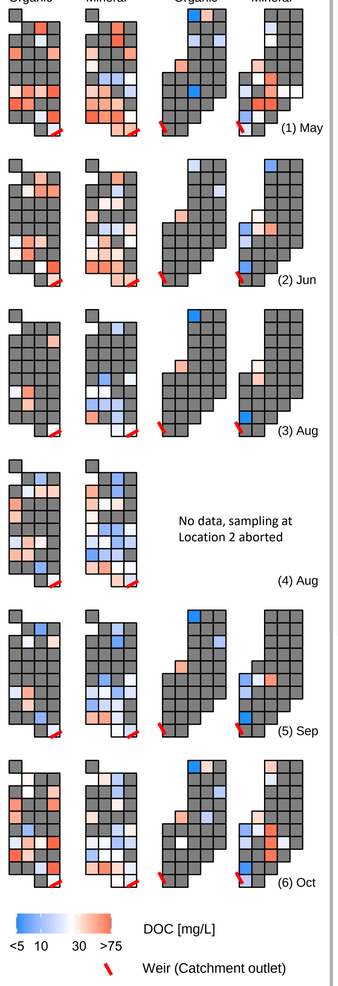
Methods

A) Spatial pore water sampling
- Grid-based approach based on James & Roulet (2007)
- MacroRhizon pore water probes inserted into the organic and mineral horizon on a 15 m grid spanning the catchment
- Soil moisture, temperature, and irradiation probes along the gradient (marked with X)
- Water chemistry (DOC, $^{2}H/^{18}O$ Isotopes, vis-NIR spectroscopy)

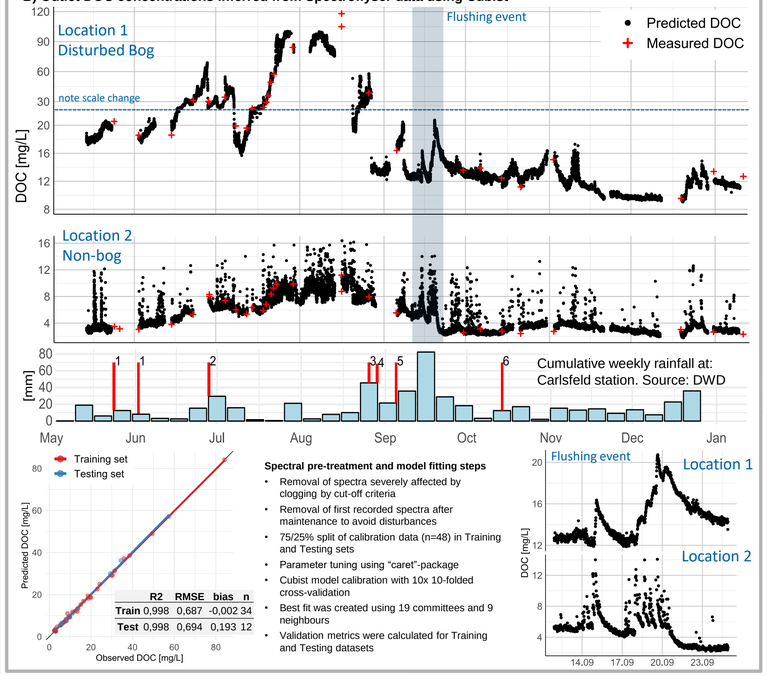
B) Catchment outlet monitoring
- Continuous sub-hourly vis-NIR scans using Spectro:lyser V3
- Discharge monitoring using V-shape weir and pressure probes
- Water chemistry (DOC, DIC , $^{2}H/^{18}O$ Isotopes, vis-NIR spectroscopy, Metals, pH, EC)

C) Irrigation experiment
Design based on Jackisch et al. (2017)
- 2 experiments per catchment
  - Dry initial conditions: First irrigation experiment was carried out on dry soil (several weeks with no or negligible precipitation prior)
  - Wet initial conditions: 2 days after the first irrigation experiment
- Irrigation water was traced with ^{2}H and ^{18}O on the first and second experiment respectively
- GPR profiles to track wetting front
- Water chemistry (DOC, $^{2}H/^{18}O$ Isotopes, vis-NIR spectroscopy, pH, EC)

A1) Pore water sampling campaigns



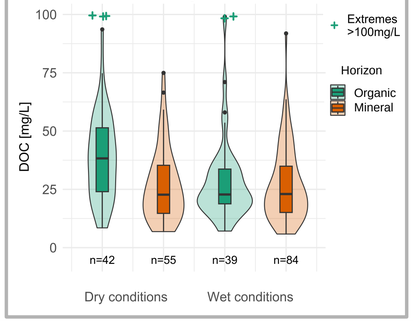
B) Outlet DOC concentrations inferred from Spectro:lyser data using Cubist



	R2	RMSE	bias	n
Train	0,998	0,687	-0,002	34
Test	0,998	0,694	0,193	12

Spectral pre-treatment and model fitting steps
- Removal of spectra severely affected by clogging by cut-off criteria
- Removal of first recorded spectra after maintenance to avoid disturbances
- 75/25% split of calibration data (n=48) in Training and Testing sets
- Parameter tuning using “caret”-package
- Cubist model calibration with 10x 10-folded cross-validation
- Best fit was created using 19 committees and 9 neighbours
- Validation metrics were calculated for Training and Testing datasets

A2) Pore water sampling at location 1 (disturbed bog): DOC concentrations at dry and wet areas



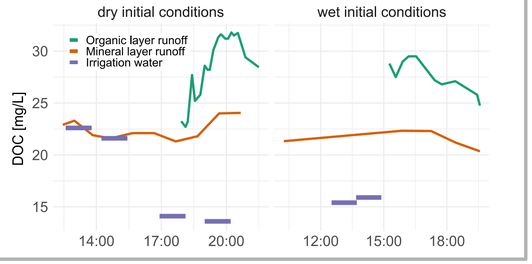
Results

A) Spatial pore water sampling
- Hydrological connectivity is retained longer along preferred flow paths
- Dry versus wet conditions:
  - Heterogenous pore water DOC concentrations during dry conditions
  - Homogenisation during wetting conditions

B) Small-catchment outlet monitoring
- Disturbed bog catchment outlet shows higher DOC concentrations than non-bog (expected), but also stronger fluctuations
- Observation of distinct DOC peaks after precipitation events
- Overall summertime DOC concentration high – much more pronounced in location 1 outlet
- Diurnal pattern: Overnight increase of DOC concentrations, daytime decrease

C) Irrigation experiment
- High amount of irrigation needed for the formation of subsurface runoff
- Flushing of DOC-enriched porewater during irrigation on dry soil
- Reduced DOC release during the second irrigation

C) Irrigation experiments at location 1: Subsurface runoff DOC concentrations



Discussion and Outlook

Proposed mechanism for increased DOC release during intermittent phases of hydrological connectivity
- Heterogeneous organic topsoil layer of the degraded bog catchment has a high water retention potential
- Disconnected pockets of pore water can accumulate DOC during dry conditions
- Reconnection of isolated pools during significant precipitation events: “Fill and Spill”-principle, McDonell et al. (2021)
- Lateral connectivity leads to the flushing of DOC-loaded pore water into the streams

Known Issues and planned improvements for 2023 and onwards
- Fouling: Spectro:lyser optics were affected by biofilms and sediment deposition. → Higher capacity batteries will allow for shorter wiping intervals.
- Specro:lyser calibration: Lack of calibration samples, especially with high DOC concentration. → Installation of autosamplers. Separate calibrations for individual Spectro:lysers.
- Local meteorological conditions: Installation of rain gauges for precise local precipitation measurements.

Citations: Jackisch, C., Angermann, L., Allroggen, N., Sprenger, M., Blume, T., Tronicke, J., and Zehe, E.: Form and function in hillslope hydrology: in situ imaging and characterization of flow-relevant structures, Hydrol. Earth Syst. Sci., 21, 3749–3775, doi:10.5194/hess-21-3749-2017, 2017.
James, A. L. and Roulet, N. T.: Investigating hydrologic connectivity and its association with threshold change in runoff response in a temperate forested watershed, Hydrol. Process., 21, 3391–3408, doi:10.1002/hyp.6554, 2007.
McDonnell, J. J., Spence, C., Karran, D. J., van Meerveld, H. J., and Harman, C. J.: Fill-and-Spill: A Process Description of Runoff Generation at the Scale of the Beholder, Water Resour. Res., 57, doi:10.1029/2020WR027514, 2021.

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