Aus der Professur für Bodenphysik
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Thesen der kumulativen Dissertation

Phosphorus Transport Processes from Soil to Surface Waters

Case Studies from a North-Eastern German Lowland Catchment

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I Rationale and research objectives

- Besides nitrate (NO_3^-), phosphorus (P) in its mobile form (PO_4^{3-}) is the main contributor to the eutrophication of north-eastern German freshwaters and the Baltic Sea.
- Nonetheless, there is a lack of understanding of P-transport processes on a variety of spatial scales from the plot and the field to the catchment scale.
- Although awareness about environmental health is increasing, and so is the willingness of responsible resource use, there is still marked P leaching from agricultural areas in north-eastern Germany.
- Understanding the hydrology and the transport pathways of P to surface waters is crucial to deliver land use- and P-management guidelines for farmers and other stakeholders and authorities.
- This thesis aims to contribute to our understanding of P-transport pathways to surface waters in agriculturally used lowland catchments, particularly by answering the following questions: (i) How does artificial drainage affect the hydrology of the Warnow river basin and its contributing sub-basins, and the predictive power of an eco-hydrologic model? (ii) How does the spatial scale affect the detectable pathways of P transport to surface waters? (iii) Do certain events play a critical role in the release of P from agriculturally used areas? (iv) Can field scale processes be reproduced at the catchment scale?

II Methods

- A top-down approach was used to determine the P-transport pathways from the catchment to the field and the soil profile scale.
- The Soil and Water Assessment Tool (SWAT) model was used to determine the impact of artificial subsurface drainage to the catchment hydrology.
- Long-term data of dissolved reactive phosphorus (DRP) and total phosphorus (TP) (derived by the State Office of Environment, Nature Conservation, and Geology of Mecklenburg-West Pomerania, LUNG MV) were analyzed for temporal trends and detectable pathways of P transport at the catchment scale.
- DRP and TP concentrations were monitored in the hydrological season 2015/2016 at our field monitoring site. The impact of rainfall and discharge events was evaluated on three spatial scales (tile drain (4.2 ha), drainage ditch (179 ha), and a brook (1,550 ha)).
- A dye-tracer study was conducted using Brilliant Blue (BB, solution) and Titanium(IV) oxide (TiO2, suspension), as tracers to visualize solute and particle transport through soils with different clay content.
- A suction lysimeter experiment was conducted to determine the preferential transport of bromide (Br-), DRP, and TP.

III Main results

- The incorporation of artificial drainage into the setup of the SWAT model significantly improved the predictive power of the model.
- The riverine concentrations of P (DRP, TP) in the Warnow river basin decreased significantly between 1990 and 2010, which is most likely related to the installation of sewage treatment works in the 1990s. Nonetheless, the contribution of diffused sources of P to surface waters was high.
- DRP followed the base-flow signal while the TP followed a fast flow component, which seems most likely related to event-based drainage discharge.
- In the study season, five rainfall events contributed 15% to 77% and 49% to 68% of the total seasonal load of DRP and TP on the three observed spatial scales at our field site respectively.
- The contribution of tile drainage to the export of TP (e.g. particulate P) from agricultural fields is higher than that for larger spatial scales. The TP:DRP ratio decreases with increasing catchment area, which indicates sedimentation.
- The spatial variability of DL-extractable soil P on the field scale is high, and shows recurring patterns.
- The transport of solutes and particles is strongly affected by preferential flow in loamy and clay soils.
- Although the overall transport of colloids to deeper soil horizons is low, the potential of fast transport through singular macropores (e.g. earthworm channels)—through which colloids are exclusively transported—is large and increased with increasing clay or silt content.
- TiO2 is a suitable dye tracer for the visualization of colloid transport in mineral soils.
- Bromide is transported preferentially through the investigated loamy soil while DRP and TP follow erratic transport patterns. The suction lysimeter test indicates a high potential of DRP being released into the groundwater through severe rainfall events.

IV Conclusion and Outlook

- Our studies indicate the importance of artificial tile drainage and rainfall events to the transport of P to surface waters on all the observed spatial scales.
- However, further research is needed on the interaction of different P pools (groundwater, soil, bed sediment, water). Particular focus should be given to the re-mobilization of bed sediments during discharge events, and the chemical and biological interaction with other nutrients (NO_3^-).
- High-frequency measurements on different scales, beginning with the tile drainage scales, will give insights into transport processes following management measures (e.g. manure application, ditch dredging, etc.).
- The integrated modeling of P and the impacts of land-use management strategies and climate change on the catchment scale will be a helpful future tool for the development of guidelines for authorities and stakeholders.
- The pollution of the Baltic Sea is still high. Since the concentrations of P observed in the larger rivers of the southern Baltic are typically small, we should extend our monitoring to smaller rivers and direct dischargers.