Universität Rostock
Traditio et Innovatio

Flux fields in a tilled loamy soil affect the spatial distribution of soil phosphorus

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Motivation

Phosphorus (P) losses from agricultural fields and watersheds are a central water quality issue because of the critical role P plays in eutrophication processes (Kleinman et al. 2015).
Preferential flow pathways through the soil are a significant source for the transport of water, dissolved and particle-bound nutrients like phosphorus (P) to surface waters. The non-uniform water flow may also influence the spatial variability of P in soils.

The targeted mitigation of P losses from arable land requires detailed knowledge and understanding of the spatial variability of P in the soil and the transport processes through the soil.
We hypothesize that the manifestation of flux fields strongly affects the distribution of P in the soil profile. Furthermore, we analyzed the spatial patterns of soil P content. We tested the comparability of the double-lactate extraction (DL-P) and the diffusive gradient on thin films (DGT-P) and the applicability of both methods.

Study Site

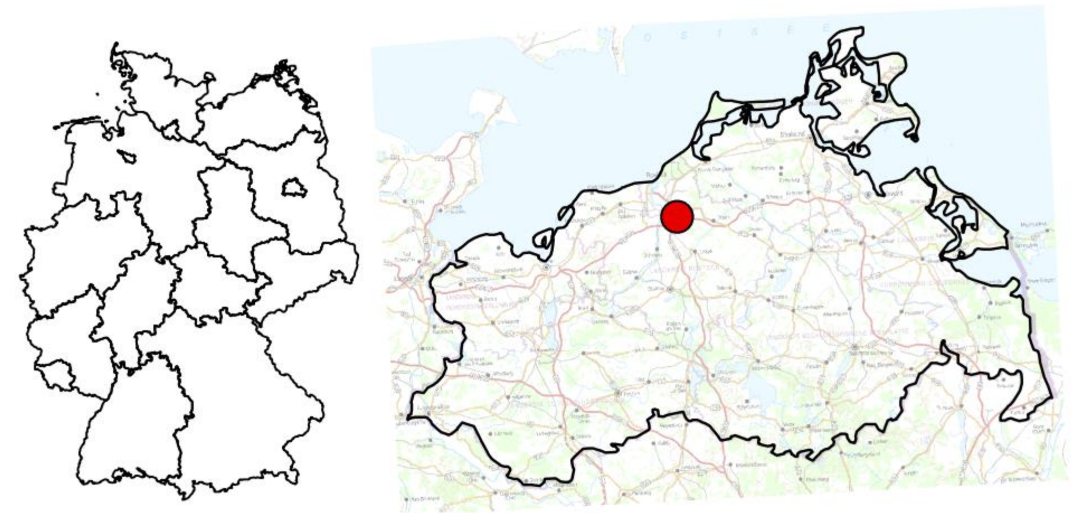

Figure 1: Location of the study site in the federal state of Mecklenburg West-Pomerania.

The study site is located in the federal sate of Mecklenburg West-Pomerania (**Figure 1**). The site lies in a pleistocene lowland landscape with a flat terrain and slight hillslopes. The landscape is predominantly agriculturally used (main crops: maize, winter wheat, winter barley, sugar beets), systematically artificially drained and the human-made environment is a mirror of the long tradition of agriculture in North-Eastern Germany. The study area's soils are ploughed annually (0.3 m) with occasional deep ploughing (0.42 m) every five years.

Material and Methods

Three replicate dye tracer experiments (replicates 1, 2, and 3) using Brilliant Blue (BB) were conducted. We used 24.5 l Water with a BB concentration of 4 g l-1. After 24 hours of infiltration time, soil profiles were cut with a spade from 0 to 40 cm depth and photographically recorded. The images were analyzed for areas of matrix flow, finger flow, preferential flow, and no flow.

From each profile, soil samples were taken from all observed flux patterns. Disturbed soil samples were collected for DL- P. Additionally, multiple undisturbed samples (V = 250 cm3) were taken using core cutters. Samples were taken from stained and unstained areas from both topsoil (0–42 cm) and subsoil (42–70 cm) for the DGT analysis and double-lactate extraction (DL-P).

The estimation of plant-available P in Germany is commonly done using double-lactate extraction. The P was extracted from 12 g soil with 150 ml lactate solution. Concentrations of P in the extraction were determined using inductively coupled plasma-optical emission spectroscopy (ICP-OES).

Diffusive gradients on thin films is a sampling method for anions (Davison and Zhang, 1994). The soil cores were saturated in the laboratory using de-ionized water. After saturation the DGT materials were carefully placed on the soil. After 24 hours, the ferrihydrite gel was extracted from the diffusive gel and the filter paper and put into a test tube with 1 ml of 1M HCl. The final sample solution was analyzed using inductively coupled plasma-optical emission spectroscopy (ICP-OES).

Results

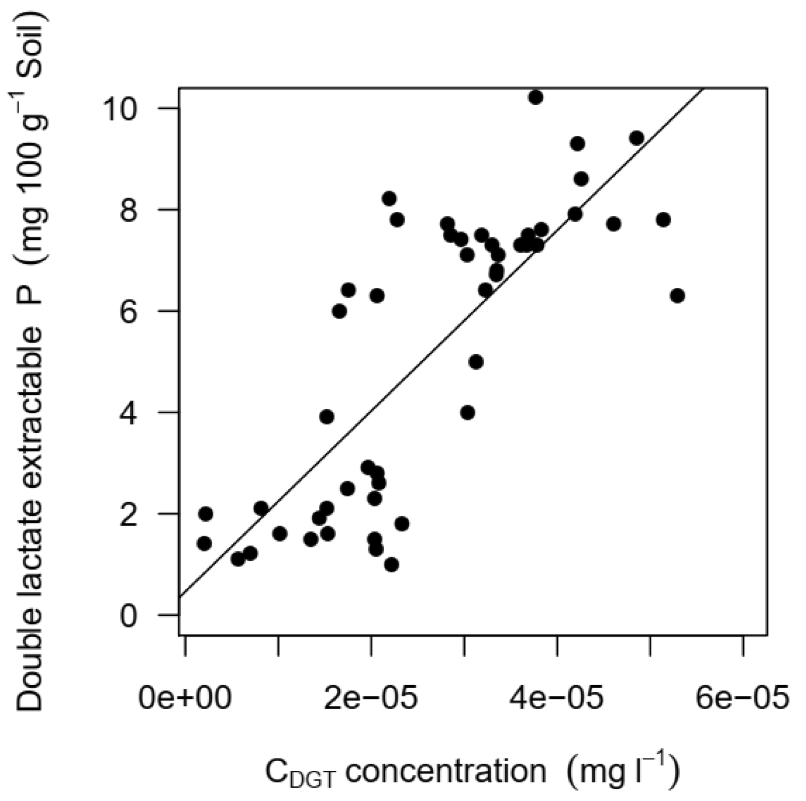

Figure 2: *Relationship between double lactate-extractable phosphorus and C_{DGT} concentrations. The black solid line represents the linear relationship (p<0.001, R²=0.63).*

Relationship between DGT-P and DL-P

- Significant linear relationship between DGT-P and DL-P (p<0.001, R²=0.63) (**Figure 2**)

➢ DL-P is a measure for a true mobile phase of soil phosphorus

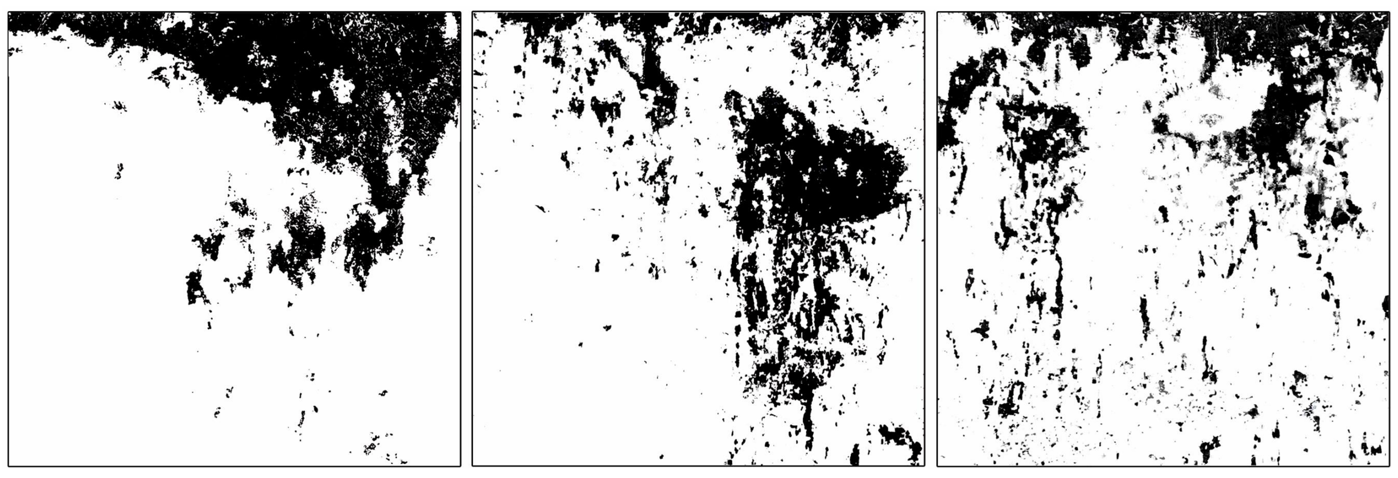

Figure 3: *Example binary images of the stained soil profiles in repetition 1 (left panel), 2 (middle panel) and 3 (right panel).The pictures show the full extent of the photographical observation (0.7 x 0.7m)*

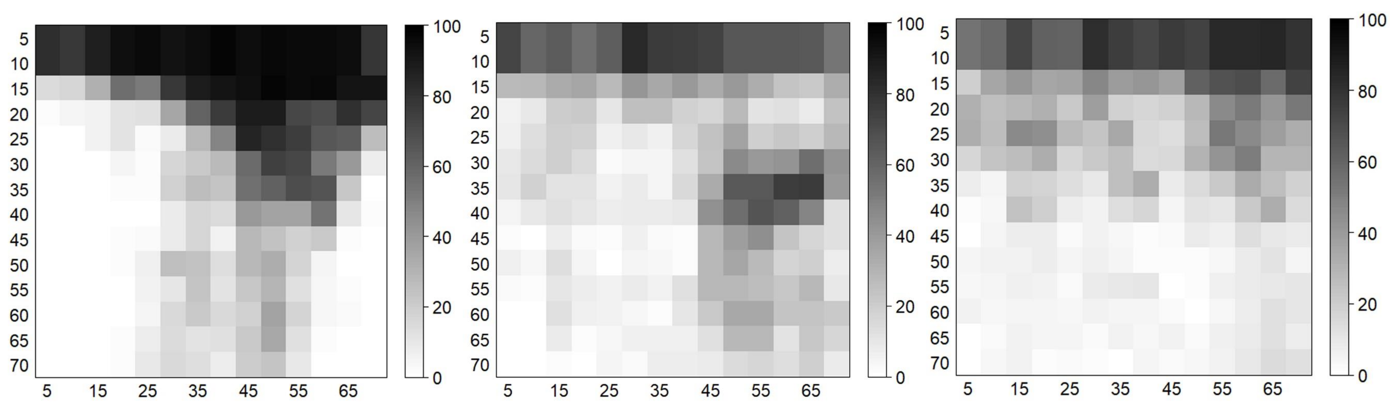

Figure 4: *Mean coverage (%) of dye tracer, as determined in 5 by 5 cm squares of all soil profiles (n = 5) per repetition.*

Dye Tracer Coverage and relationship to Soil P content

- Variable manifestation of matrix flow, finger flow and preferential flow between the replicates 1, 2 and 3 (**Figure 3 and 4**)
- The DL-P contents showed a large range across all observed soil profiles with higher P contents in the topsoil than in the subsoil
- The magnitude of DL-P contents follow the order
  $P_{matrix} > P_{finger} > P_{noflow} > P_{preferential}$ (**Figure 5**)

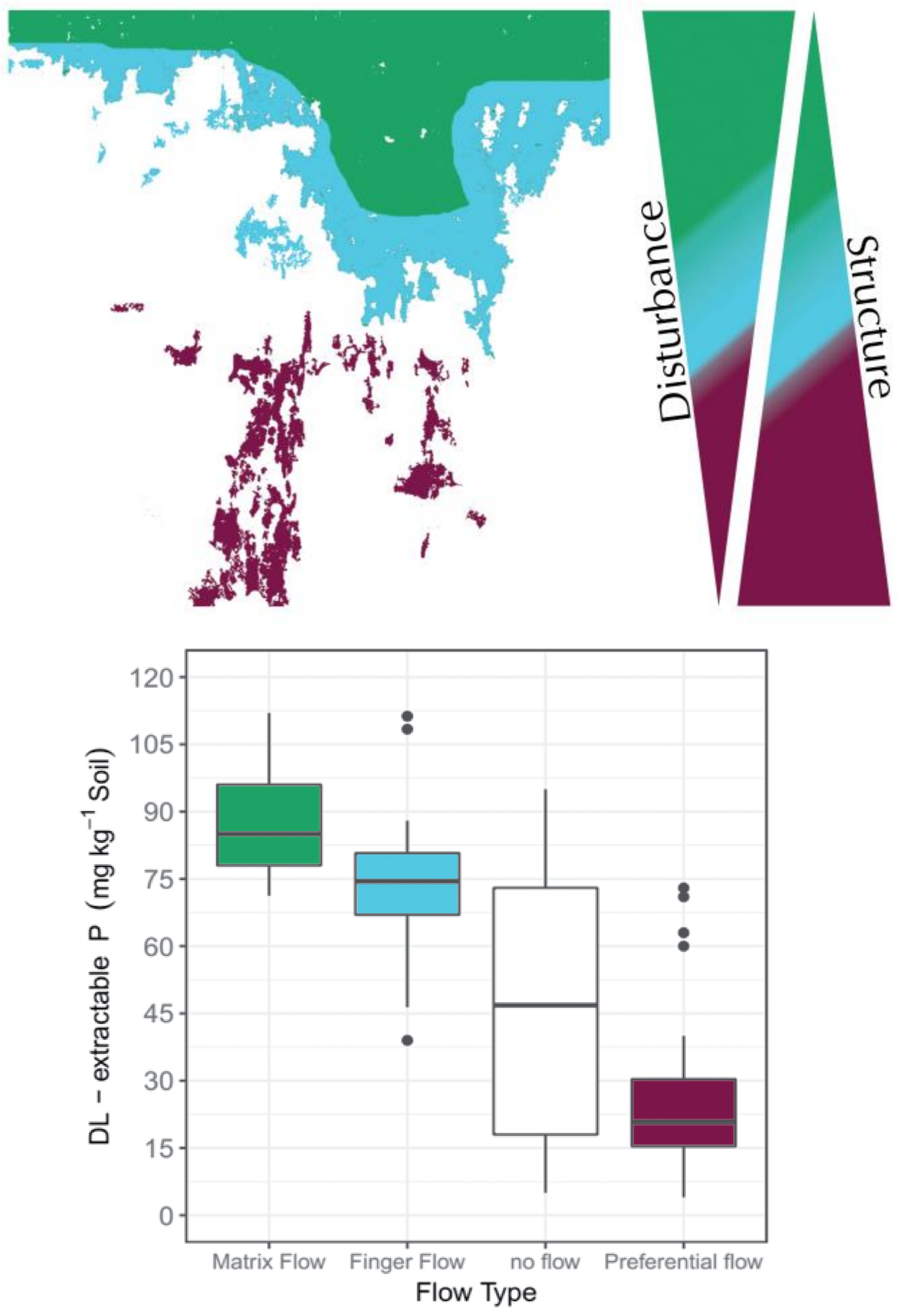

Figure 5: *Areas of matrix flow (green), finger flow (blue), preferential flow (red) and no flow (white) (lower panel) and the according distribution of double lactate-extractable P (upper panel) with increasing soil structure with increasing depth and decreasing soil disturbance with increasing depth (p<0.005).*

Summary and Conclusion

- The double-lactate extraction method determines a true mobile phase of soil P despite the use of an extracting agent
- The spatial variation of soil P is large on a small spatial scale and strongly correlated to the soil's flux regime
- It seems that preferential flow paths are P-depleted and areas of matrix flow are P-enriched

➢ **A detailed understanding of the distribution of P, as well as the continuity of preferential flow pathways between topsoil and subsoil, are crucial for mitigating P losses to ground and surface waters.**
➢ **Further research is needed in the field of short-term and mid-term effects of tillage and repeated organic fertilization on the spatial patterns of soil-P.**

Literature

Davison, W., Zhang, H., 1994. In situ speciation measurements of trace components in natural waters using thin-film gels. Nature 367, 546–548.
Kleinman, P.J.A., Sharpley, A.N., Withers, P.J.A., Bergström, L., Johnson, L.T., Doody, D.G., 2015. Implementing agricultural phosphorus science and management to combat eutrophication. Ambio 44, 297–310.

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