

Streams in forested headwater catchments: Availability of organic nutrients

Livia V. C. Charamba¹, Tobias Houska¹, Klaus Kaiser², Tobias Krause¹, Gabriela F. Razzetto¹, Pavel Krám^{3,4}, Jakub Hruška^{3,4}, Karsten Kalbitz¹

¹ Institute of Soil Science and Site Ecology, TUD Dresden University of Technology, Tharandt, Germany (livia.charamba@tu-dresden.de)

² Institute of Agricultural and Food Sciences, Martin-Luther-University Halle-Wittenberg, Halle (Saale), Germany

³ Czech Geological Survey, Prague, Czech Republic

⁴ Global Change Research Institute of the Czech Academy of Sciences, Brno, Czech Republic

Introduction

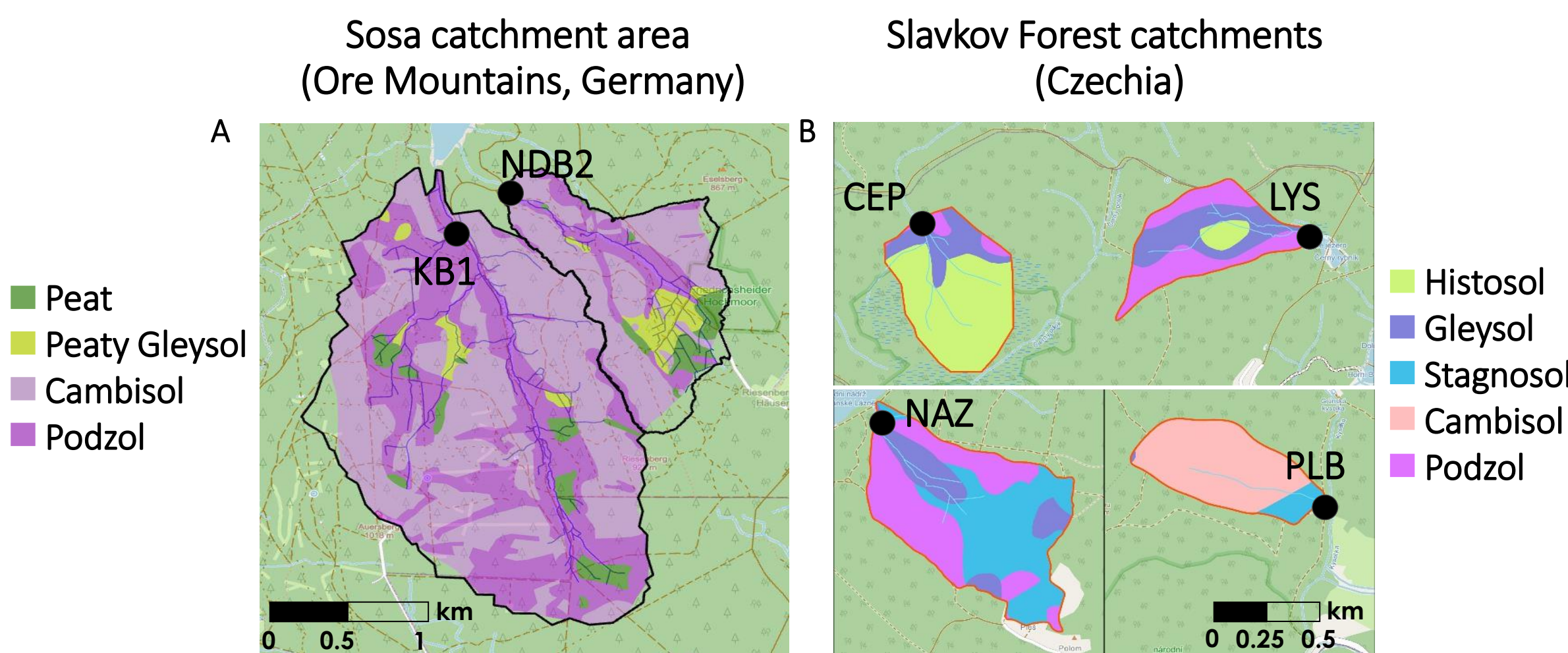
- Dissolved organic matter (DOM) is crucial for carbon and nutrient processing by aquatic microorganisms in headwater streams.
- DOM chemical diversity derives from different terrestrial inputs and in-stream processing, modified by environmental factors.
- Dissolved organic carbon (DOC) provides energy for microbial activity, while dissolved organic nitrogen (DON) and phosphorus (DOP) can be either energy or nutrient sources, depending on in-stream nutrient availability.
- Ratios (DOC:TN, DOC:TP, TN:TP) indicate nutrient limitation but don't capture DOM composition variability^{1,2}.

Research question:

Does DOM chemical composition govern DON and DOP dynamics in forested headwater streams?

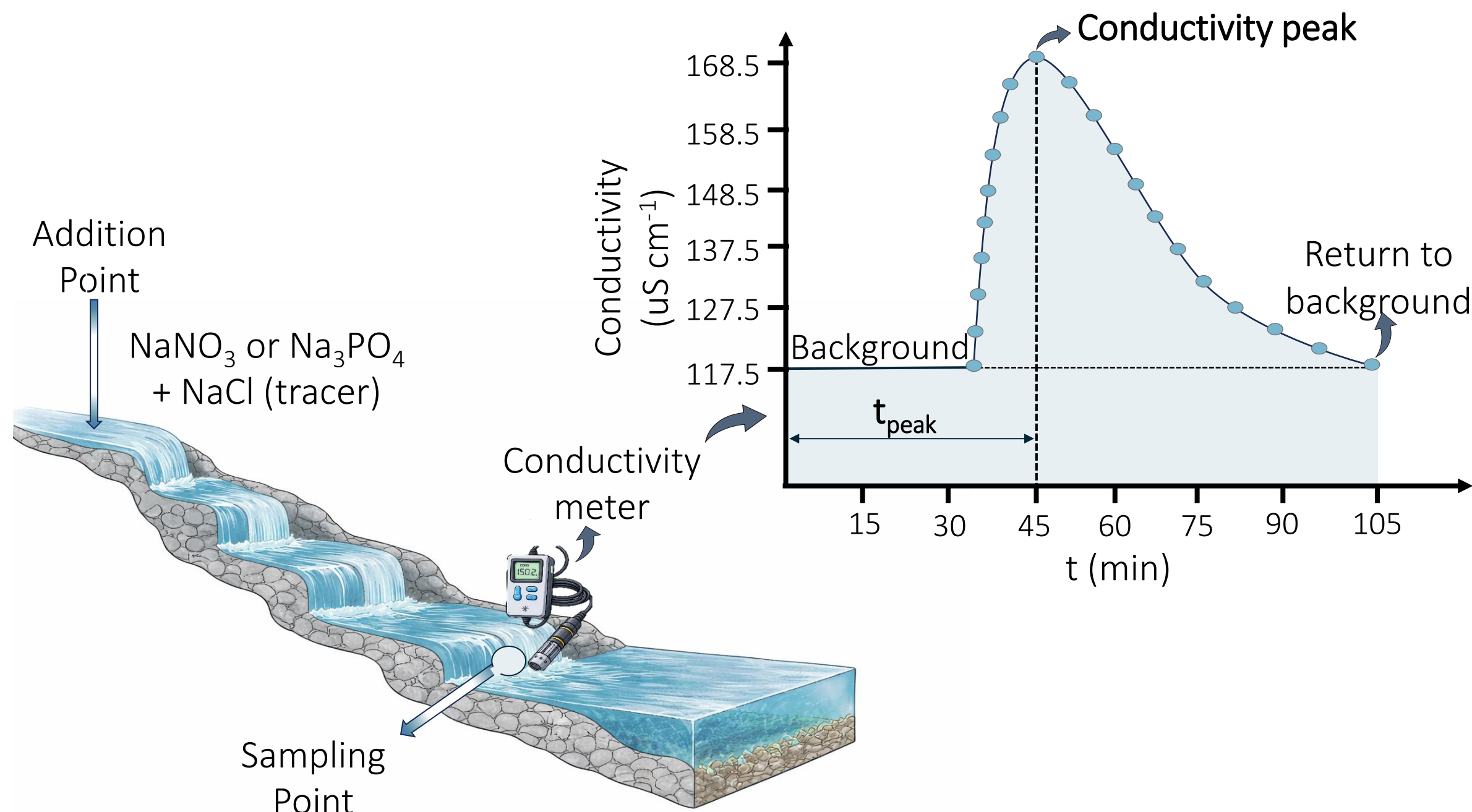
Methodology

Study Site



Pulse Nutrient Addition Experiment

Single pulse additions of nitrate and phosphate were conducted in six headwater streams in the Ore Mountains and the Slavkov Forest to achieve a 2-20 times increase in the background concentration of the inorganic nutrients. Samples were collected according to the increase in electrical conductivity, as well as reference samples before and after the experiment.

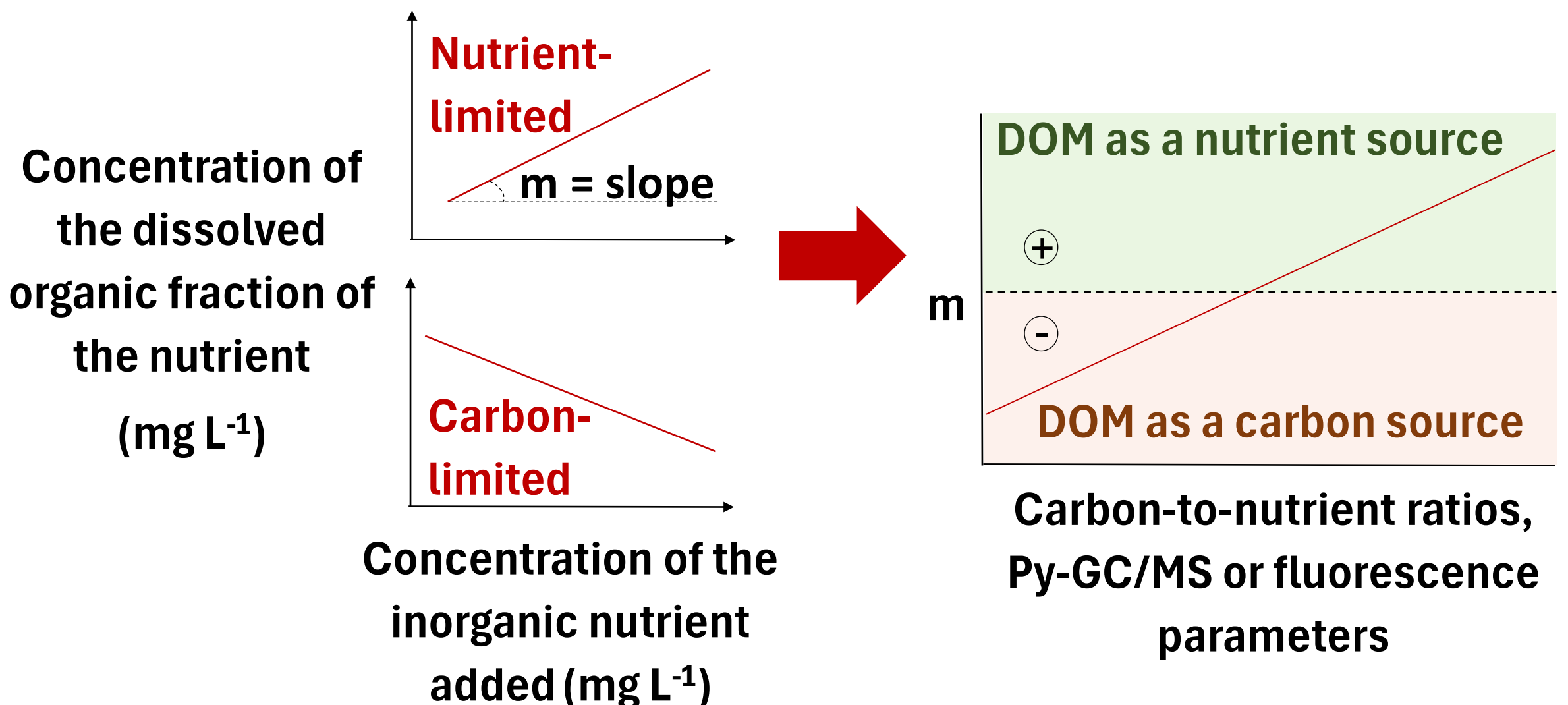


Laboratory Analyses

- Stream water samples were analyzed for: DOC, total nitrogen (TN), nitrate-N and ammonium-N, total P and ortho-phosphate.
- Stream water samples were analyzed using:
 - Pyrolysis chromatography mass spectrometry (Py-GC/MS): an automated pipeline in Rstudio³ identified and grouped the compounds;
 - Fluorescence spectroscopy.

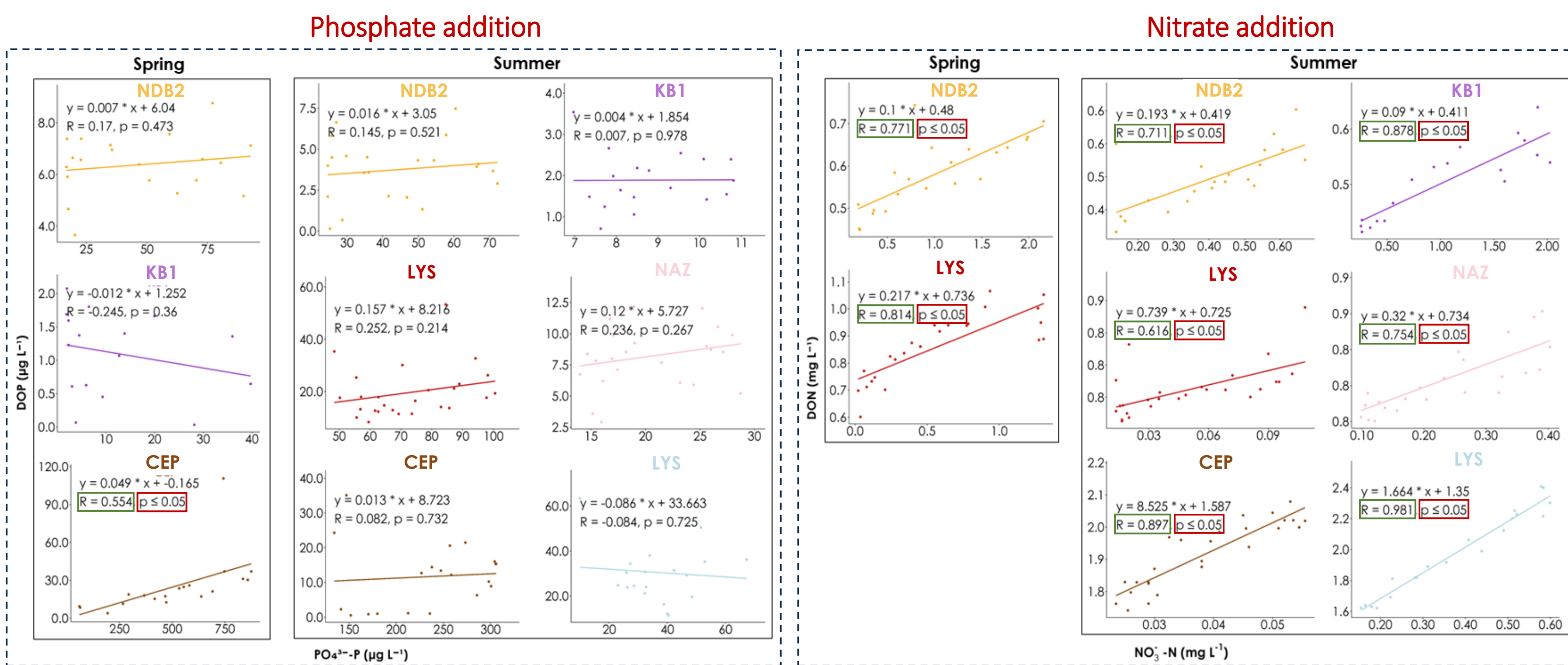
Statistical Analysis

- Correlations between nitrate-N-DON and phosphate-P-DOP were assessed via linear regression (Pearson R and p-values).
- The resulting slopes (m) were correlated with carbon-to-nutrient ratios (e.g., DOC:DON, DOC:DOP, DOC:TN, DOC:TP, DON:DOP and TN:TP) and DOM composition indicators from Py-GC/MS and the fluorescence spectroscopy.



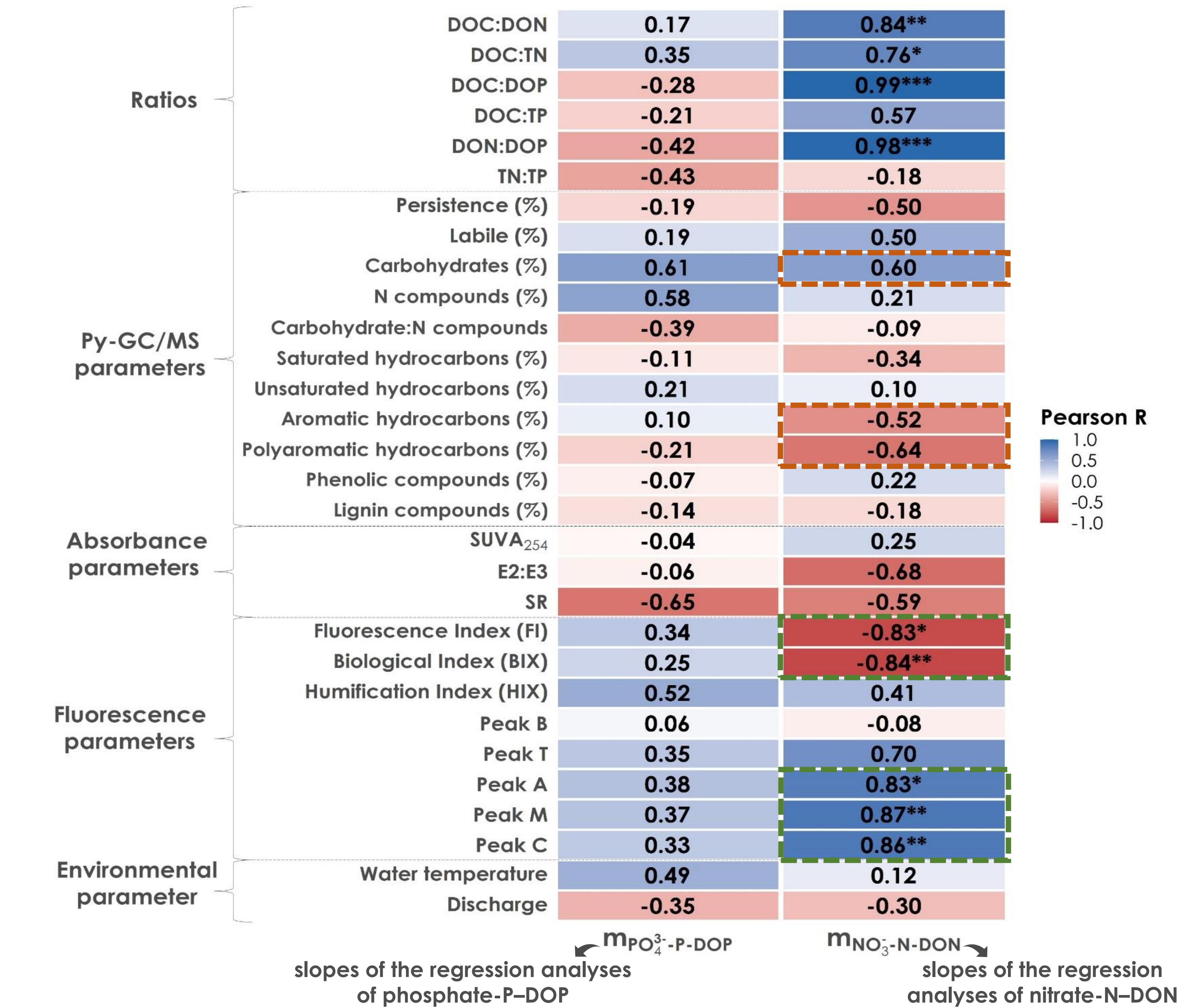
Key Findings and Conclusions

Are the headwater streams carbon- or nutrient-limited?



- Correlations for phosphate were only significant in one stream in spring (CEP), whereas correlations for nitrate addition were significant ($p \leq 0.05$).
- Positive correlation ($m > 0$) between organic and inorganic nutrient = microorganisms shifted from organic towards inorganic sources when inorganic nutrient became available = **Nutrient-limited streams**.

Does DOM composition regulate nutrient dynamics in headwater streams?



DON and DOP dynamics responded differently to inorganic nutrient additions because **N and P play different roles** in aquatic biogeochemistry.

✗ Phosphate additions → DOP did not strongly react during phosphate additions = **P dynamics is likely governed by abiotic processes**.

✓ Nitrate additions → broader DOM properties (source, processing state, molecular weight, aromaticity) analyzed through optical parameters **regulate nutrient dynamics**.

⚠ Nitrate additions → Py-GC/MS parameters did not significantly correlate with nutrient slopes, but directional patterns were observed ($p > 0.05$) = **DOM molecular composition might have some relevance**:
1. streams with **higher carbohydrate** fractions showed greater DON availability (**steeper slopes**).
2. streams dominated by **aromatic and polyaromatic** compounds showed **reduced DON availability**.

References

- Graeber, D., McCarthy, M. J., Shatwell, T., Borchardt, D., Jeppesen, E., Søndergaard, M., Lauridsen, T. L., & Davidson, T. A. (2024). Consistent stoichiometric long-term relationships between nutrients and chlorophyll-a across shallow lakes. *Nat. Commun.*, 15(1), 809. doi: 10.1038/s41467-024-45115-3
- Zhang, X., Yang, X., Hensley, R., Lorke, A., & Rode, M. (2023). Disentangling in-stream nitrate uptake pathways based on two-station high-frequency monitoring in high-order streams. *Water Resour. Res.*, 59(3). doi: 10.1029/2022WR032329
- Huan Chen, et al. (2018). Integration of an automated identification-quantification pipeline and statistical techniques for pyrolysis GC/MS tracking of the molecular fingerprints of natural organic matter. *Journal of Analytical and Applied Pyrolysis*, 371-380. doi: 10.1016/j.jaap.2018.07.002