Nutrient Balances of Rewetted Fens – Groundwater Lysimeter Results

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Keywords: rewetting fens, peat forming plants, lysimeter, North East Germany

Abstract
With the raising of groundwater levels to protect fens and the climate, there may be a risk of nutrients, such as nitrogen or potassium, leaching into the groundwater. Great amounts of nutrients, which are accumulated largely by peat forming plants like *Phragmites australis* and *Carex* spec., are conveyed into rewetted fens through high amounts of introduced water. Nitrogen leaching into the groundwater is very low even at the beginning of flooding and there is no sudden, pronounced leaching. Only a portion of potassium is taken up by plants whereas the rest might be found in the groundwater. Increasing nutrient inputs must be expected as soon as more contaminated water is added contributing to the regeneration of groundwater and increasing the pollution with nutrients at once.

Introduction
Peatlands contribute greatly to the world's climate as they can be carbon sinks in their natural state or carbon sources when drained (Couwenberg et al. 2011). Two grave consequences of draining and usage of peatlands is the mineralization of the peat layer which causes the release of greenhouse gases and fertilization leading to accumulation of nutrients. To mitigate impacts of climate change and reduce the greenhouse gas emissions these peatlands need to be rehydrated.
Broad fen areas exist in the lowlands of North East Germany which have been drained and used in agriculture, mostly grassland, since several hundred years. When rewetting fens released nutrients from the decomposition of peat might leach out and accumulate in the groundwater (Behrendt, Schalitz, Hölzel 1998; Harpenslager et al. 2015), decreasing the water quality and potentially polluting neighboring ecosystems through high inputs of nutrients.
This article investigates nutrient balances of peat forming plants such as reed and sedges on rewetted fen soils.

Methods
This study was conducted using the groundwater lysimeters at the experimental station of ZALF e.V. in Paulinenaue. The lysimeters contain fen soils of differing peat thickness obtained as monoliths from fen areas in North East Germany classified as eutric histosols (Haveländisches Luch, Rhinluch and Peenehaffmoor), are 1.5 m deep and have a surface area of 1 m^2. During the vegetation period groundwater levels were kept constant at 0 cm below surface by additional water from glass jars simulating groundwater flow. The effluent groundwater after rainfall events, which seeped through the soil, was collected in a canister followed by an analysis of contents. In- and effluxes were documented daily. The data used in this study was gathered form 2019-2021.
Only lysimeters with *Phragmites australis, Carex acutiformis* and *Carex disticha* were included in the analysis as these plants naturally occur in fens and they are known to be peat forming species.
The experimental station has its own meteorological station recording precipitation, air and soil temperature, relative humidity, global radiation, sunshine duration and wind speed. Mean annual precipitation was around 539.2 mm, during April and October 354.1 mm, and mean annual temperature averaged at 10.3 °C (2011-2021).

Water analysis
Samples were stored in a freezer until analysis to impede chemical processes. NH_4-, NO_3-, P- and K-contents were determined simultaneously with an ASS analyzer.

Plant analysis

Plant dry mass was recorded followed by grinding and determination of nitrogen, phosphorus and potassium. Total nitrogen was identified through digestion with volcanite acid and hydrogen peroxide, phosphorus through digestion with sulphuric acid and hydrogen peroxide, reacting to NH_4VO_3 and ammonium molybdate, and potassium was identified with sulphuric acid and hydrogen peroxide.

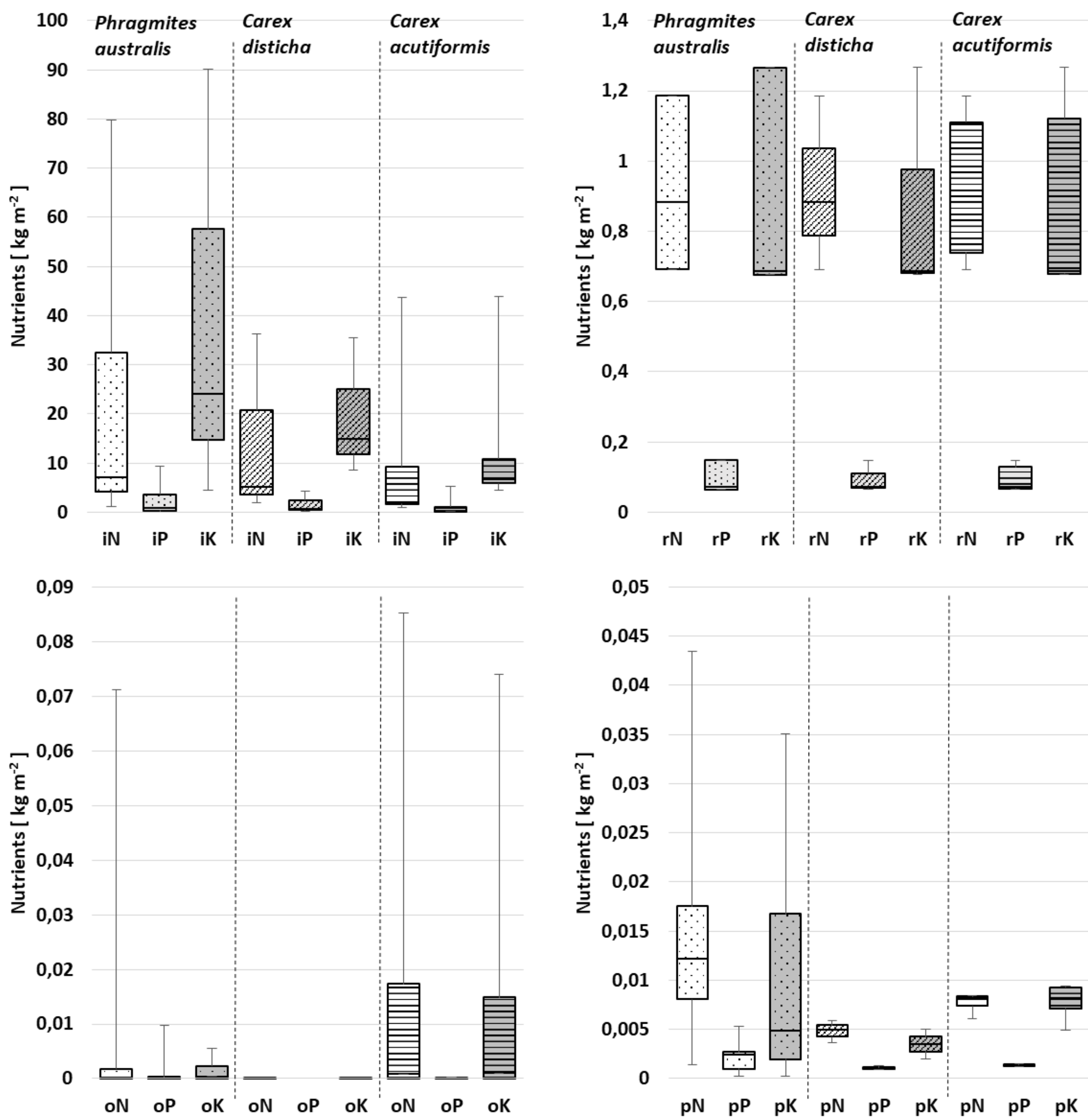

Figure 1. Nutrient contents [kg/m²] from influx, precipitation and efflux water as well as the harvested plant material for the investigated plant species. Abbreviations describe the influx (i), precipitation (r), efflux (o), plant (p), nitrogen (N), phosphorus (P) and potassium (K). Black bars display the median, boxes 50 % and whiskers 75 % of the data.

Results and Discussion

The results show elevated nutrient inputs through the influx water for all investigated lysimeters and species. Analysis of efflux water and plant material display overall low nutrient contents. The former results from little to no efflux (median = 2 liters). Together with data from the plant materials which show no greater nutrient deposit one could assume that the water introduced into the systems was stored in the plants or more likely contributed to the evapotranspiration leaving the nutrients in the soil. Other studies which investigated nutrient leaching after rewetting of recently abandoned agricultural fen areas identified higher concentrations of phosphorus and ammonium in the pore water of degraded peat soils (Zak & Gelbrecht 2007; van de Riet, Hefting & Verhoeven 2013). The results of this study however were conducted on agricultural fen soil monoliths that have been rewetted over 30 years ago and weren't managed with fertilizers or such since then. Previous experiments which accompanied the rehydration of these monoliths documented low nitrogen but high potassium leaching into the groundwater during the first years (Behrendt, Schalitz, Hölzel 1998). So it is possible that nutrients from fertilizers or animal feces initially located in the soils leached into the groundwater over time and are now washed-out almost entirely. This could explain the low nutrient contents of the effluent groundwater and plant material measured in this study.

Conclusions

In connection with soil nutrient analysis lysimeter studies contribute the risk determination for nutrient leaching from agricultural fen soils after rewetting. Long-term experiments could even help to estimate the time for leaching processes into the groundwater.

Acknowledgements

J. Hoysagk wrote the first draft. M. Pesch helped with displaying the data. M. Pesch and A. Behrendt reviewed the first draft. F. Eulenstein and A. Behrendt provided access to the lysimeter station and the data conducted from the experiments.

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