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Nitrogen Transport & Retention Dynamics Across Central European Catchments using Large-sample Data

Photo: André Künzelmann - UFZ

Tam Nguyen[1], Jan Fleckenstein[1], Fanny Sarrazin[2], Pia Ebeling[1], Stefanie Lutz[3], Andreas Musolff[1], and Rohini Kumar[2]

[1]Department of Hydrogeology, Helmholtz-Zentrum für Umweltforschung GmbH - UFZ, Leipzig, Germany (tam.nguyen@ufz.de)
[2]Department of Computational Hydrosystems, Helmholtz Centre for Environmental Research - UFZ, Leipzig, Germany
[3]Copernicus Institute of Sustainable Development, Utrecht University, 3584 CB Utrecht, the Netherlands

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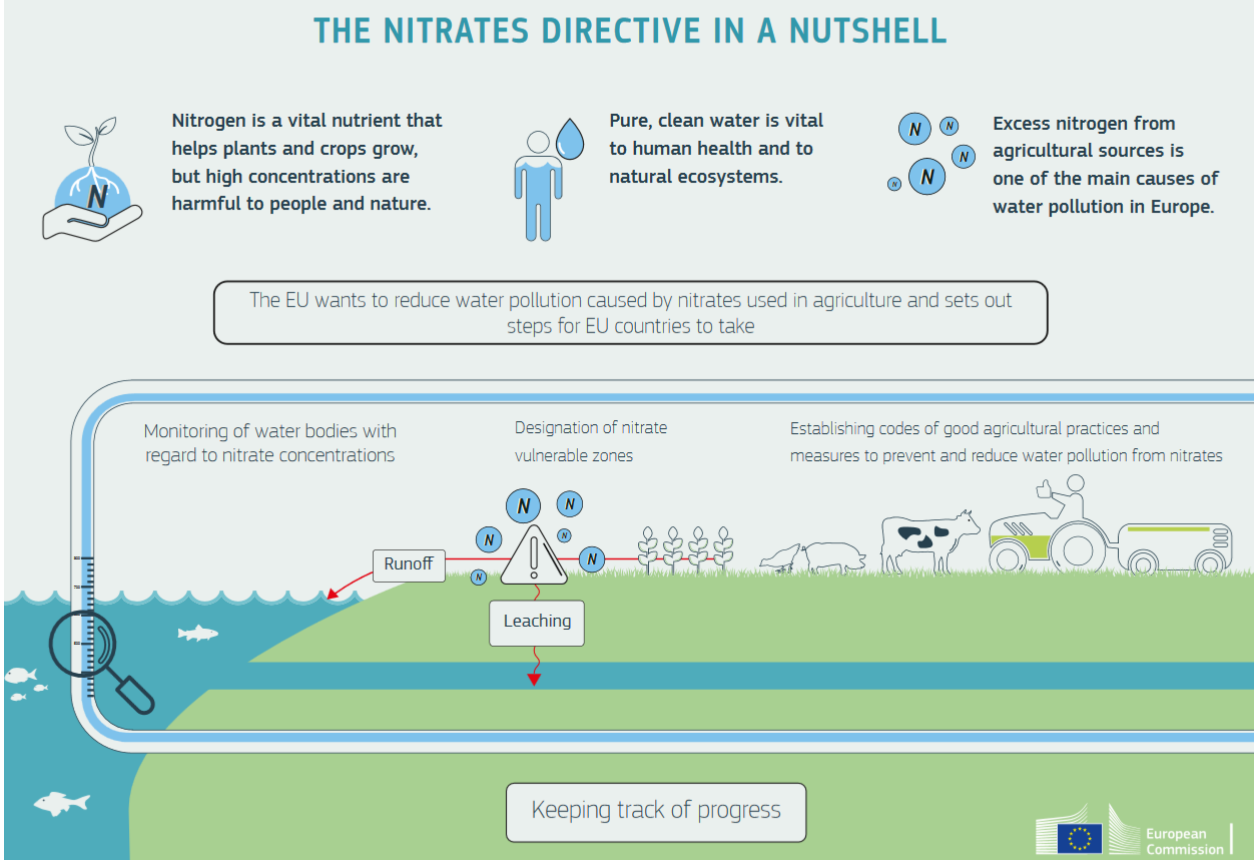
Motivation – Nitrogen (N) Problem



Since the implementation of the EU Nitrates Directive, in-stream nitrate concentration have decreased by 0.02% per year in the period 1992-2018, while no appreciable changes have been measured in groundwater (EEA, 2020).

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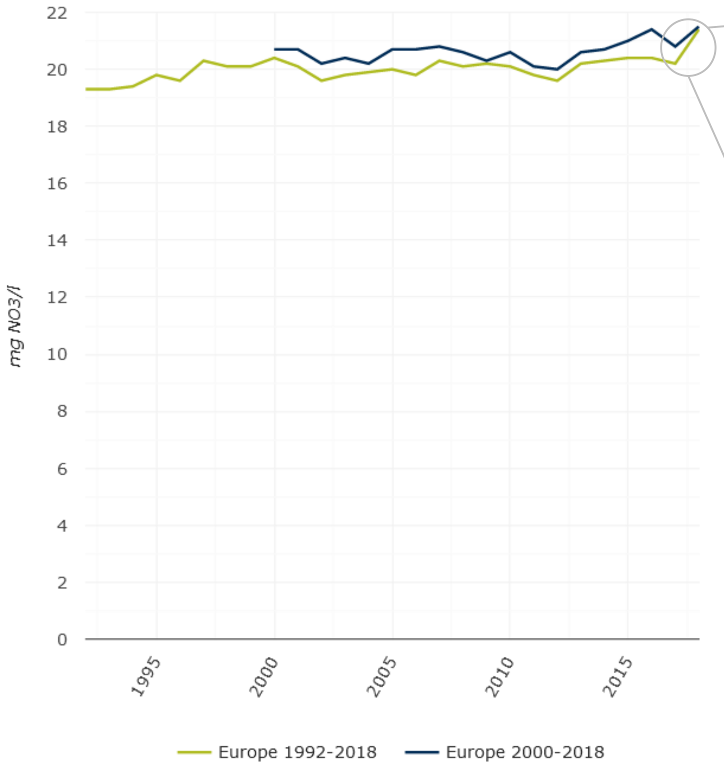
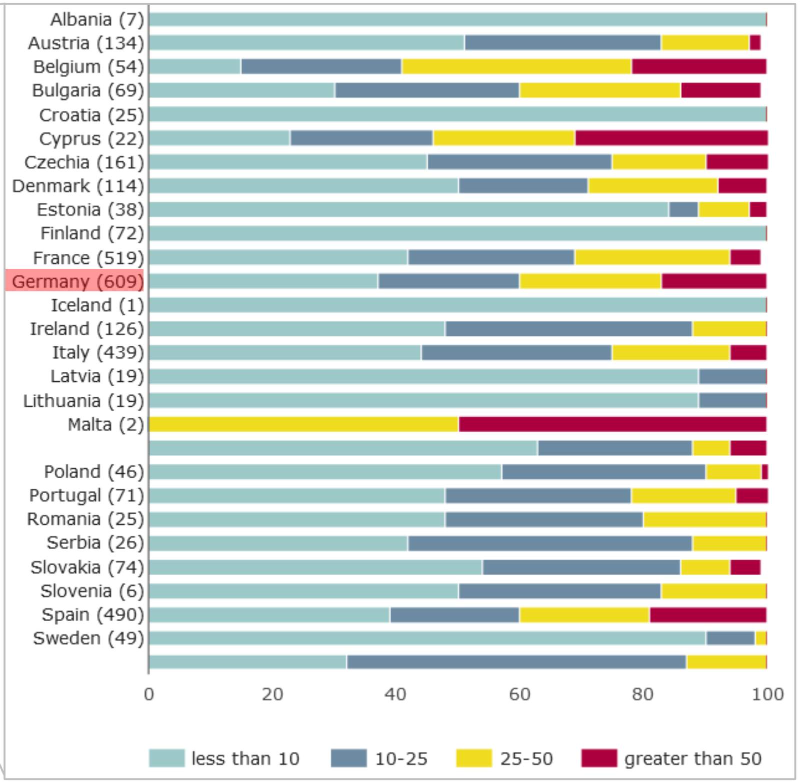
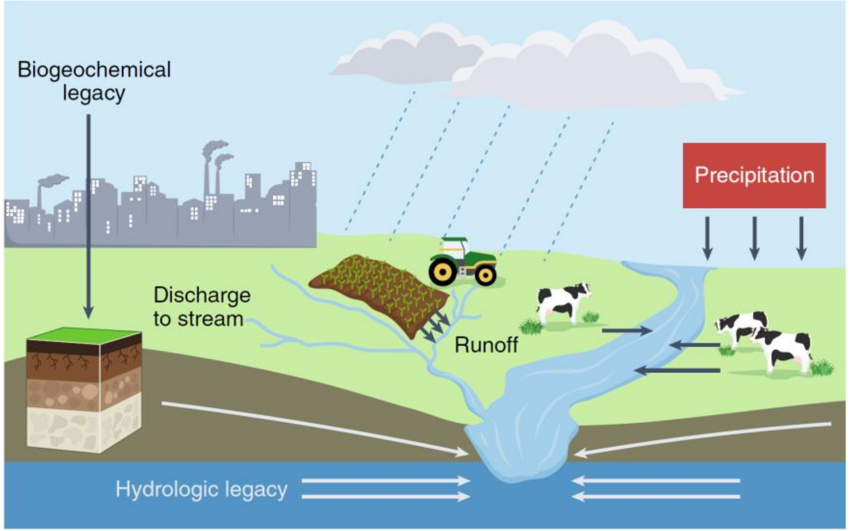


Nitratkonzentration im Grundwasser in Europa (1992-2018) (EEA, 2020)



(EEA, 2020)

Motivation – Nitrogen (N) Problem



N transport and retention at the catchment scale
Biogeochemcal and hydrologic legacies (Basu et al., 2022)

Mississippi River Basin (Van Meter et al., 2016, 2017):

- 53% N surplus was accumulated in the soil in form of organic N (ON) => takes 35 years to deplete 99% of this soil ON
- 55% of recent annual riverine N > 10 years

New Zealand (McDowel et al., 2021)

- Lag times between soil N leaching & riverine N export: 1 to 12 years

Europe (Dupas et al., 2020; Ehrhardt et al., 2021):

- Time lags between N surplus and peak riverine N export: 2-14 years
- „missing N" (fraction of N surplus stored in catchment + removed by denitrification) is higher in catchments with deeper aquifers and lower in catchments with higher fraction of consolidated and porous aquifers

→ Research objectives: to unravel different components of 'missing N' across Central European catchments, Germany to understand the linkages between long-term N dynamics to catchment attributes

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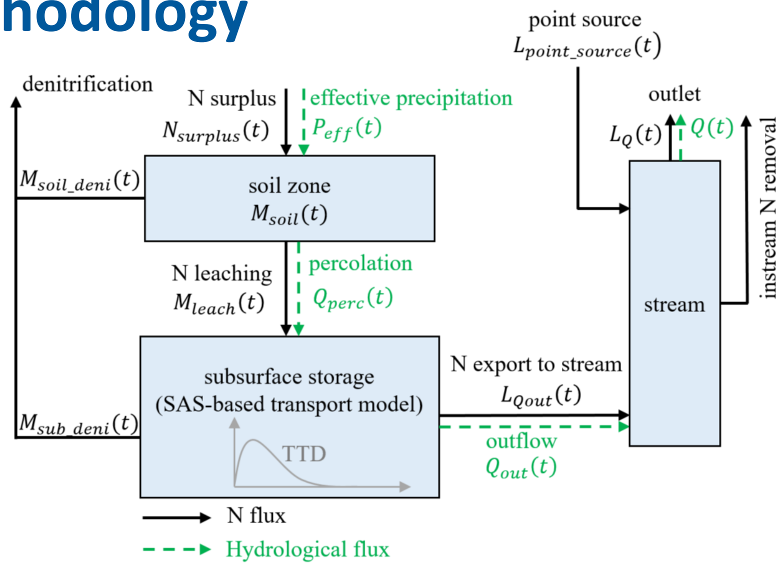
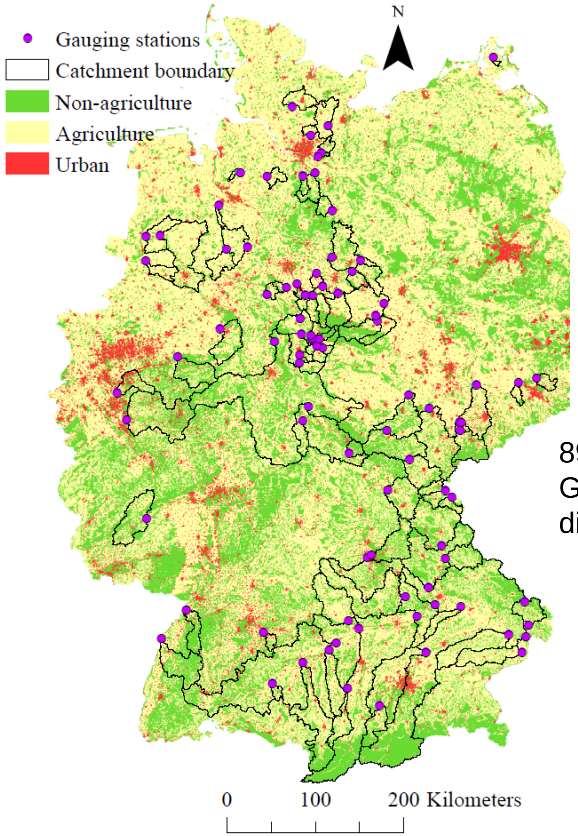
Methodology



Conceptual model for N transport (adapted from Nguyen et al., 2022)

- Spatially lumped model
- Yearly time step (from 1950-2014)
- Input data: N suprlus + effective precipitation,...
- Calibration data: instream nitrate concentrations



89 catchments in Germany with diverse settings

→ k-means clustering → find the underlying long-term N characteristics → relate to the catchment attributes

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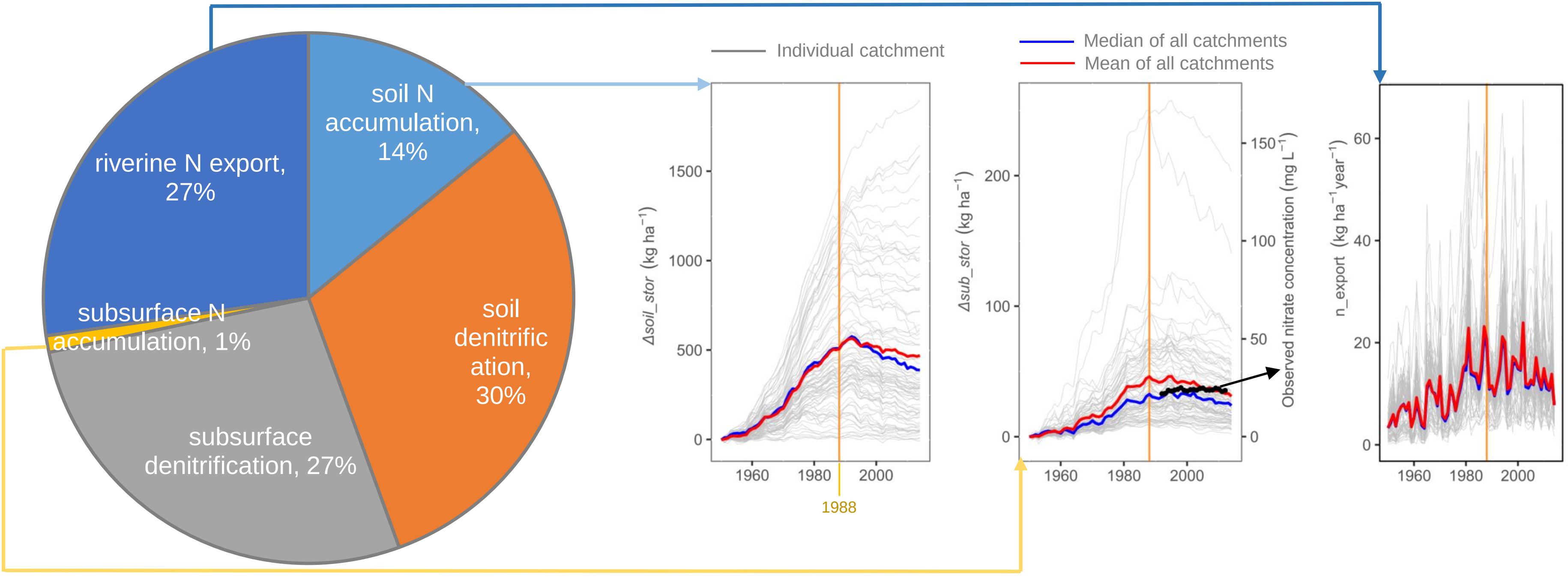
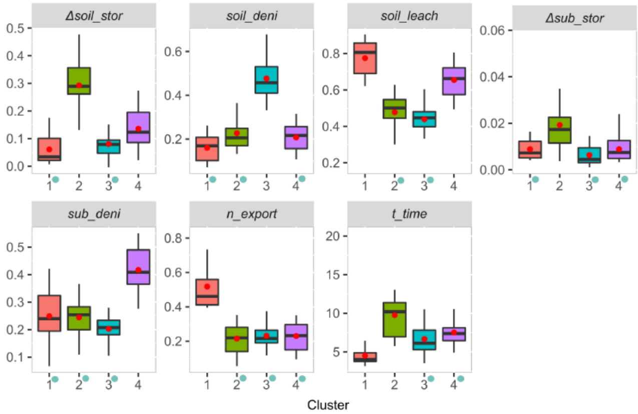
Results: Long-term N balance (1950-2014)



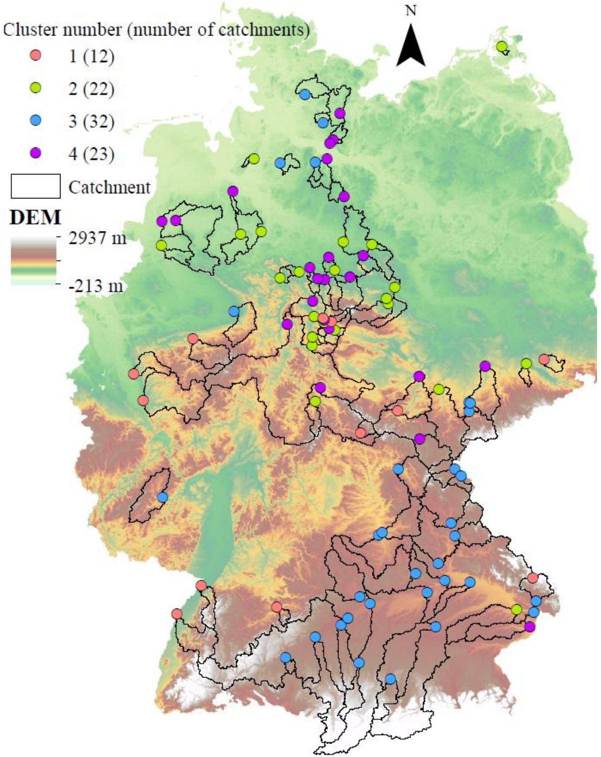
Average N balance during the 1950-2014 period (%N surplus) across 89 catchments (mean transit times = 7.1 years)

Simulated soil N, subsurface N accumulation, and riverine N export from each of 89 catchments during the 1950-2014 period

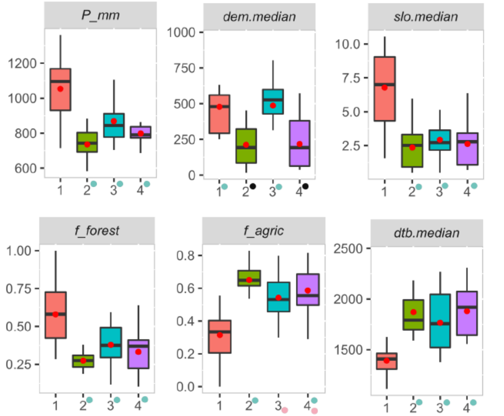
Results: N clusters vs. catchment characteristics



Variables used for the k-means clustering and boxplots of each clusters



Spatial distribution of four catchment clusters



Some catchment attributes in each cluster

Long-term average (1950-2014) N characteristics for clustering:

- Δ*soil_stor*: soil N accumulation (% N surplus)
- *soil_deni*: soil N denitrification (% N surplus)
- *soil_leach*: soil N leaching to the subsurface (%N surplus)
- Δ*sub_stor*: soil N accumulation (% N surplus)
- *sub_deni: subsurface denitrification* (% N surplus)
- *n_export: riverine N export* (% N surplus)
- *t_time: subsurface transit times (years)*

P_mm: annual average precipitation (mm)
dem.median: median elevation (m)
slo.median: median topographic slope
f_forest: areal fraction of forest land cover
f_agric: areal fraction of agriculture land cover
dtb.median: median aquifer depth (cm)

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Conclusions

- A significant amount of N was accumulated in the root zone, which could continue to affect groundwater and river water quality in the coming years.

- Subsurface N accumulation is low, but it is dissolved form and the transit time might be long => a consistently high subsurface nitrate concentration is expected

- Based on the long-term N-dynamics, four catchment area clusters can be distinguished, which can be explained by catchment area attributes.

- Management and evaluation program should take into account N accumulation in the root zone and subsurface transit times

Thank you for your attention