Integrative Isotope Techniques to Evaluate the Fate and Transport of Nitrogen in an Alpine Foothill Catchment

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HELMHOLTZ CENTRE FOR ENVIRONMENTAL RESEARCH – UFZ

Motivation

Problem description

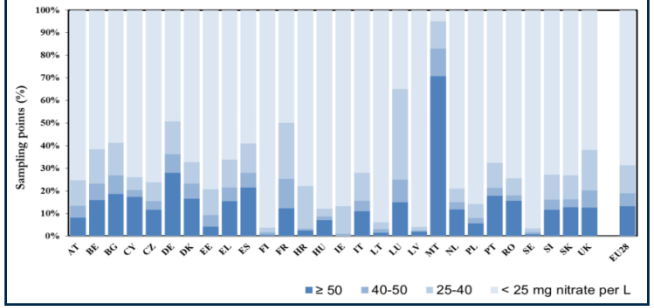
Nitrate (NO_3^-) pollution in EU (2012–2015)

- Groundwater:
  - 13.2% - exceedance of drinking water threashold (50 mg L^{-1})
  - 5.7% - 40 to 50 mg L^{-1}
- Rivers:
  - 12% - eutrophic
  - 7% - hypertrophic

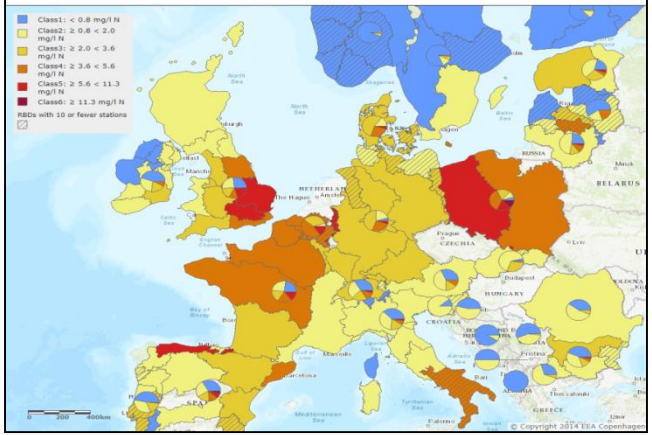
Knowledge gap

Development of effective management strategies requires thorought understanding of the main drivers of nitrate export in large river catchments.

Mean annual NO_3^- concentration in groundwater



Mean annual NO_3^- concentration in rivers



Objective

Our goal

To investigate dynamics of **nitrate** export from a mesoscale river basin impacted by **agriculture** and how it is shaped by different **drivers** using multi-isotope techniques coupled with geo-statistical methods and Bayesian mixing models.

Three drivers controlling NO_3^- export

Driver 1: microbiological N-turnover processes

Driver 2: land-use

Driver 3: hydrological conditions

Methodology

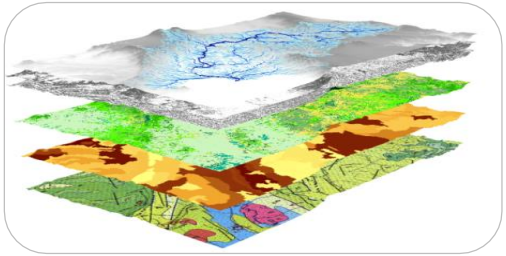
Monitoring

- **high spatial resolution** seasonal surface water monitoring over several years
- event-based monitoring in selected locations
- precipitation
- measured parameters

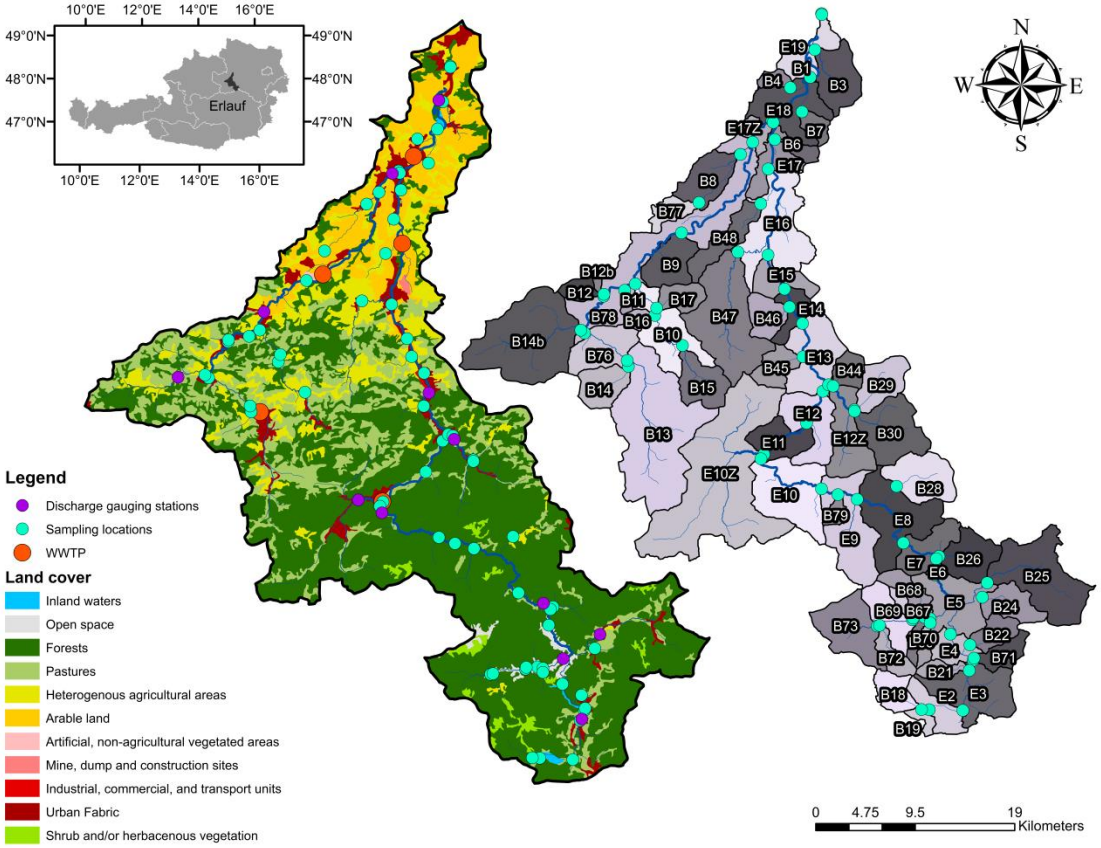
in field	laboratory
dissolved oxygen	nitrate isotopes ($\delta^{15}N$, $\delta^{18}O$)
temperature	water isotopes ($\delta^{2}H$, $\delta^{18}O$)
EC	$\delta^{13}C$ of DIC
pH	major ions
	DOC

Data analysis and modelling

- spatio-temporal distribution patterns and correlation analysis
- Top-kriging technique & runoff separation
- Bayesian stable isotope mixing model



Study area



Name	Erlauf
Tributary of	Danube
Area	632 km^2
Discharge	14 m^3 s^{-1}
Elevation min	220 m a.s.l.
Elevation max	1900 m a.s.l.

Results

Driver 1: microbiological N-turnover processes

- **correlations:** very weak for $\delta^{15}N_{NO3}$ and $\delta^{18}O_{NO3}$, strong for $\delta^{15}N_{NO3}$ and NO_3^-
- **message:** no signal of NO_3^- degradation

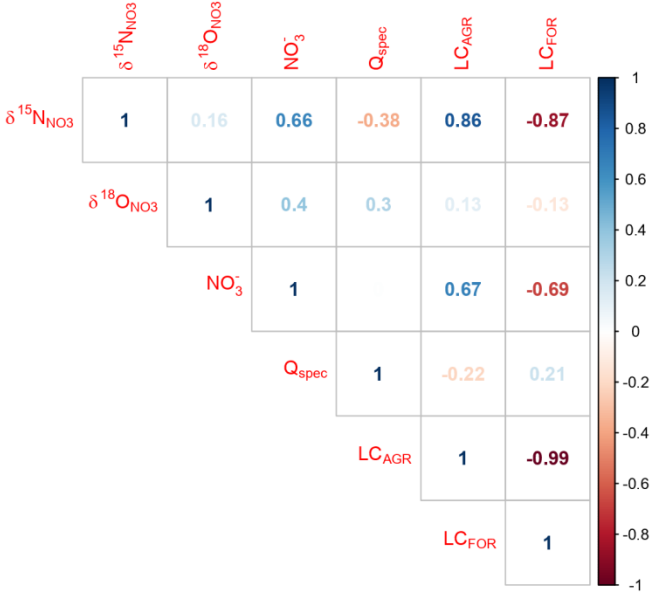
Driver 2: land-use

- **correlations:** very strong to strong between percentage of land cover and $\delta^{15}N_{NO3}$, and NO_3^- but not for $\delta^{18}O_{NO3}$
- **message:** high importance, change in source

Driver 3: hydrological conditions

- **correlations:** weak for Q_{spec} and other parameters
- **mesage:** low impact of dilution, change in sources/pathways

Spearman pairwise correlation matrix



Results

Driver 1: microbiological N-turnover processes

- analysis of changes along the main river

  $\delta^{15}N_{NO3,}$ $\delta^{18}O_{NO3}$, NO_3^-, NO_3^- loads

- analysis of correlations location wise

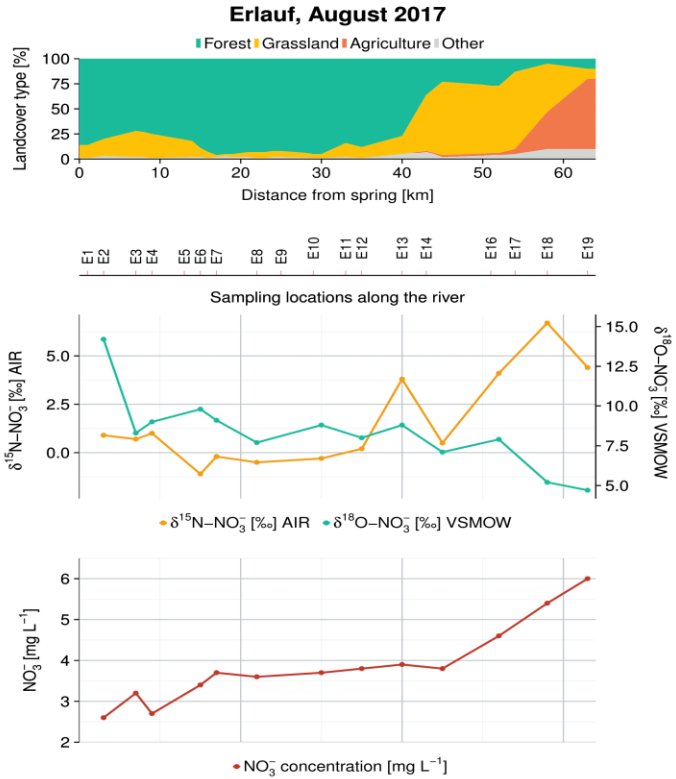
  $\delta^{15}N_{NO3}$ vs $\delta^{18}O_{NO3}$

  $\delta^{15}N_{NO3}$ vs $\ln(NO_3^-)$

  $\delta^{18}O_{NO3}$ vs $\delta^{18}O_{H2O}$

- conclusions

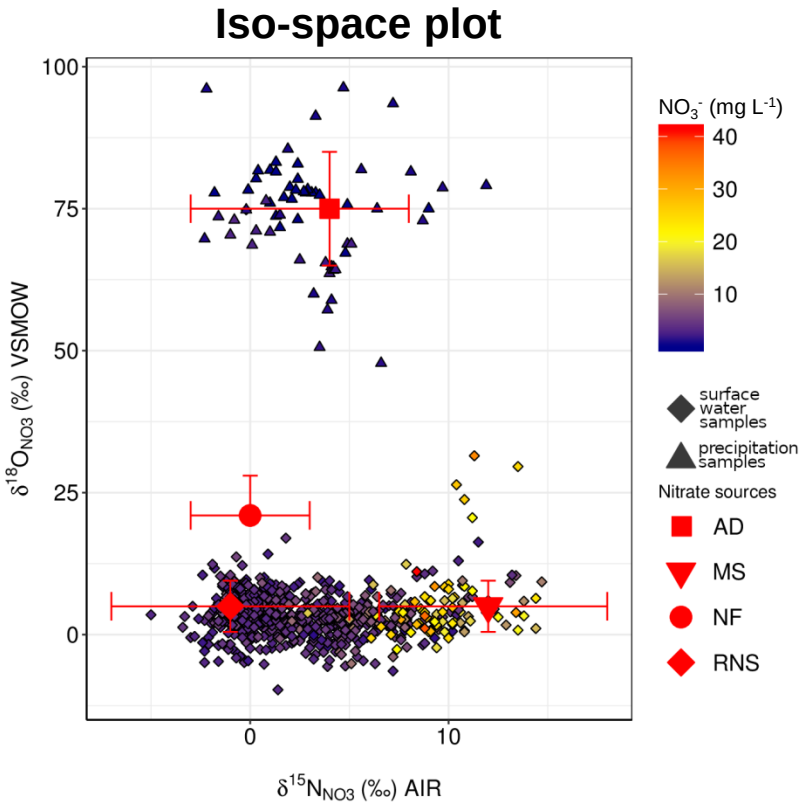
  in regional scale in-stream denitrification plays only a minor role in Erlauf catchment



Results

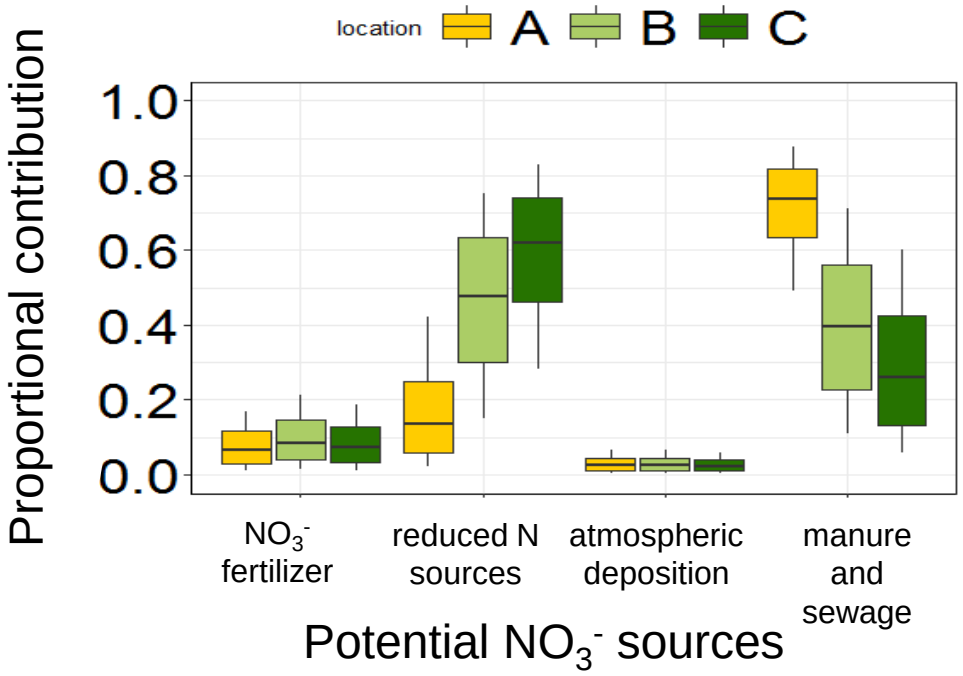
Driver 2: land-use

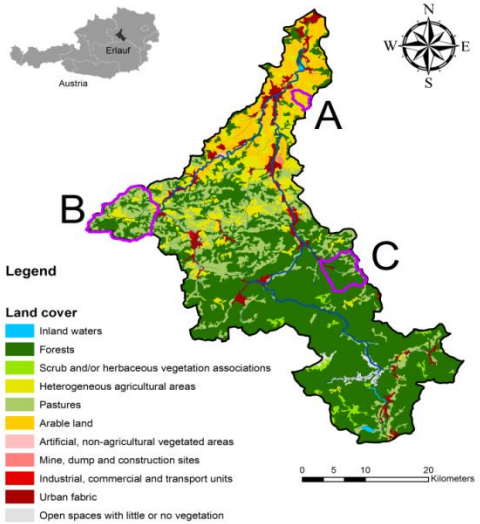
- Bayesian stable isotope mixing model
- potential NO_3^- sources and their isotopic compositions:
  1. atmospheric deposition (**AD**)
  2. manure and sewage (**MS**)
  3. nitrate fertilizer (**NF**)
  4. reduced N sources (**RNS**)



Results

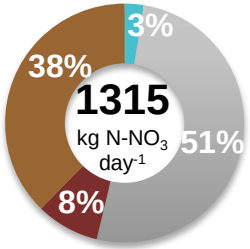
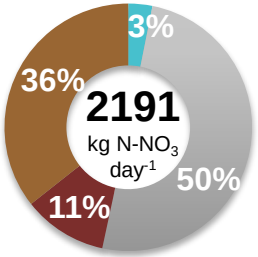
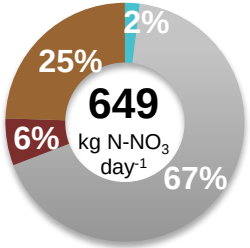
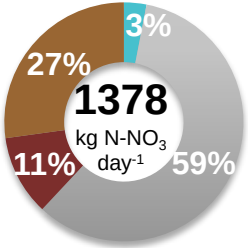
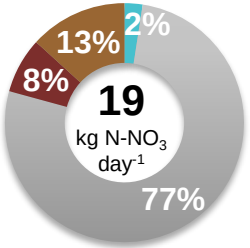
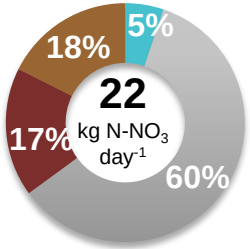
Bayesian stable isotope mixing model

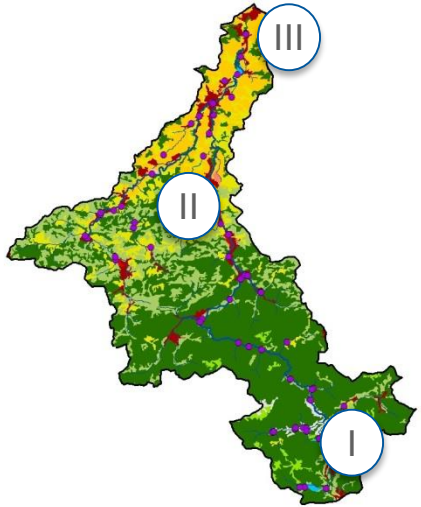




Land cover [%] \ Sub-catchment	A	B	C
Arable land	**60**	-	-
Heterogeneous agricultural areas	40	13	-
Pastures	-	**47**	16
Forests	-	39	**82**
Urban fabric	-	1	2

Results

	April 2017	November 2017
III Outlet		
II Middle course of the river		
I Headwaters		

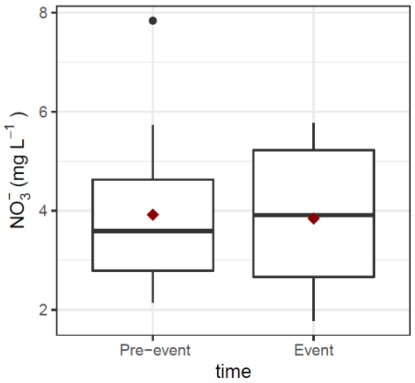


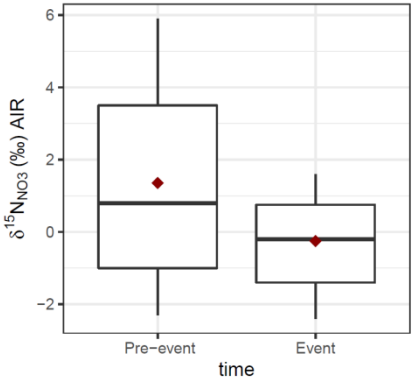
- Nitrate fertilizer
- Reduced N sources
- Atmospheric deposition
- Manure & sewage

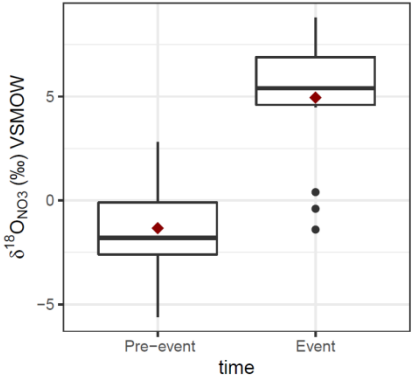
Results

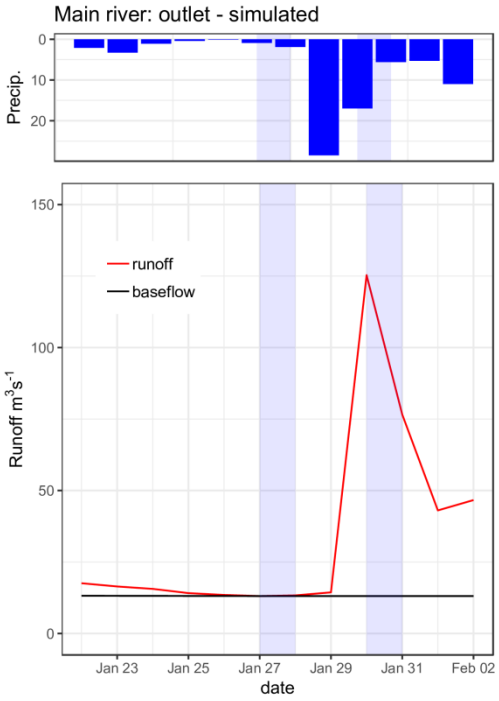
Driver 3: hydrological conditions

- low impact of dilution
- mobilization of the NO_3^- pools from the unsaturated zone with lower $\delta^{15}N_{NO3}$ coming from RNS and elevated $\delta^{18}O_{NO3}$ caused by the shorter residence time and therefore lower exchange with water $\delta^{18}O$









Conclusions

Conclusions

- **Driver 1:** NO_3^- degradation potential is not sufficient to control the nitrate export
- **Driver 2:** agriculture is related to a considerable shift in the proportional contribution of manure and sewage and nitrate loads
- **Driver 3:** different NO_3^- export pathways occur during base flow and high flow conditions
- **Methodology:** measurement of NO_3^- alone would not be sufficient to trace all different controls on NO_3^- export

Outlook

Tripple catchment study

Thank you for your attention

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