Modelling history for future considerations: Nutrient emissions into German surface waters in 1880

Karoline Morling & Stephan Fuchs, KIT

Why modelling 1880?

- status of coastal and transitional waters assessed using reference conditions, for which historical periods are considered

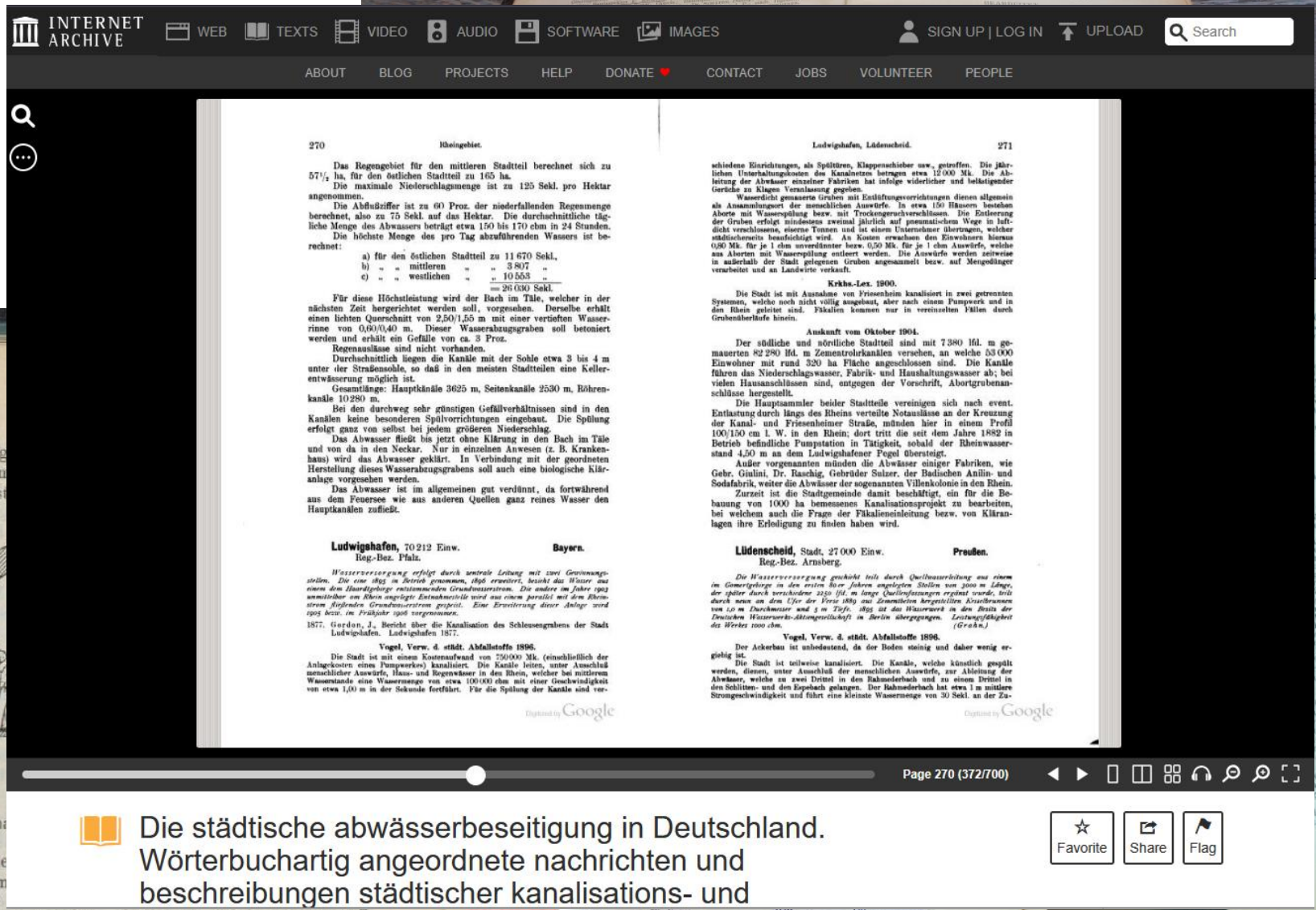
- Several modelling studies using inconsistent approaches and providing differing results
  - for German Baltic Sea catchments in 1880 (Hirt et al. 2014)
  - For North Sea catchments in 1880 (Gadegast & Venohr 2015) and in 1900 (Blauw et al. 2019)

- **Objectives:**
  - Revised historical N and P emission scenario for 1880 for all German North Sea and Baltic Sea river basins

How does 1880 looks like?

How does 1880 looks like?

- Libraries
- Internet Archive



INTERNET ARCHIVE

Google Books

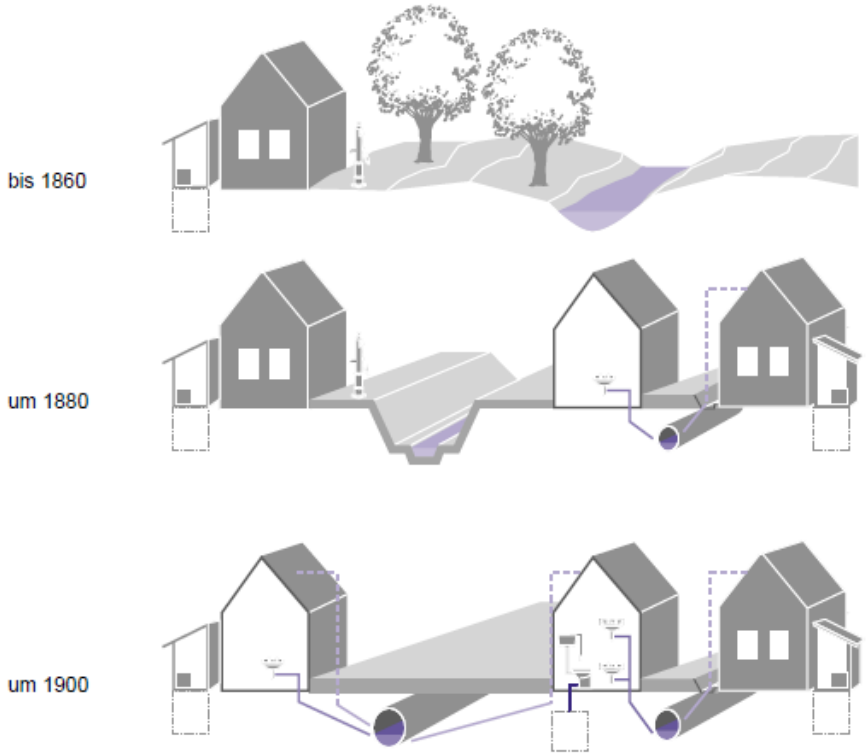
How does 1880 looks like?

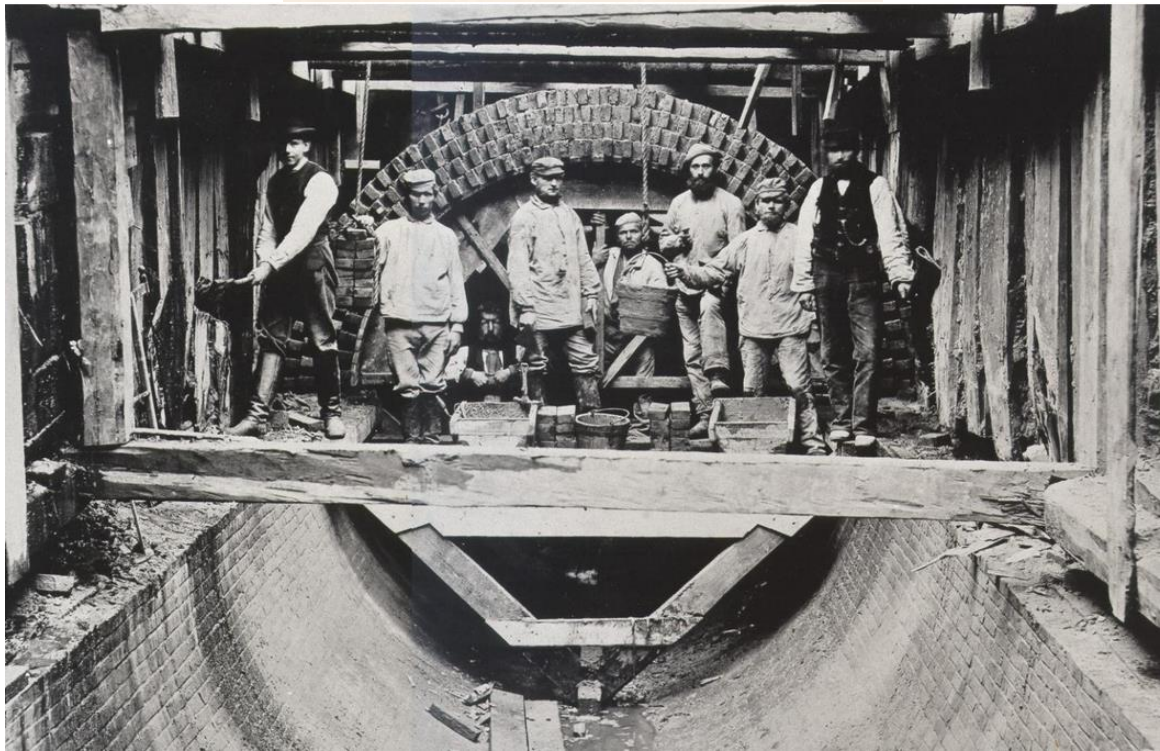
- Agricultural production was still a lot of manual work

How does 1880 looks like?

- Agricultural production was still a lot of manual work
- Massive construction of sewer systems in cities

»Besichtigung des corrigirten Landgrabens durch Sn. Königl. Hoheit den Großherzog am 3. Januar 1885«



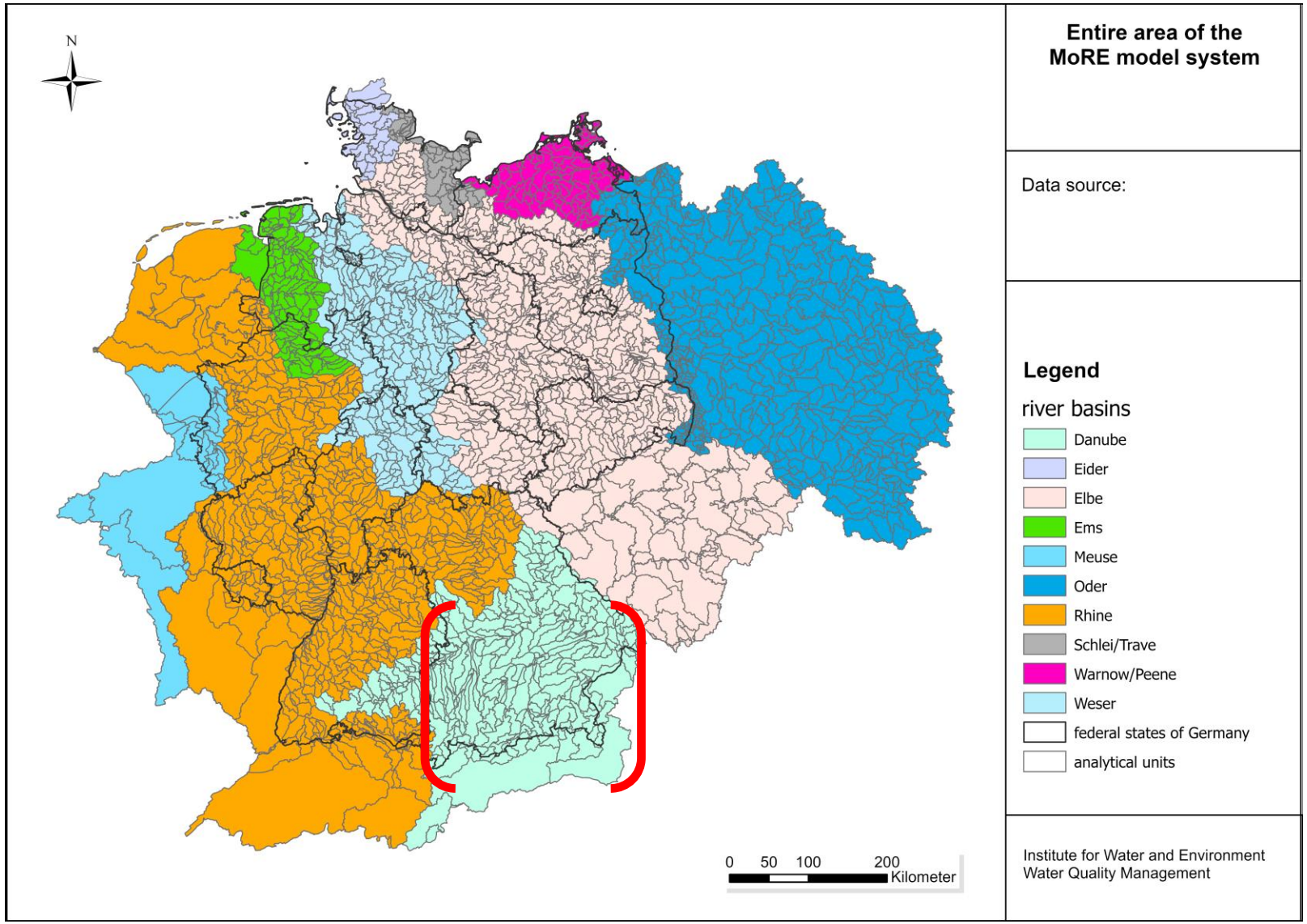


How does 1880 looks like?

- Agricultural production was still a lot of manual work
- Massive construction of sewer systems in cities
- Collection of faeces (night soil) for fertilizing fields

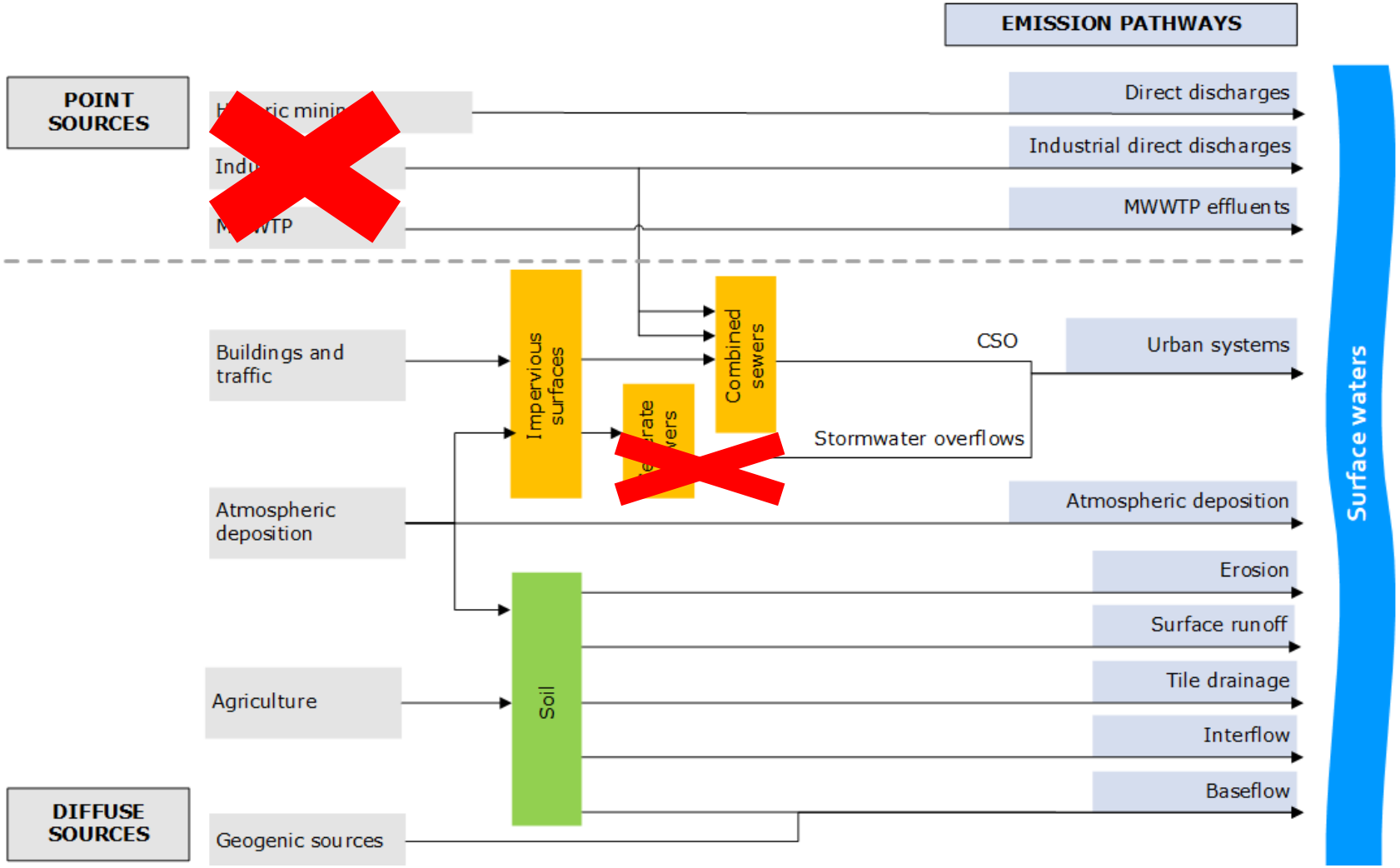
MoRE (Modeling of Regionalized Emissions)

- All German river basins including foreign parts
- Analytical units as spatial modeling units



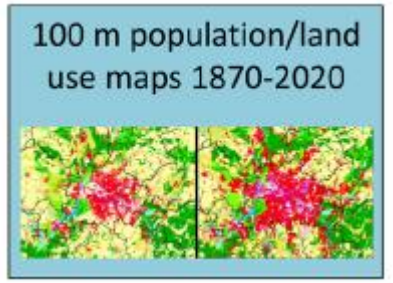
MoRE (Modeling of Regionalized Emissions)

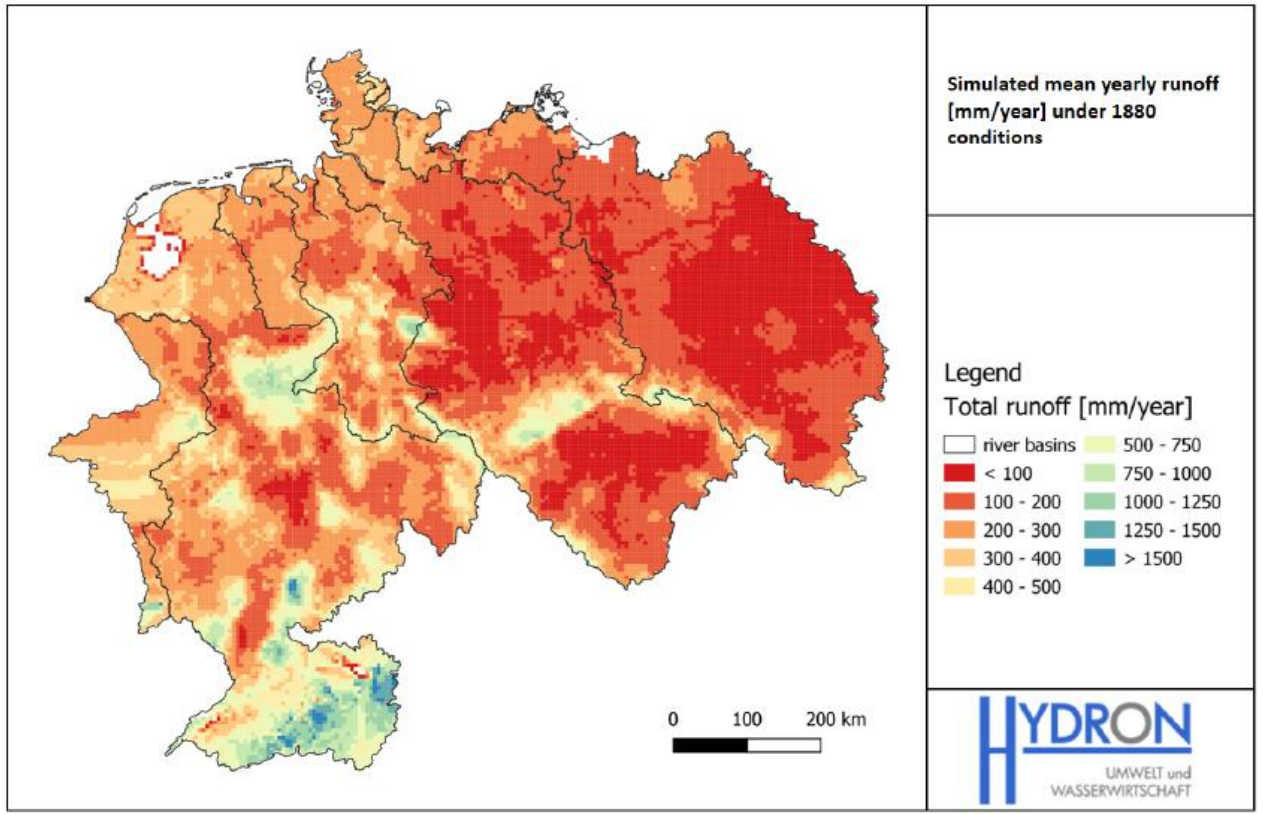
- Modelling N and P
- Emission pathways simplified for 1880 scenario:
  - No point sources
  - Only combined sewers



Input data and model approaches

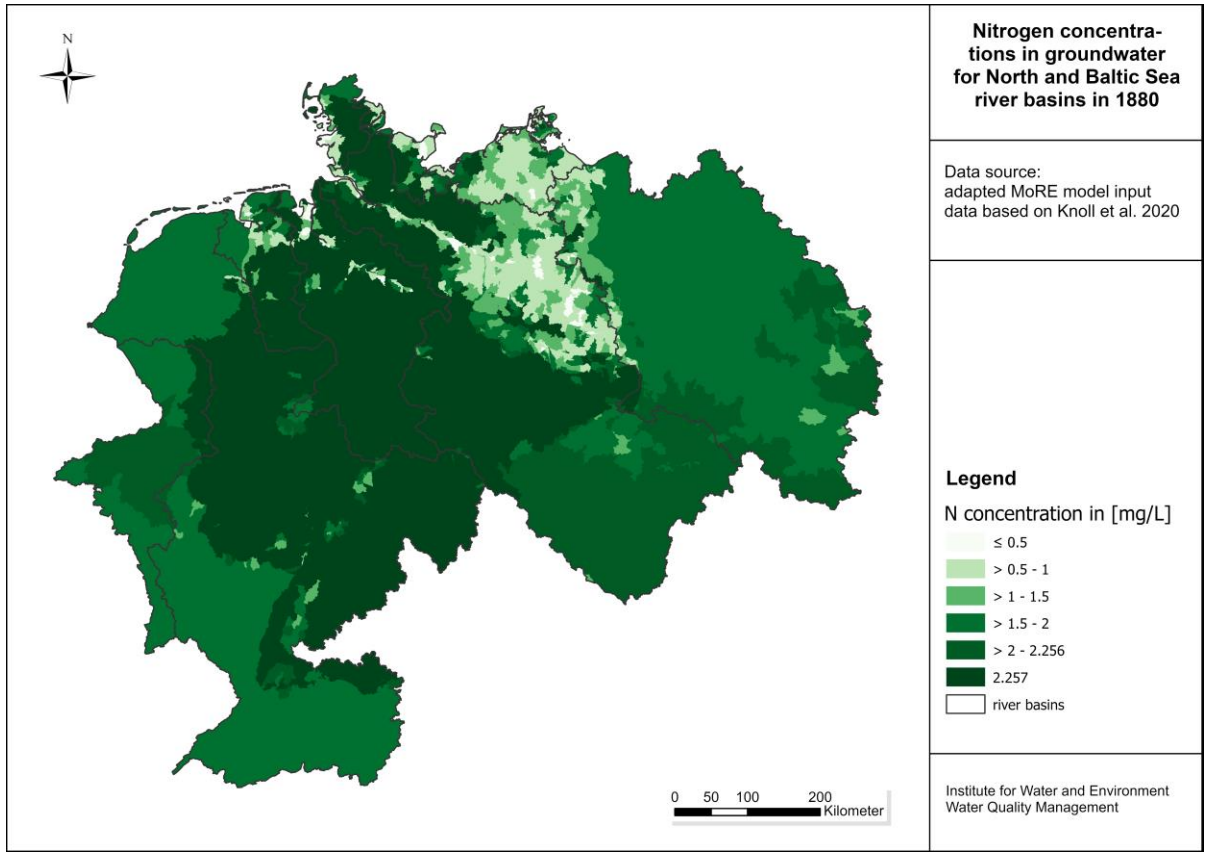
- Already available data sets for historical conditions
- Land use and population from HANZE 2.0 dataset (Paprotny & Mengel 2023)
  - Connection to sewers based on population density
- Historical water balance with LARSIM-ME (HYDRON colleagues)
  - Based on re-analyses data, using climate change vectors
- Erosion: adaptation of R and C factors to obtain soil loss (VisDat colleagues)





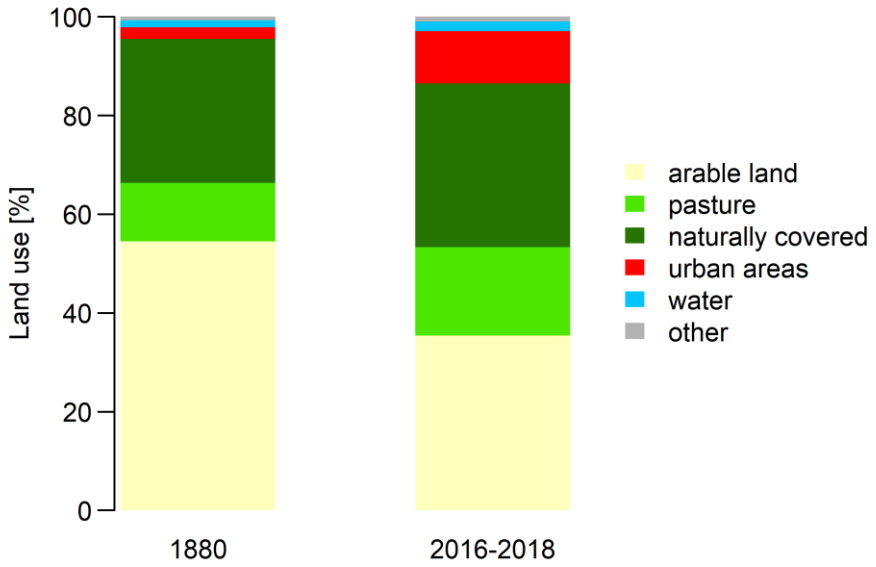
Input data and model approaches

- Already available data sets for historical conditions
- N concentrations in interflow/base flow
  - N surplus often negative
  - Replaced by maximum concentration of 10 mg/L nitrate (2.257 mg/L N)
- P content in topsoil of arable land
  - Barely available from longterm experiments, no clear trends
  - Using the current P content of naturally covered areas instead
- Many more input data, assumptions, simplifications and adapted model approaches …



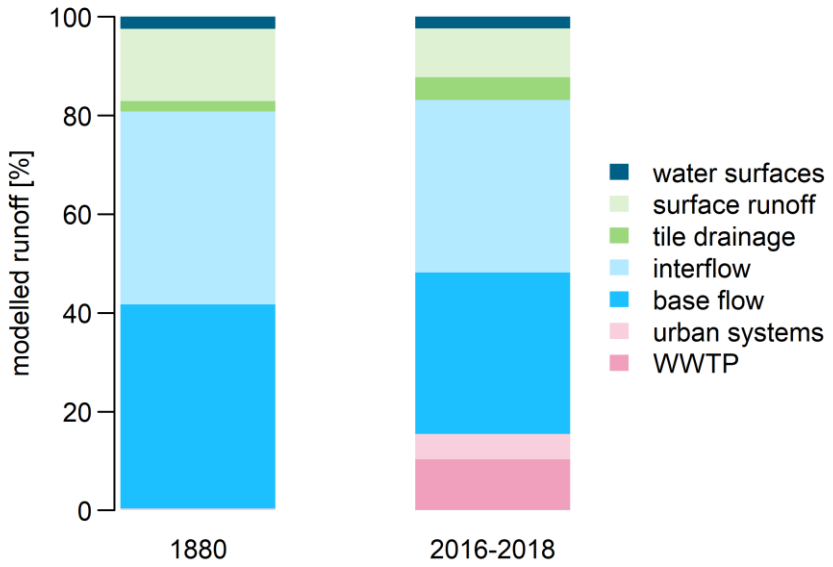
Let‘s have a look into the results.

Land use changes



- Decrease of arable land (54 % → 35 %)
- Increase of urban areas (~2 % → 11 %)

Water balance changes

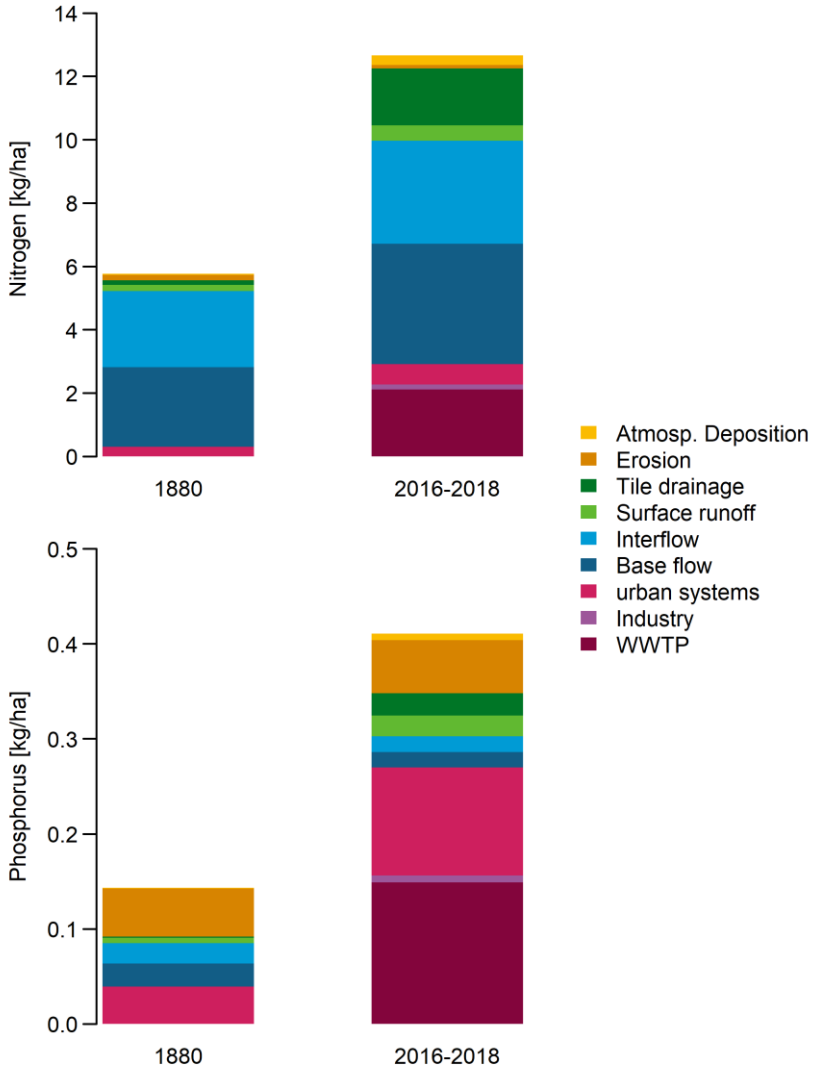


- Redistribution of water
  - Decrease in Interflow/base flow (80 % → 68 %)
  - Increase in runoff from urban areas (<1 % US → 5 % US, 10 % WWTP)

Nutrient emissions into surface waters

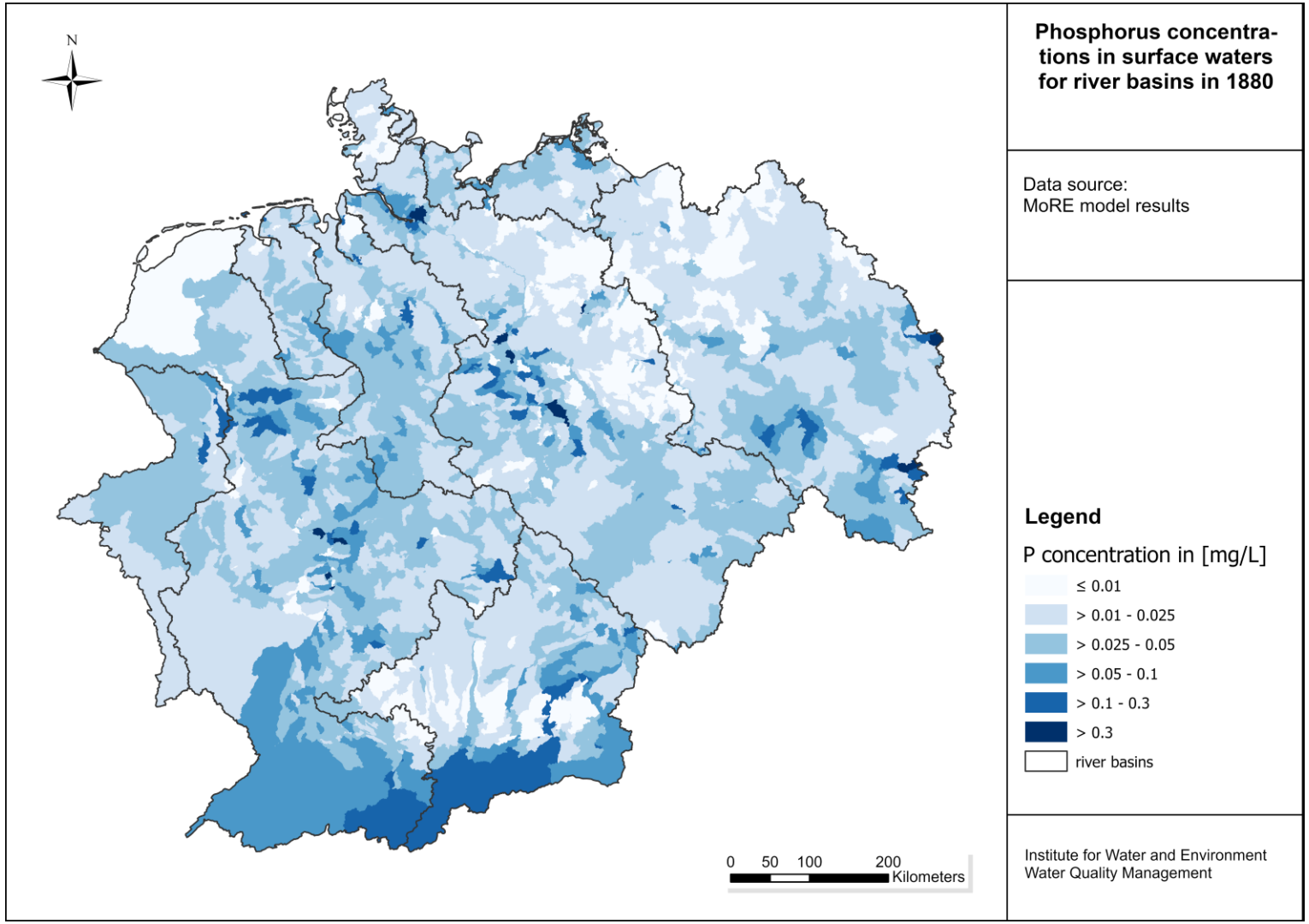
- Nitrogen
  - Emissions more than doubled
  - Main pathways Interflow and base flow (85 % → 56 %)
  - Presently tile drainage and urban areas increased in importance

- Phosphorus
  - Emissions almost tripled
  - Historically erosion was the main pathway (35 % → 14 %)
  - Presently urban areas are the main sources (27 % → 54 % US + WWTP)



Nutrient concentrations

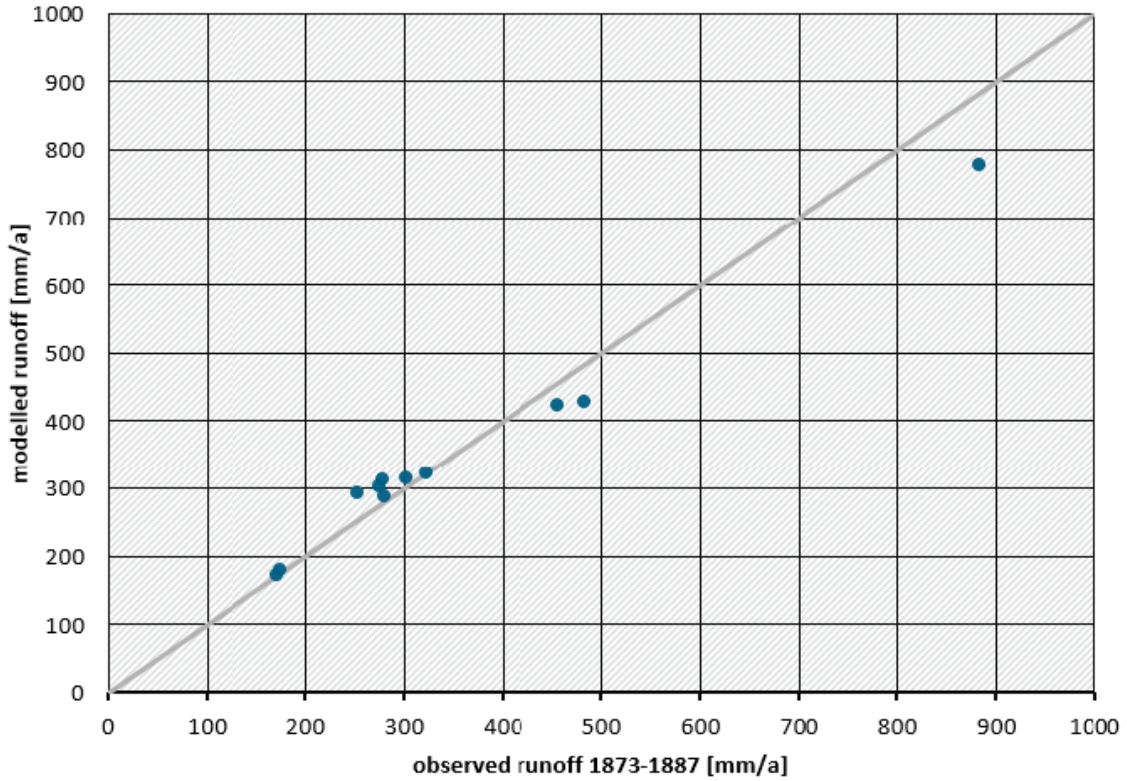
- Riverine concentrations in 1880 generally lower than today
  - TP concentrations widely in pristine range (< 0.05 mg/L)
  - Higher concentrations in cities



Validation

- Hampered by lack of suitable data from historical period
- Check on plausibility (spatial patterns, value ranges) and order of magnitude instead fitting individual data
- Average annual runoff for 11 gauging stations

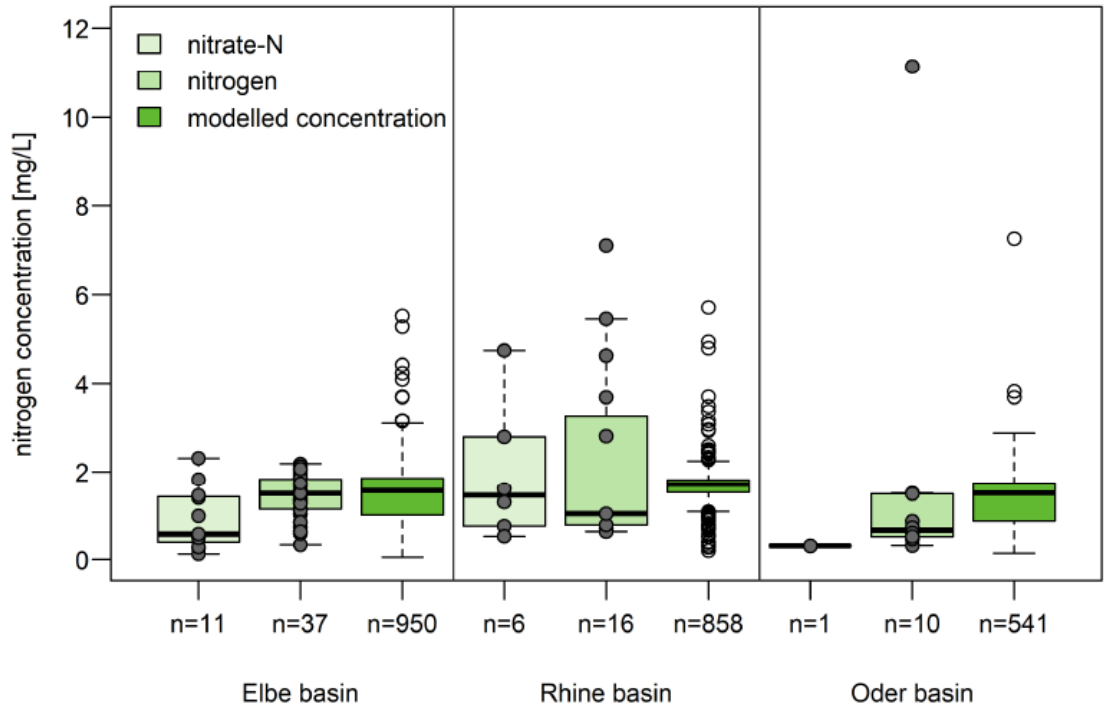
Comparison of observed and modelled runoff. Observed runoff was obtained from GRDC data (BfG 2024) and averaged for the period 1873 – 1887 (refer to Appendix A.6).



Validation

- Hampered by lack of suitable data from historical period
- Check on plausibility (spatial patterns, value ranges) and order of magnitude instead fitting individual data
- Average annual runoff for 11 gauging stations
- Most historical literature data on water samples for nitrogen
  - Treatment of samples and analysing methods not known
  - Overall good agreement

Figure 30: **Observed historical nitrate-N and nitrogen concentrations obtained from literature compared to modelled total nitrogen concentrations in surface waters in 1880 (Figure 28). Single values of the literature data overlay the boxplots as grey dots.**



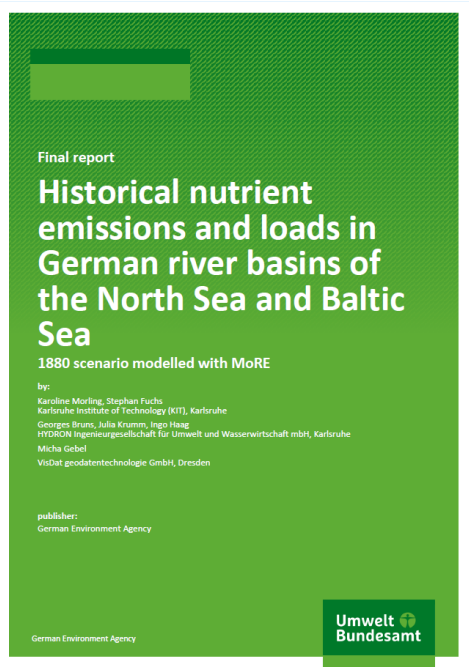
Conclusions & Outlook

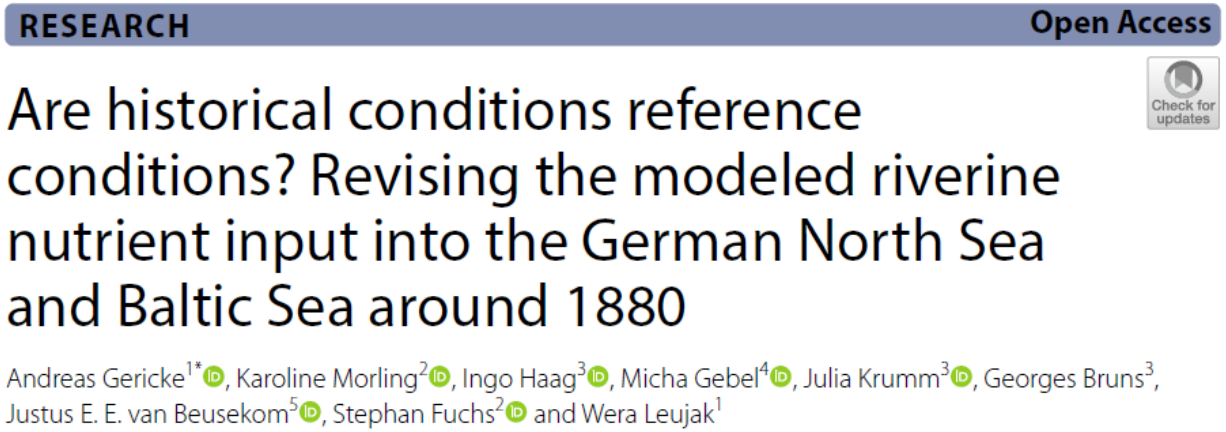
- Results represent pre-industrial state with distinct anthropogenic impacts before the intensification of agricultural production
- Limitations and uncertainties exist
- Results consistent with historical records and other modelling studies

- Results shown in MoRE Toolbox: https://stoffeintraege-more.de/ (presentation Micha Gebel)

- Report to be published

- Results contribute to critical revision of currently implemented target values for TN and TP for North Sea and Baltic Sea tributaries (Gericke et al. 2025): https://doi.org/10.1186/s12302-025-01185-8





Julia Krumm
Ingo Haag
Georges Bruns
Micha Gebel
Andreas Gericke

Thank you!

References

Blauw, A.; Eleveld, M.; Prins, T.; Zijl, F.; Groenenboom, J.; Winter, G. et al. (2019): Coherence in assessment framework of chlorophyll a and nutrients as part of the EU project ‘Joint monitoring programme of the eutrophication of the North Sea with satellite data’. (Ref: DG ENV/MSFD Second Cycle/2016). Activity 1 Report, 2019. https://www.informatiehuismarien.nl/publish/pages/163016/1_coherent_assessment.pdf

Gadegast, M.; Venohr, M. (2015): Modellierung historischer Nährstoffeinträge und -frachten zur Ableitung von Nährstoffreferenz- und Orientierungswerten für mitteleuropäische Flussgebiete. Erstellt im Auftrag des Niedersächischen Landesbetriebs für Wasserwirtschaft, Küsten- und Naturschutz. Berlin, 2015. https://www.nlwkn.niedersachsen.de/download/98787

Gericke, A.; Morling, K.; Haag, I.; Gebel, M.; Krumm, J.; Bruns, G. et al. (2025): Are historical conditions reference conditions? Revising the modeled riverine nutrient input into the German North Sea and Baltic Sea around 1880. In: Environ Sci Eur 37:133 (133). https://doi.org/10.1186/s12302-025-01185-8

Hirt, U.; Mahnkopf, J.; Gadegast, M.; Czudowski, L.; Mischke, U.; Heidecke, C. et al. (2014): Reference conditions for rivers of the German Baltic Sea catchment: reconstructing nutrient regimes using the model MONERIS. In: Regional Environmental Change 14 (3), S. 1123–1138. https://doi.org/10.1007/s10113-013-0559-7

Paprotny, D.; Mengel, M. (2023): Population, land use and economic exposure estimates for Europe at 100 m resolution from 1870 to 2020. In: Scientific data 10 (1), S. 372. https://doi.org/10.1038/s41597-023-02282-0