

Land use Water Quality – 3.-6. June 2025, Aarhus, Denmark

National nitrogen model for regulation of nitrogen in Denmark

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Photo: Emil Skole Henriksen

Introduction

- Gradually transition from uniform to spatially targeted regulation of nitrogen usage in Denmark
- Most strict regulations in areas with low nitrogen reduction between root zone and marine recipients
- Nitrogen reduction maps as basis for regulation



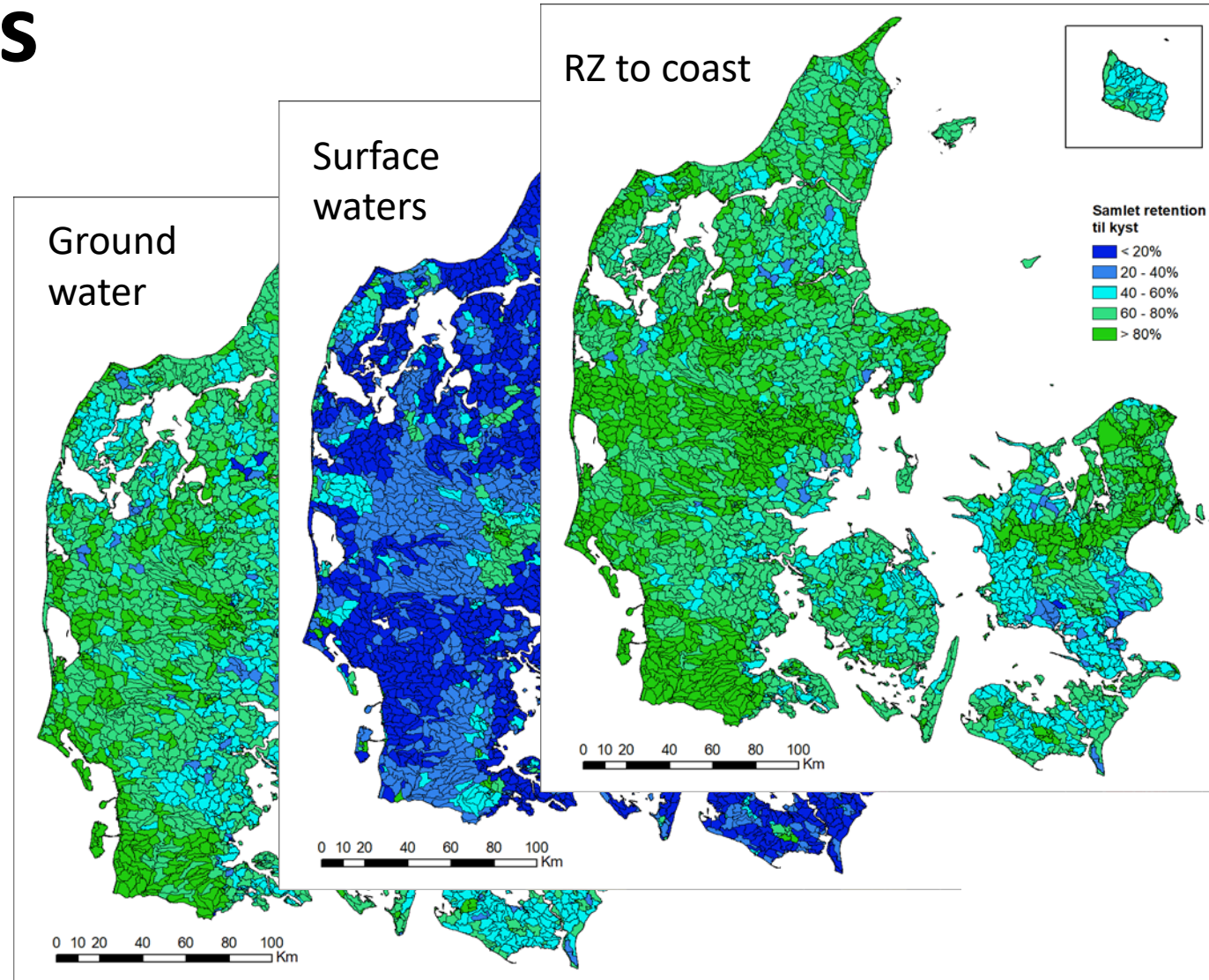
Nitrate retention maps

Status

- First national maps in 2015, update in 2020
- For topographical catchments, mean area ~1500 ha
- Used to prioritise N-mitigation measures in spatially targeted regulation at coastal catchment scale

Next steps

- New agreement on N-regulation at finer scale (closer to farm-scale)
- New green deal



National Nitrogen Model

Nitrate leaching

- Agriculture: NLES5, empirical model, estimating nitrate leaching ~ 1 m below terrain
- Other areas: Standard leaching values

AU: DCA

Groundwater

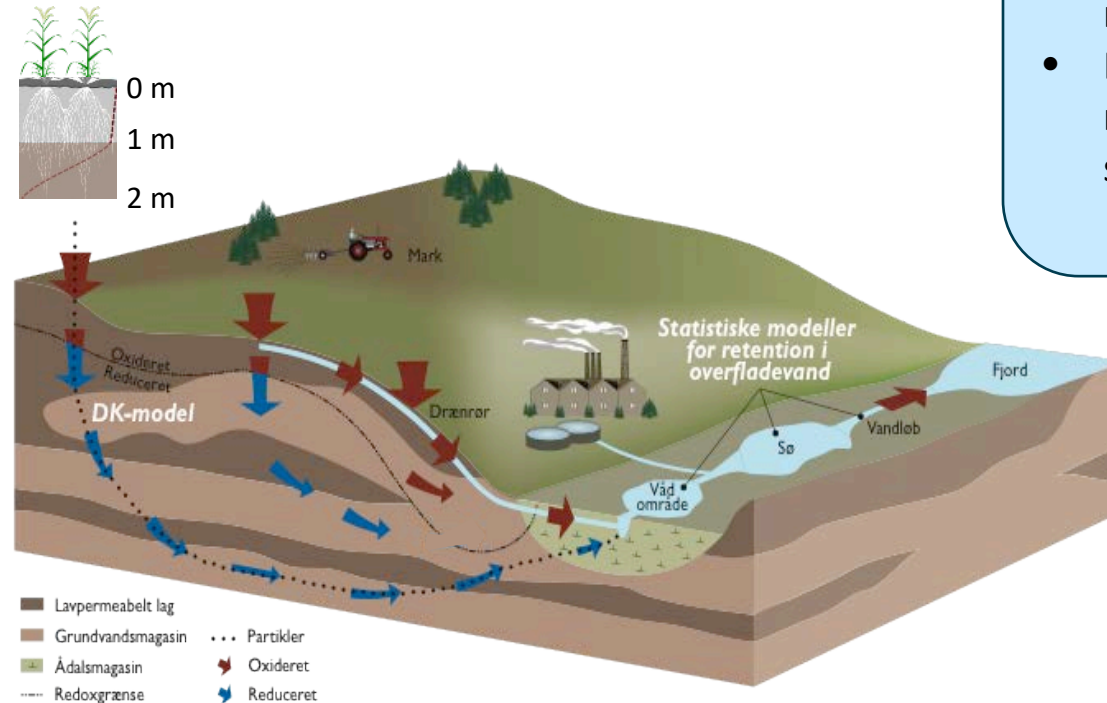
- National Hydrological Model (DK-model), transport in groundwater
- Geochemical model, reduction in groundwater

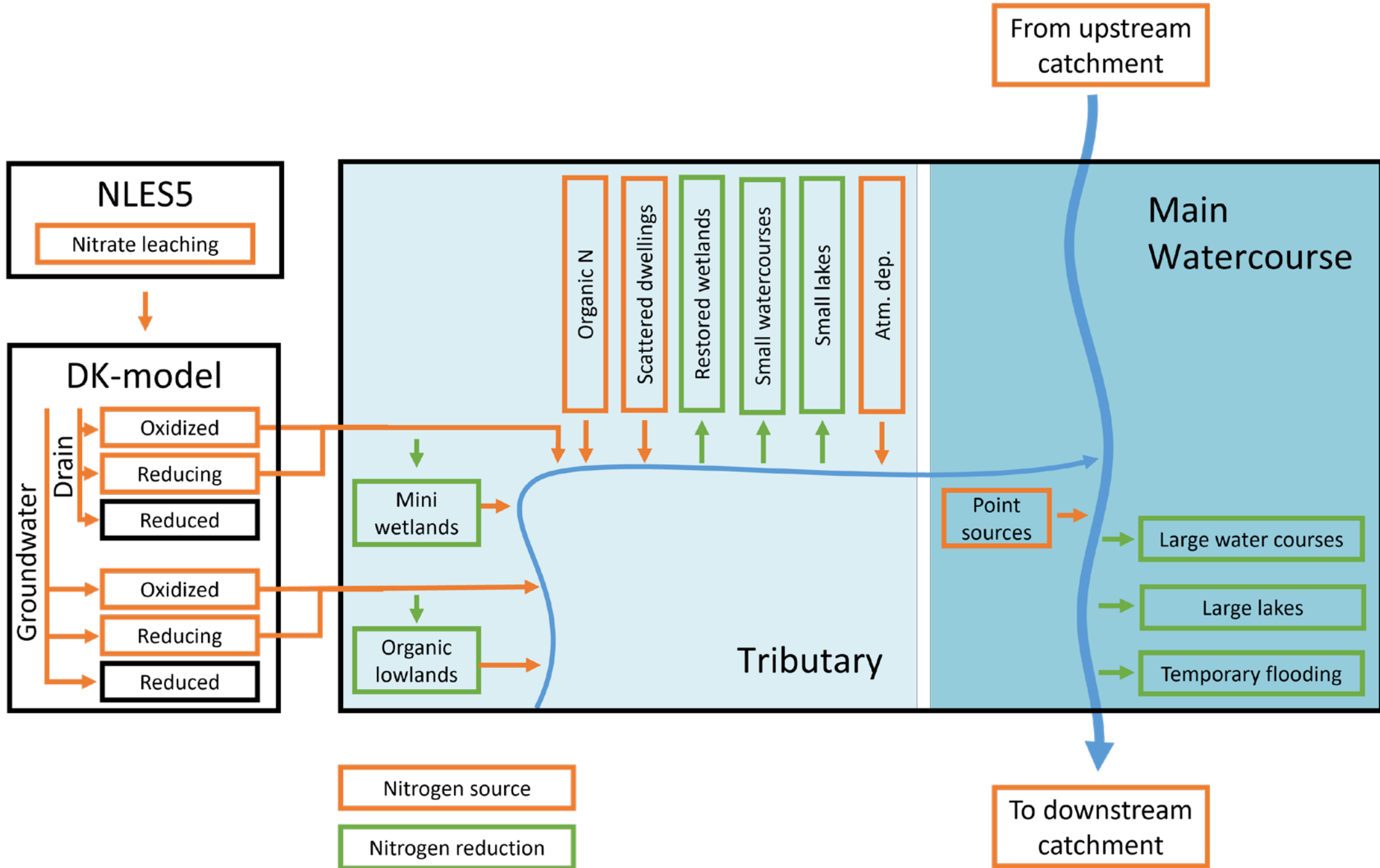
GEUS

Surface water

- Empirical models for each surface retention environment
- Developed from national monitoring data and local field studies

AU:DCE





Related LuWQ25 talks

Nitrate leaching

#65 *Impacts of annual weather conditions and available soil data on modelling nitrate leaching from farmland at regional and national scale.* Christen Duus Børgesen

Groundwater retention

#53 *Literature review and meta-analysis of denitrification rates for unconsolidated sedimentary aquifers.* Denitza Voutchkova

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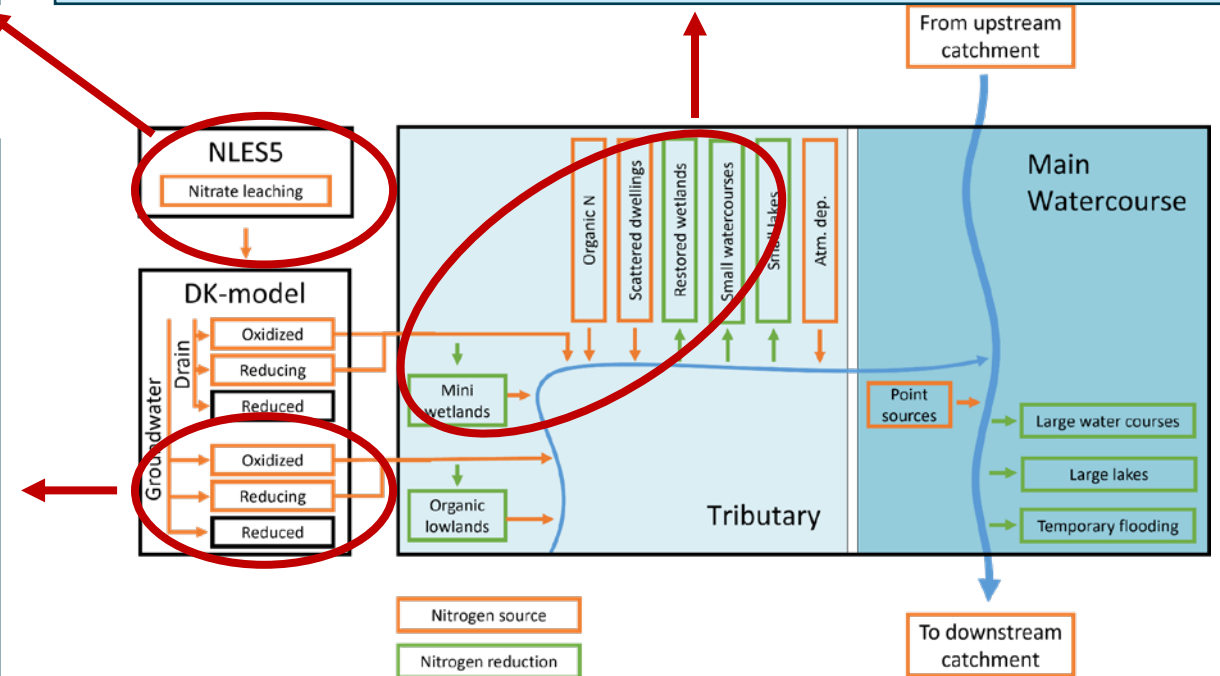
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Surface water retention

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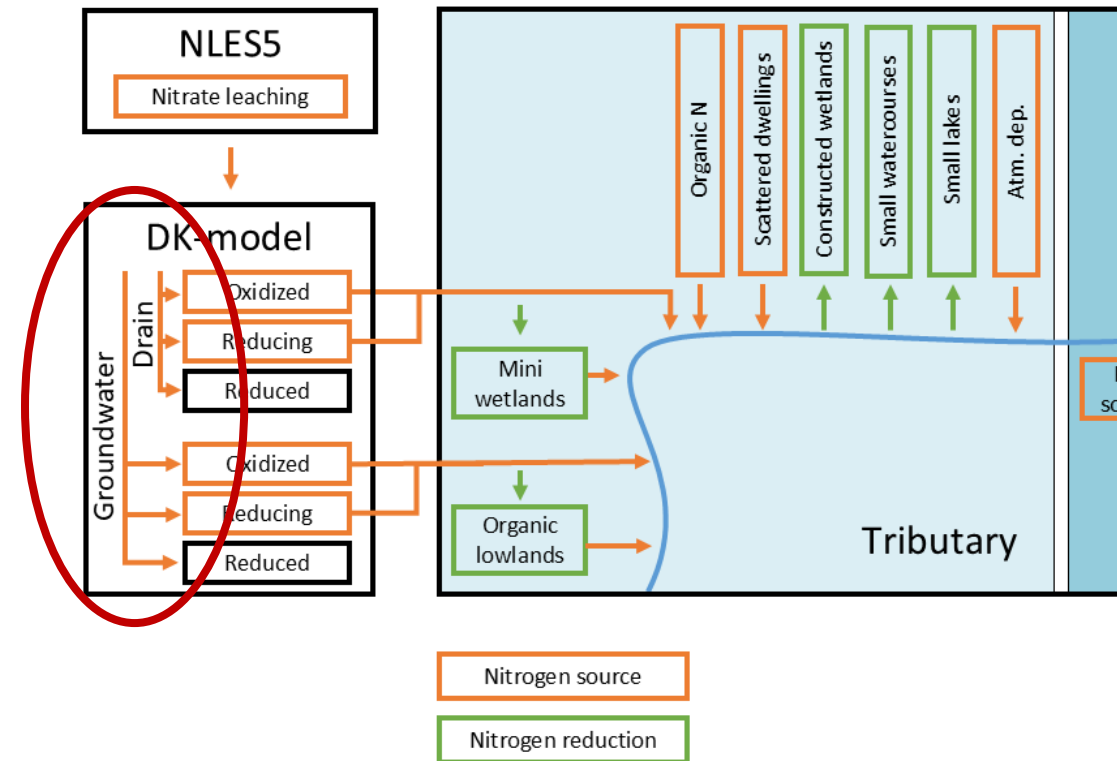


Content

Drainage

Uncertainty

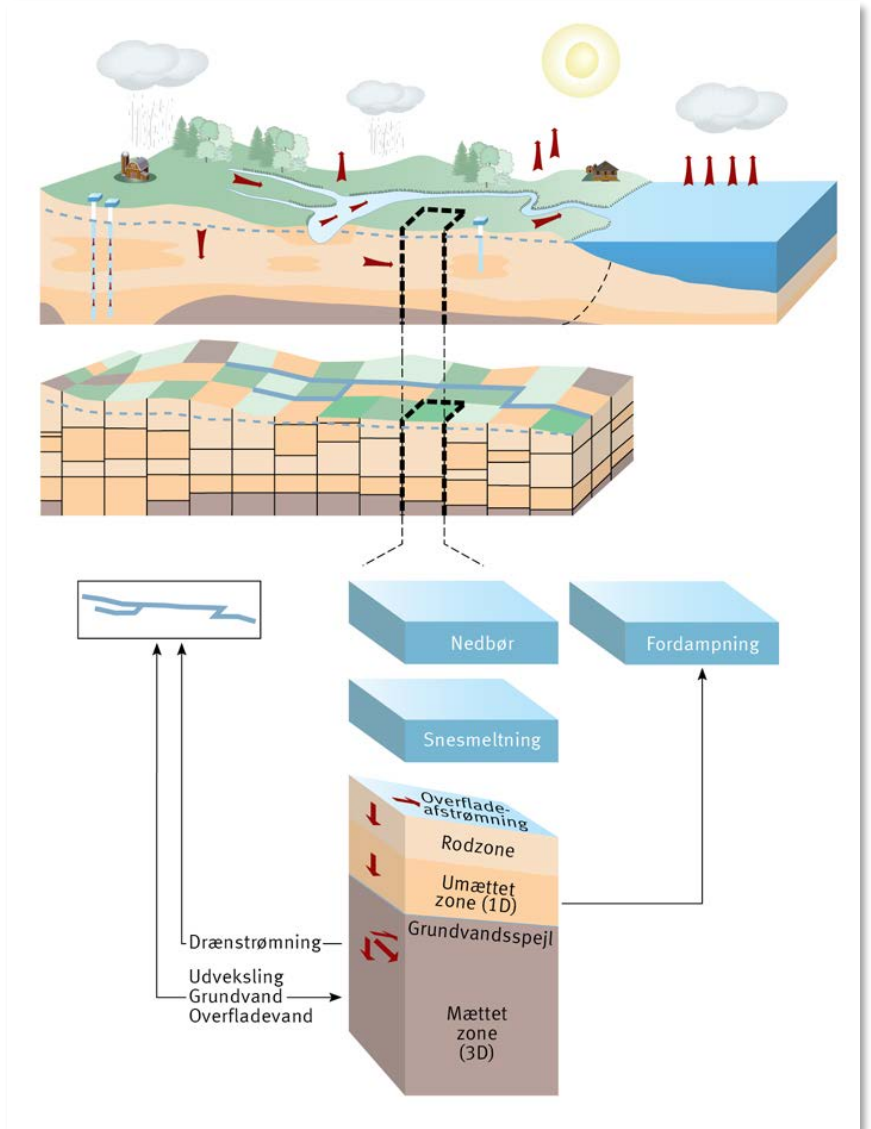
Conclusion



Groundwater

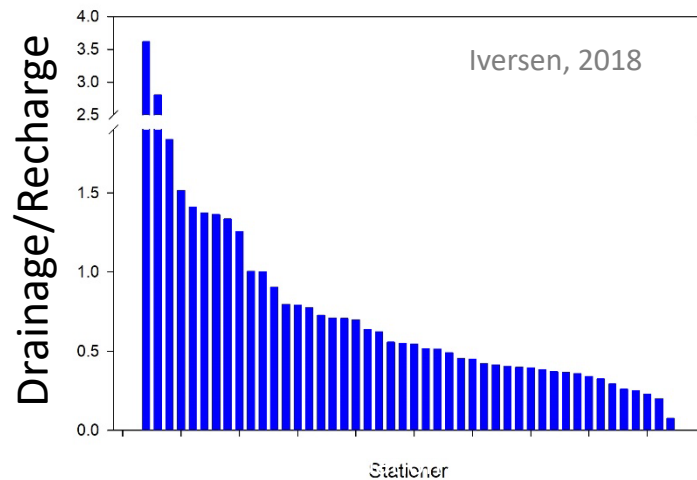
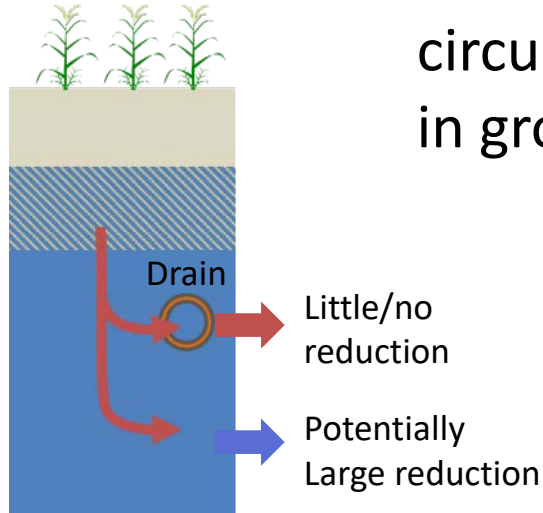
The National Hydrological model DK-model

- Physically based distributed coupled surface and groundwater model
- Hydrostratigraphy based on > 150 local to regional models from the national groundwater protection programme
- Coupled to the national database on groundwater extractions and observations
- Continuously developed since 1996 supported by and supporting research activities
- Backbone for numerous national assessments supporting national obligations and legislations: WFD implementation, climate change impact/adaption, Groundwater resources



Tile drain

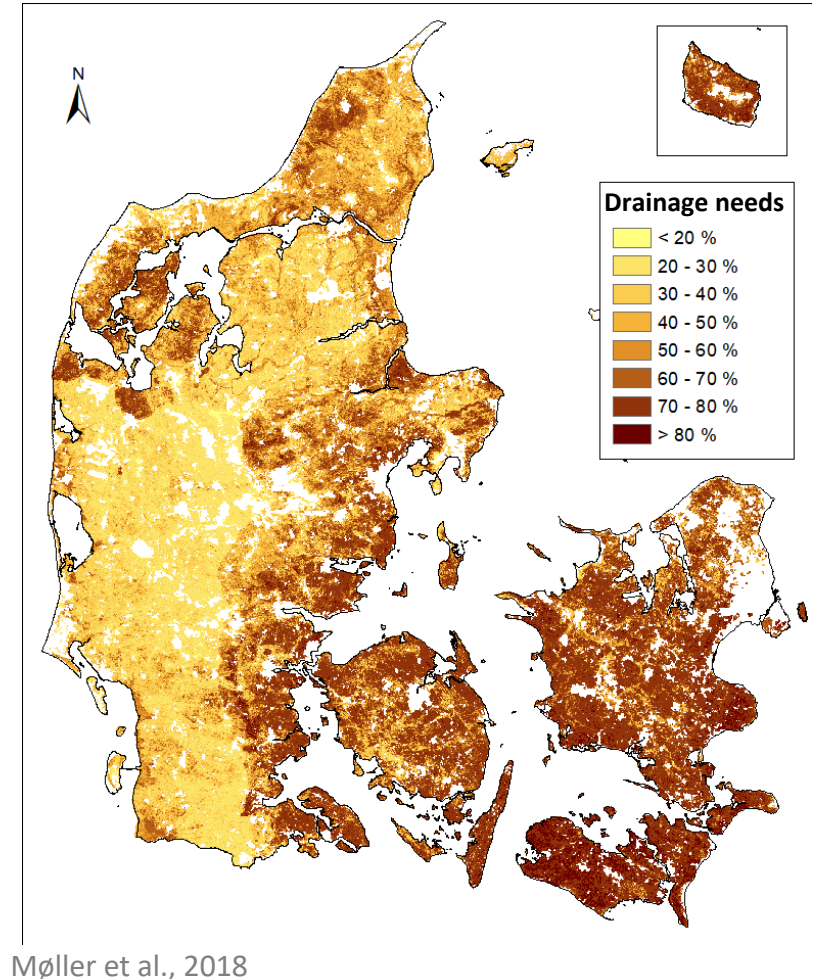
Drain as transport short circuits, bypassing reduction in groundwater



Large variation in efficiency

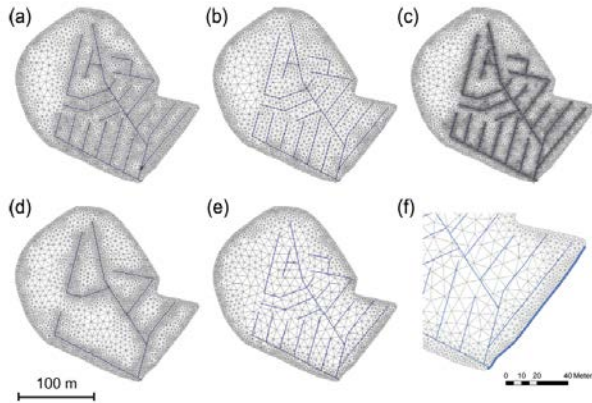
Large spatial variation

50% of agricultural land in Denmark is drained



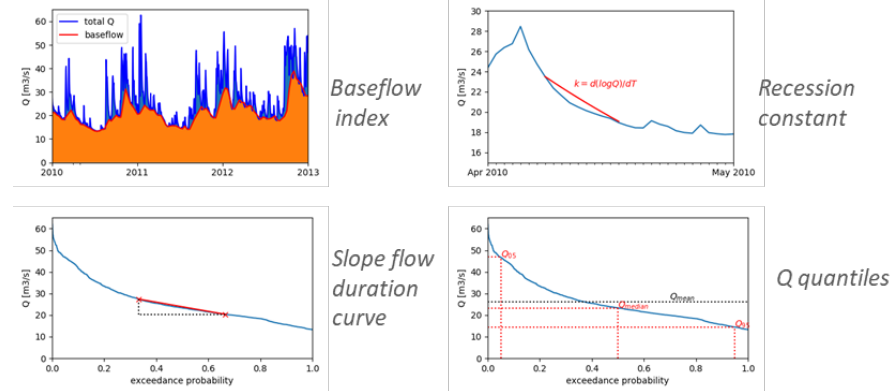
From point to catchment

Representation of drains



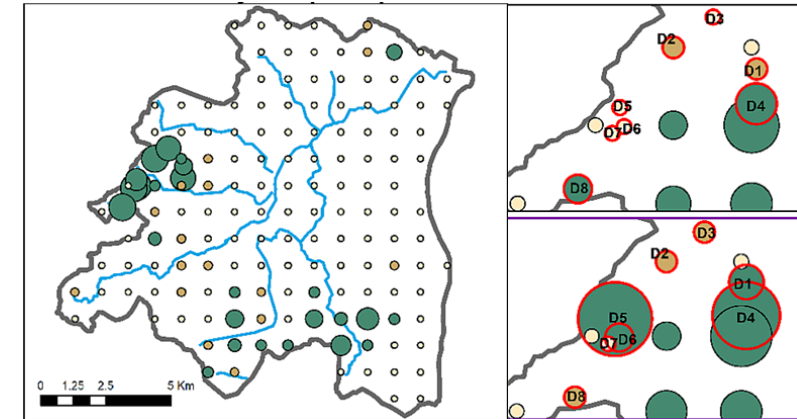
De Schepper et al. (2015) *Journal of Hydrology*
Boico et al. (2022) *Journal of Hydrology*

Calibration targets, e.g. stream flow signatures



Schneider et al. (2021) *Water*

Calibration approach, e.g. Pilot points

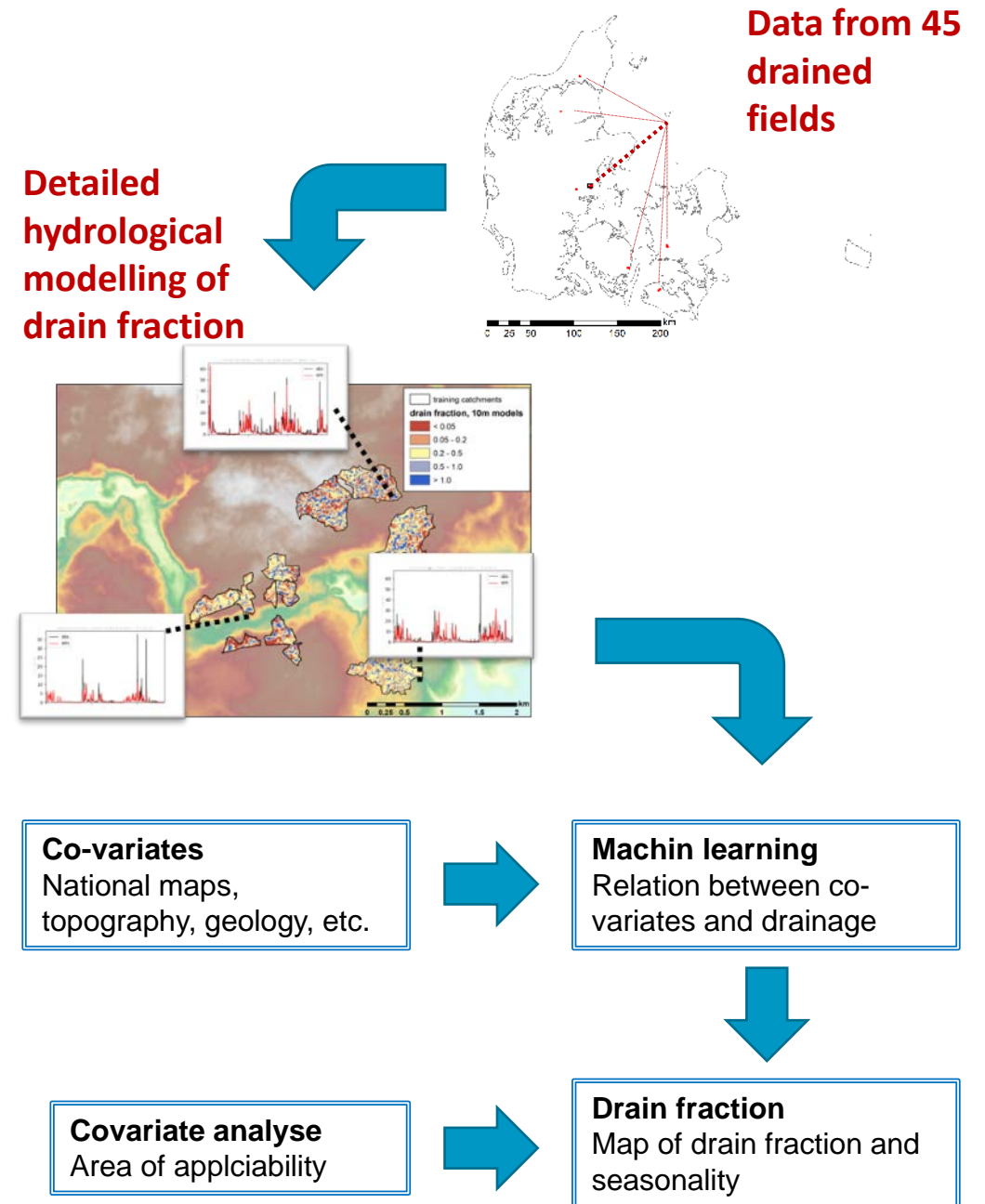


Seidenfaden et al. (2022) *Journal of Hydrology X*

- Simplified geometry adequate for catchment scale modelling
- Signatures contains information on drainage, but inadequate for improving drain flow heterogeneity representation in catchment scale models
- Using Pilot Points drain data can inform locally on hydrogeology, but only very locally

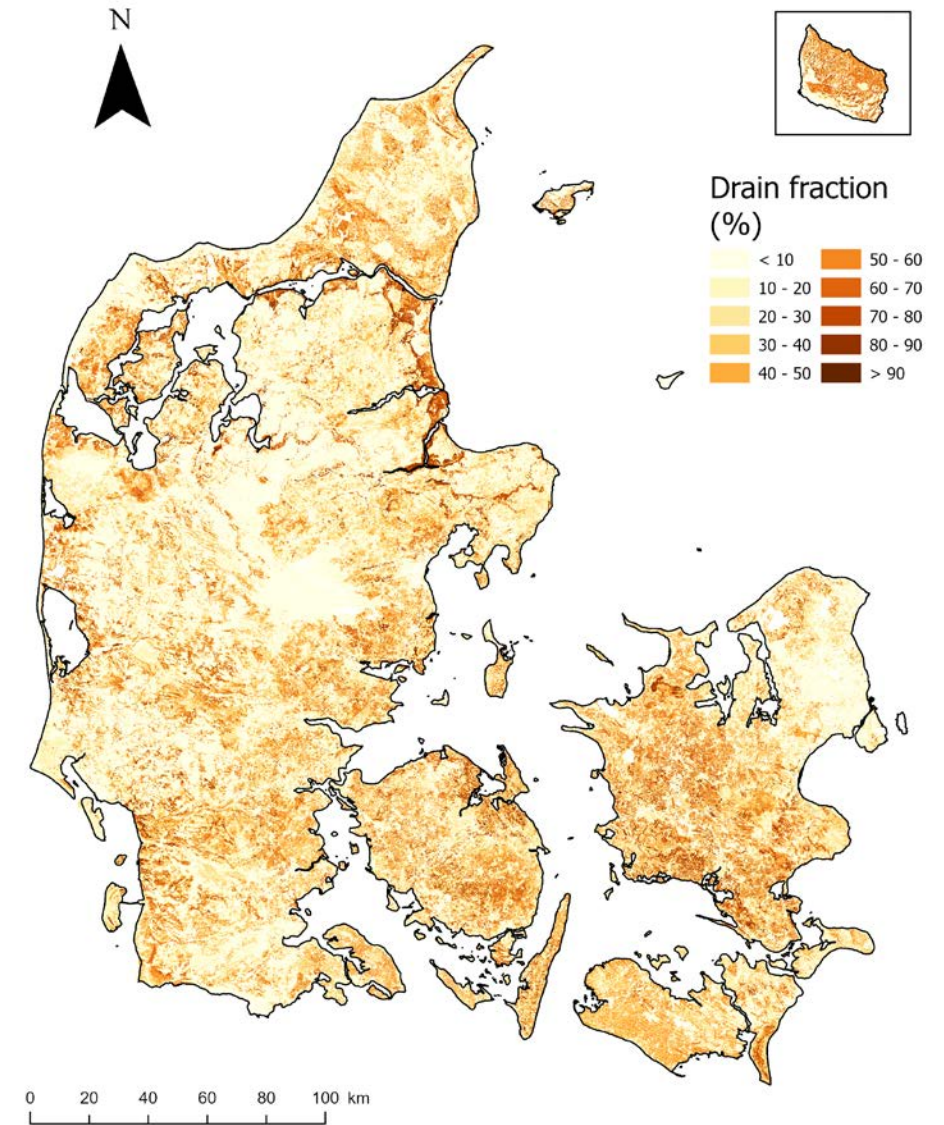
Drain fraction

- Joint calibration of 45 detailed hydrological models to observed drainage
- Relating drainage to recharge (drain fraction)
- Machine learning
 - GBDT
 - 12 co-variates



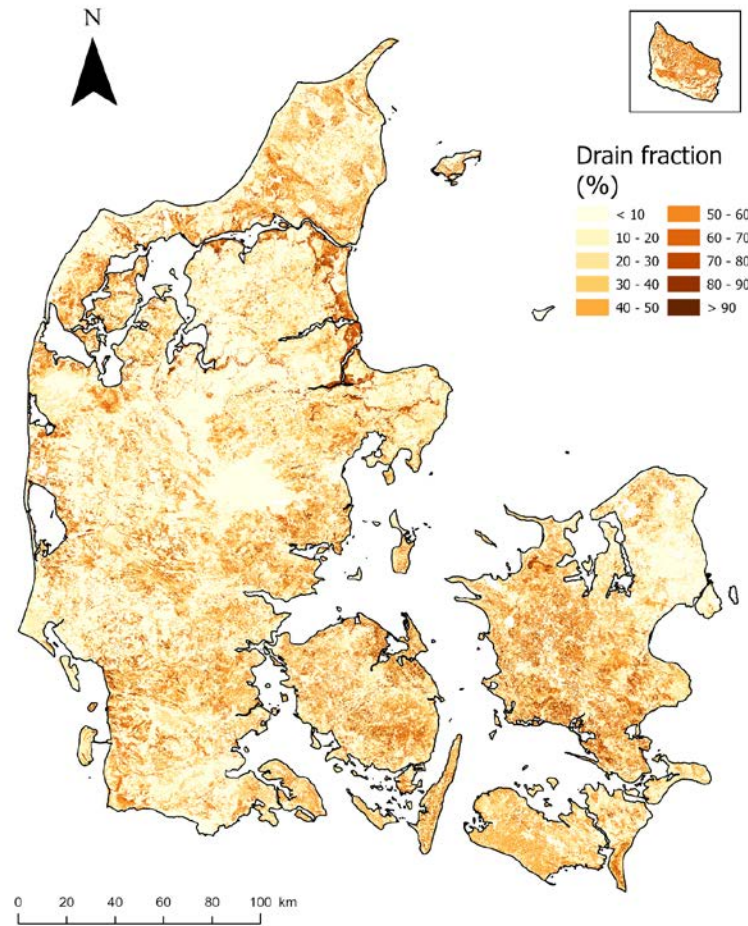
Drain fraction

- Joint calibration of 45 detailed hydrological models to observed drainage
- Relating drainage to recharge (drain fraction)
- Machine learning
 - GBDT
 - 12 co-variates
- National map of drain fraction
- Used in calibration of national hydrological model

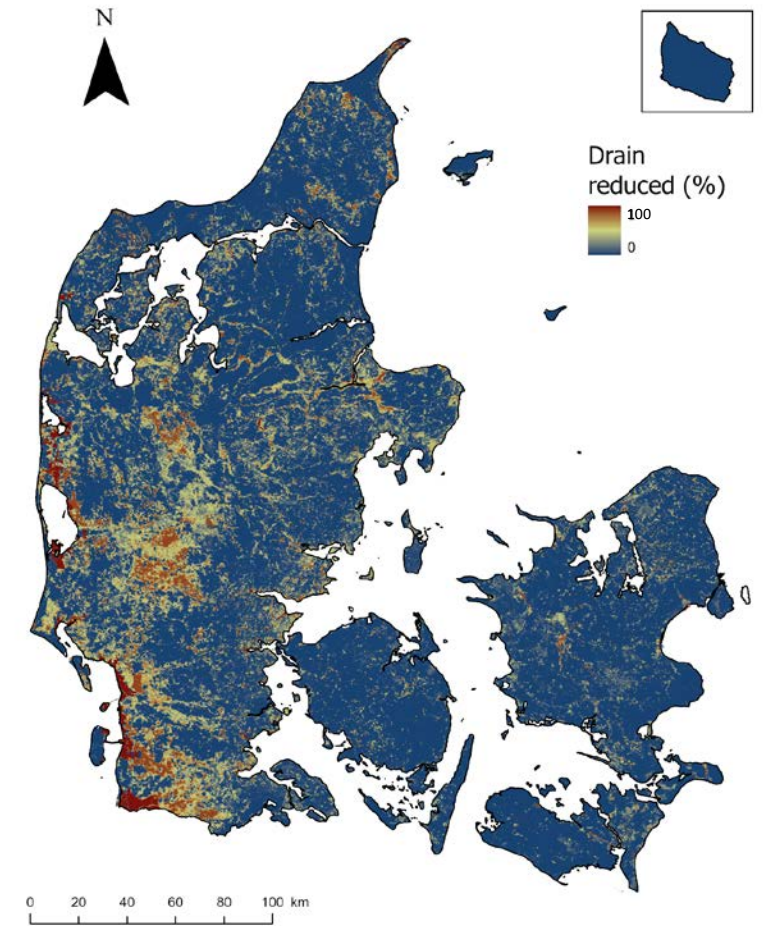


Drain and reduction

- Drain may be located in reducing environments
- Drain transport may be significant, but nitrate reduced before it enters the drains



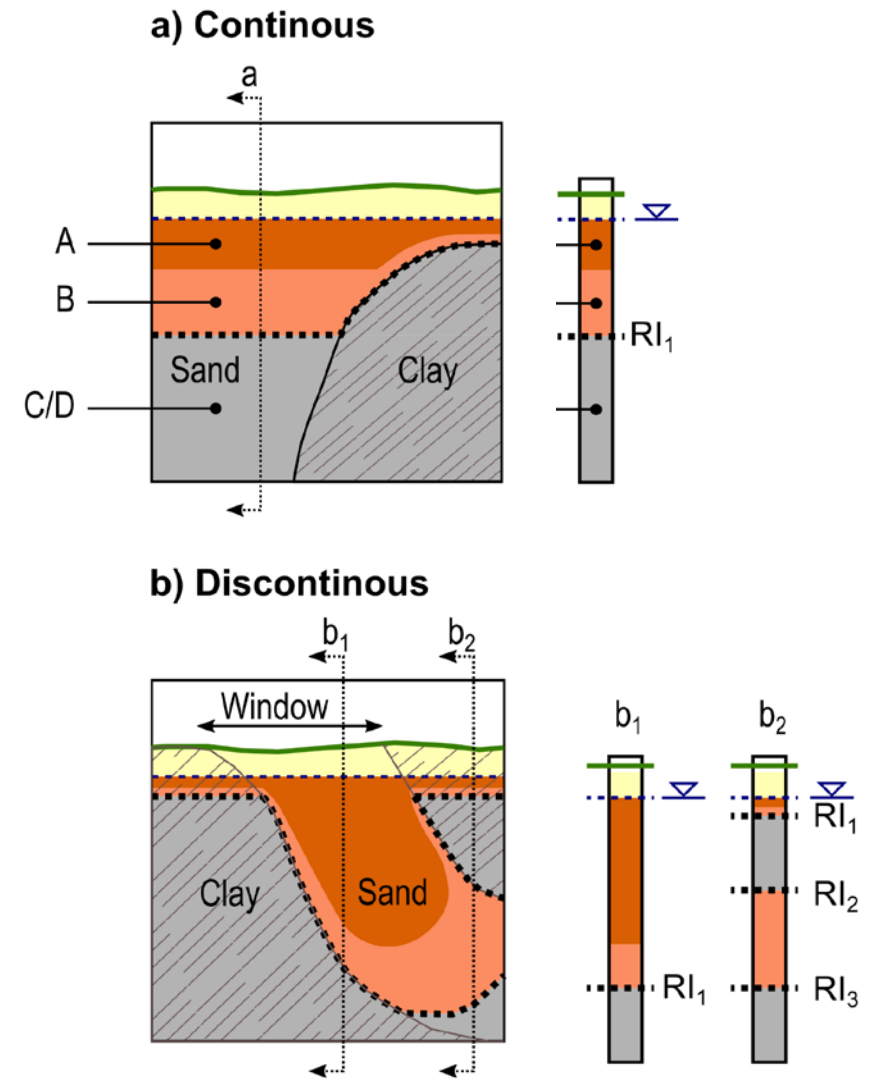
Drain fraction



Potential reduction in GW before drains

Redox conditions

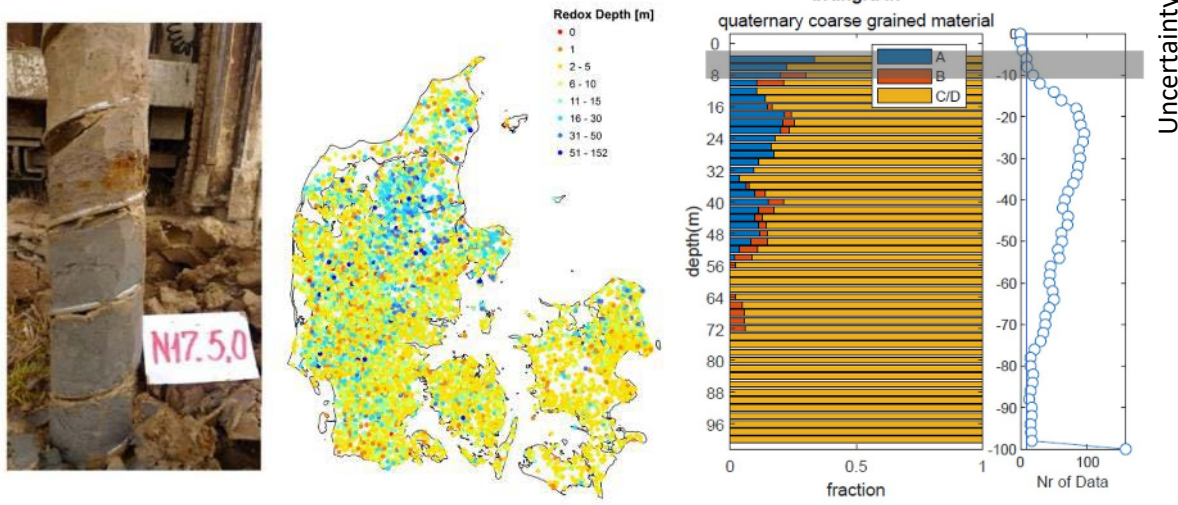
- Three redox states
 - A: Oxic
 - B: Reducing
 - C: Reduced
- Homogeneous and complex redox conditions with depth
- Drain in zone B or C receives partially or fully reduced water



Voutchkova DD, 2025

Reduction in groundwater

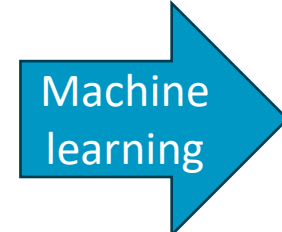
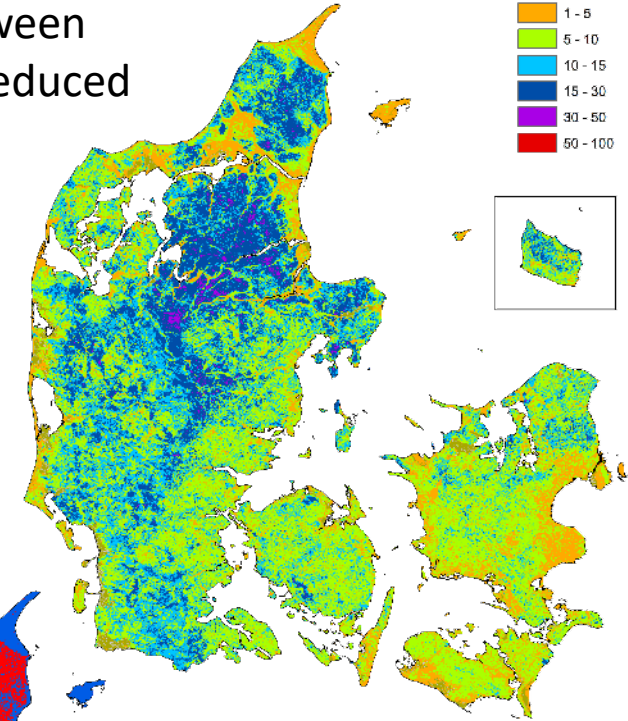
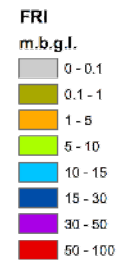
Sediment colour description + water chemistry data



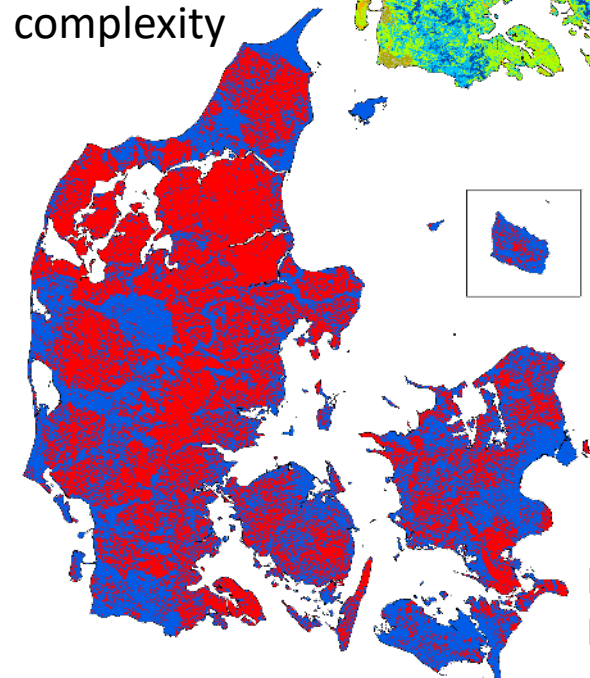
Extensive analyse of concurrent sediment colour descriptions and groundwater chemistry data

#103 Sediment color as a predictor for subsurface redox conditions at large scale. Hyojin Kim

Redox interface transition between reducing and reduced conditions



Redox complexity



Blue: continuous
Red: Discontinuous

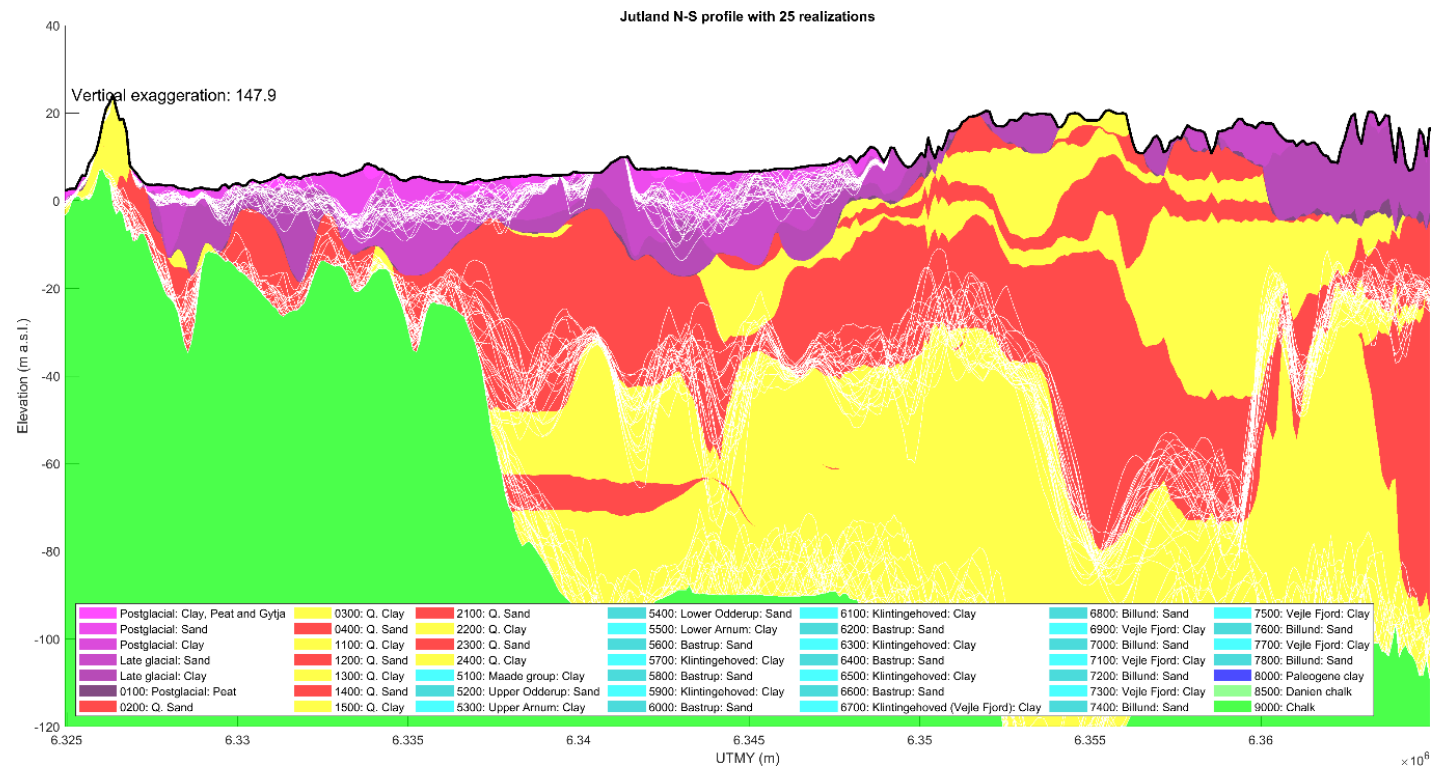
Koch et al. (2024)

Uncertainty

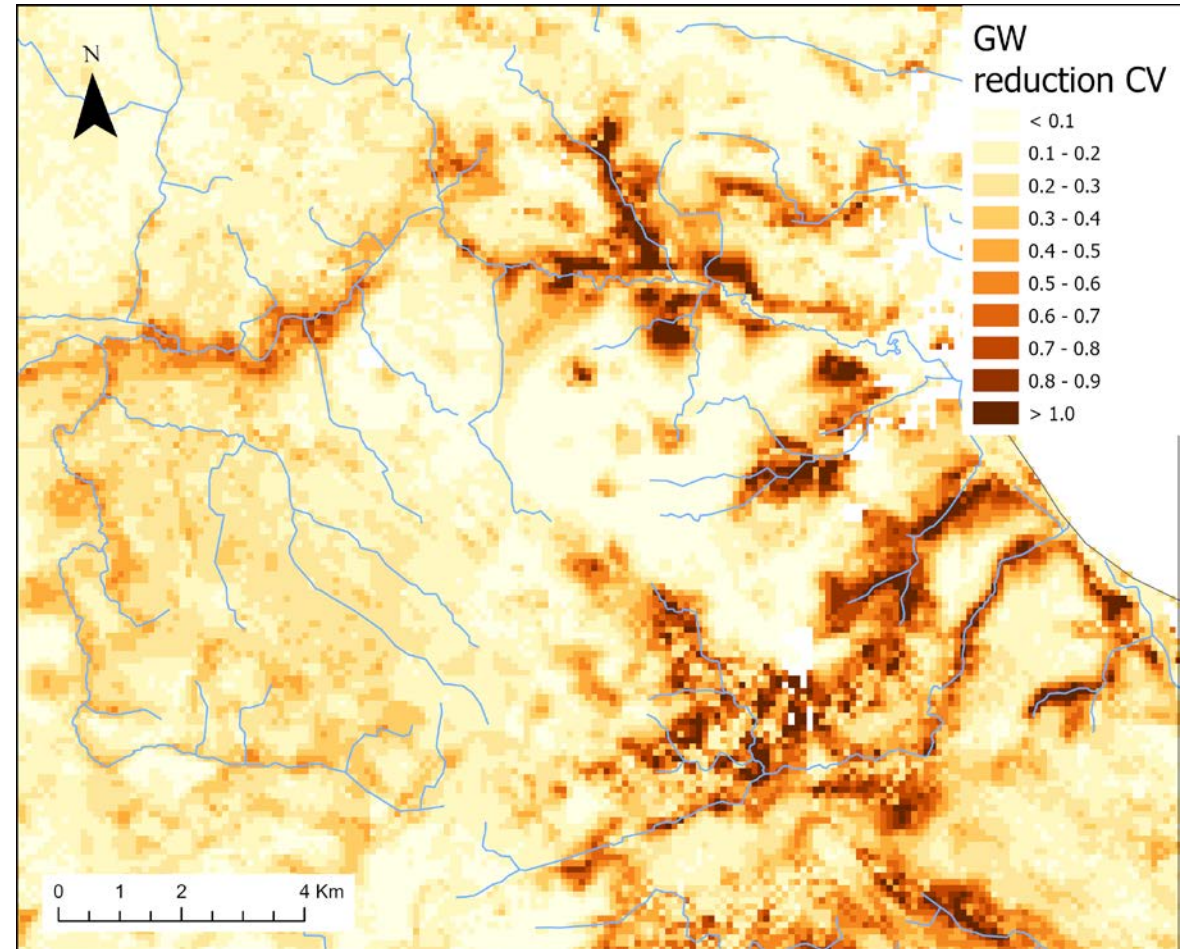
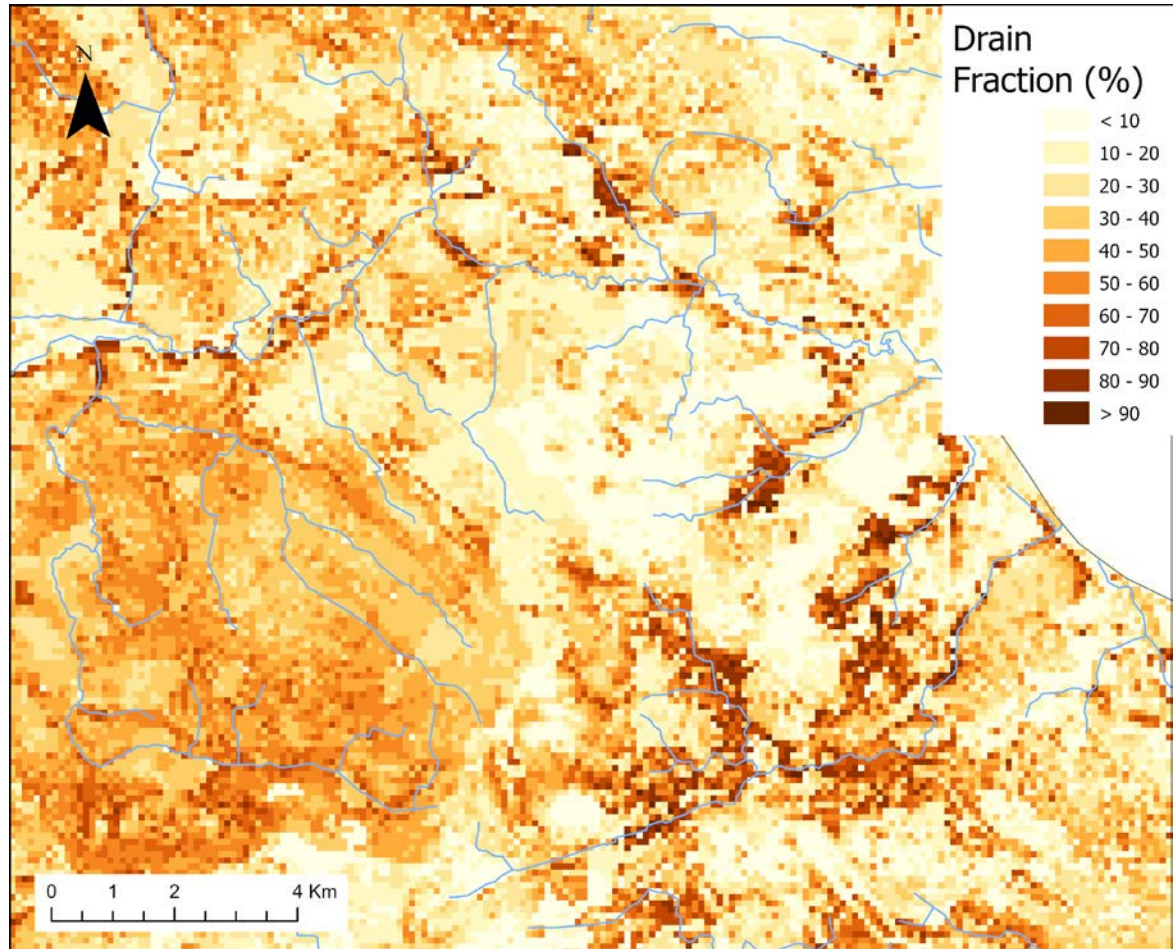
Monte Carlo simulations

- Hydrostratigraphy
- Hydraulic parameters
- Geochemical model – linked to hydrostratigraphy
- Surface water retention – larger lakes

- Uncertainty in drainage through uncertainty in hydrostratigraphy and hydraulic parameters



Drainage and uncertainty



Summary

- New national nitrogen reduction maps developed at small spatial scale
- Maps associated with uncertainty assessment
- Draining:
 - Highly impacts total nitrate reduction
 - Generally associated with high uncertainties

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