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GEUS

ON THE TRACK OF TARGETED REGULATION OF NITRATE – EXPERIENCES FROM DENMARK

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DK settings

- 43.000 km^2
- Land use
  - 10% Nature
  - 10% Forest
  - 6% Urban
  - 60% Agriculture
- 5.6 mill. People
- 25 - 30 mill. pigs
  (produced per year)
- Cows ~1 mill.

18,026km from NZ
22hr and 54 min by air
12hr difference

National actions plans: Kick-off

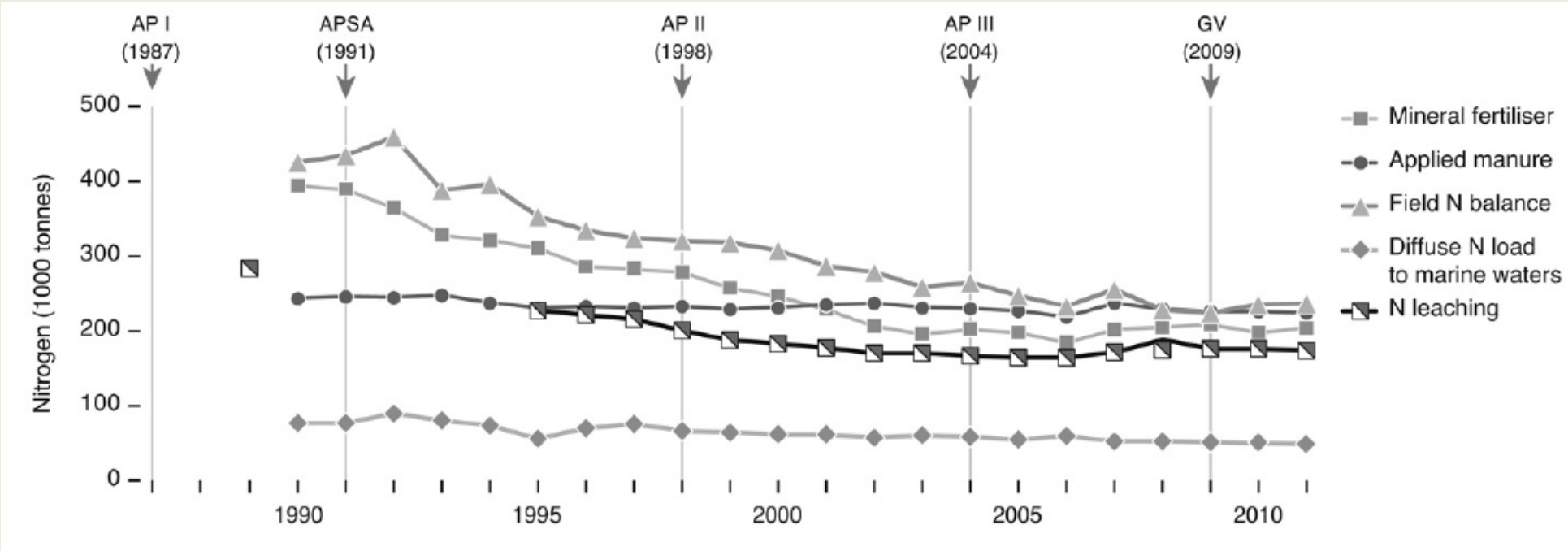
October 1986

- Dead lobsters in Kattegat

National actions plans

- Several actions plans (AP) since mid 1980'ties
- Total N-load to Danish water decreased by ~50% since 1990 at national level

- GMP
  - Slurry tanks, restricted spread
- Restrictions
  - Reduced N-norm
  - Mandatory buffer strips

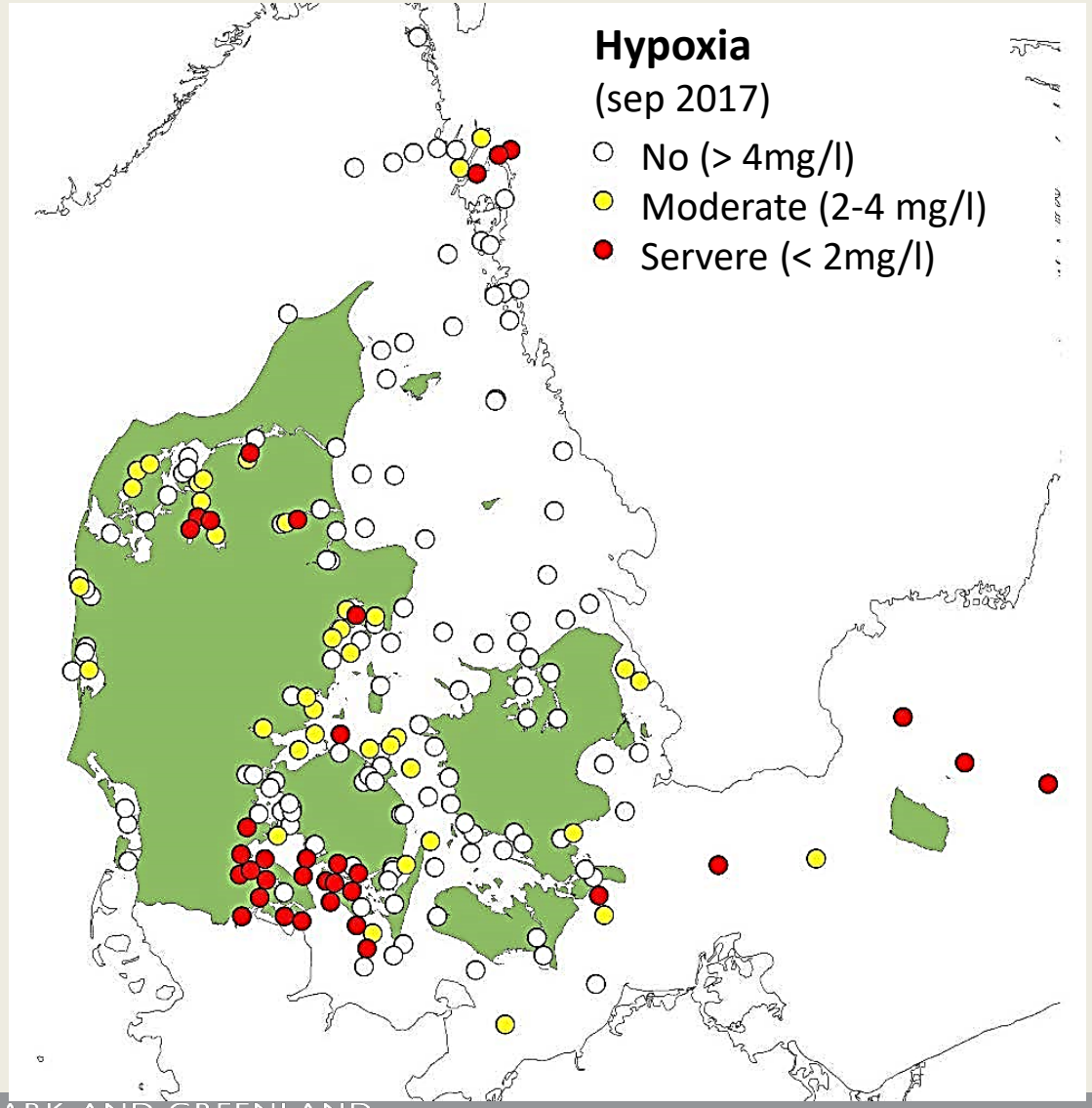


Blicher-Mathiesen et al., 2014

National marine monitoring

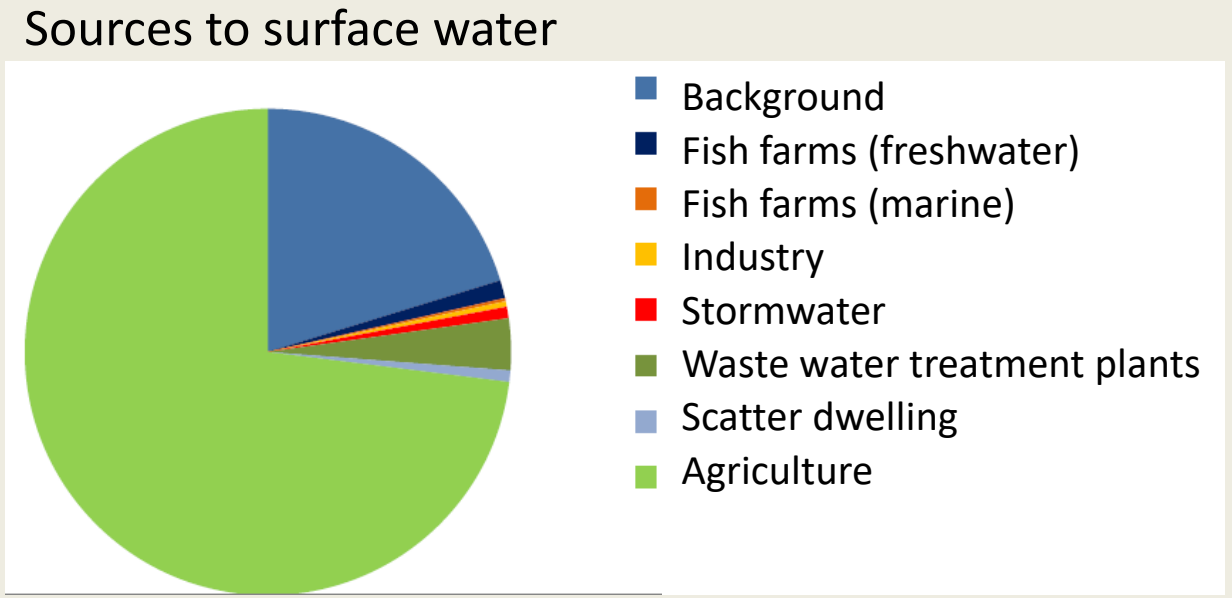
Small country but long coastline

- Fjords with little exchange
  → vulnerable recipients
- Open marine areas
  → less vulnerable



Present challenges

- Further abatements needed
- N-loads to surface
  - ~ 90% from diffuse sources
  - ~ 70% from agriculture



- Historically, regulation has been uniform (and national) (same regulation/restriction all over)
  - Has been successful in reducing loads since the mid 1980'ties, but too expensive if further reduction is to be met

➢ Need for new and innovative measures and regulation strategies

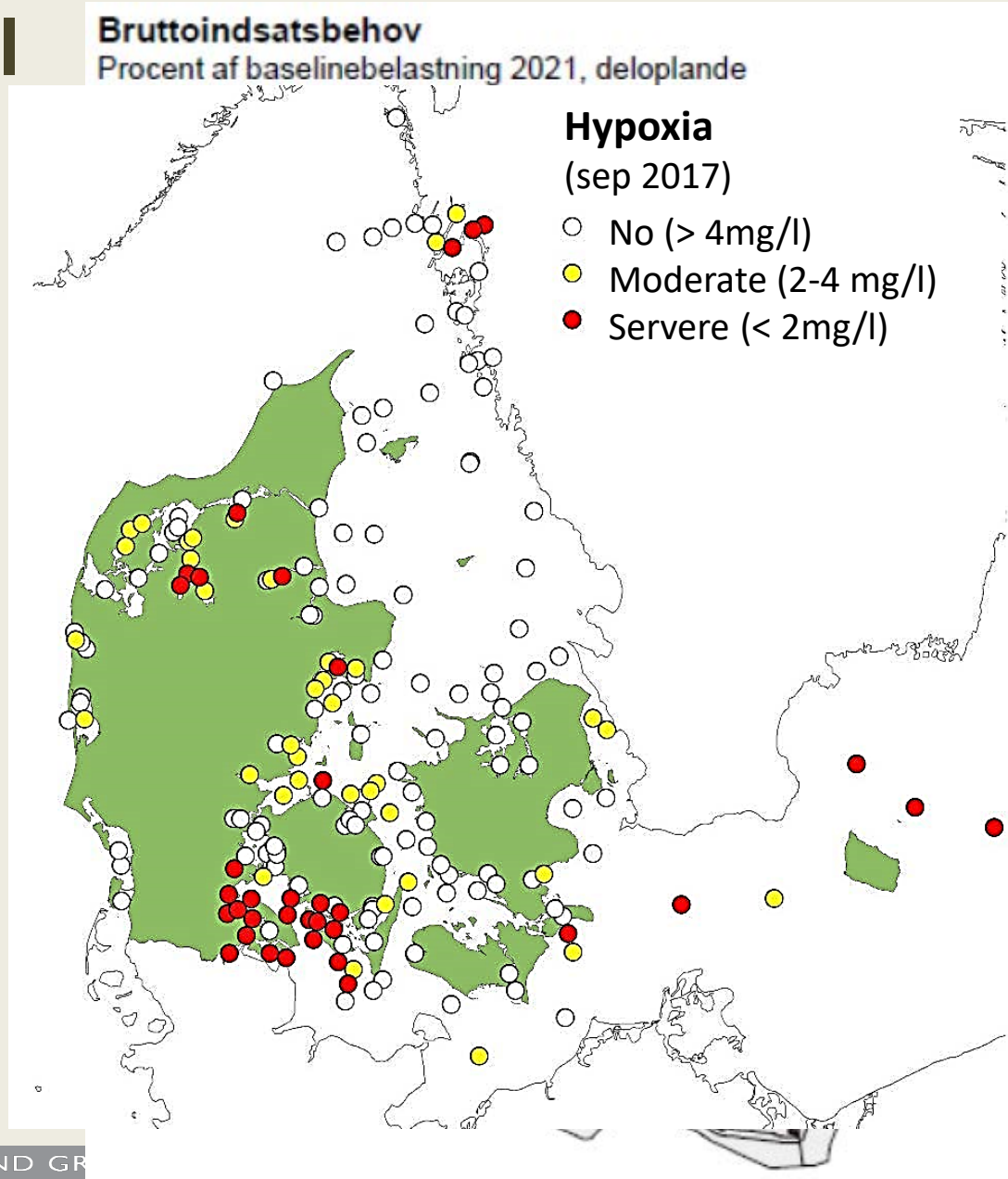
Required reduction at regional level

EU-WFD: River basin management plans 2015-2021

Required abatement estimated for 90 marine areas (based on ecological criteria)

Estimated reduction needs: 13.800TN/yr.

- Nationally ~14% further reduction
  - Some areas OK
  - Some areas need more than 50% reduction

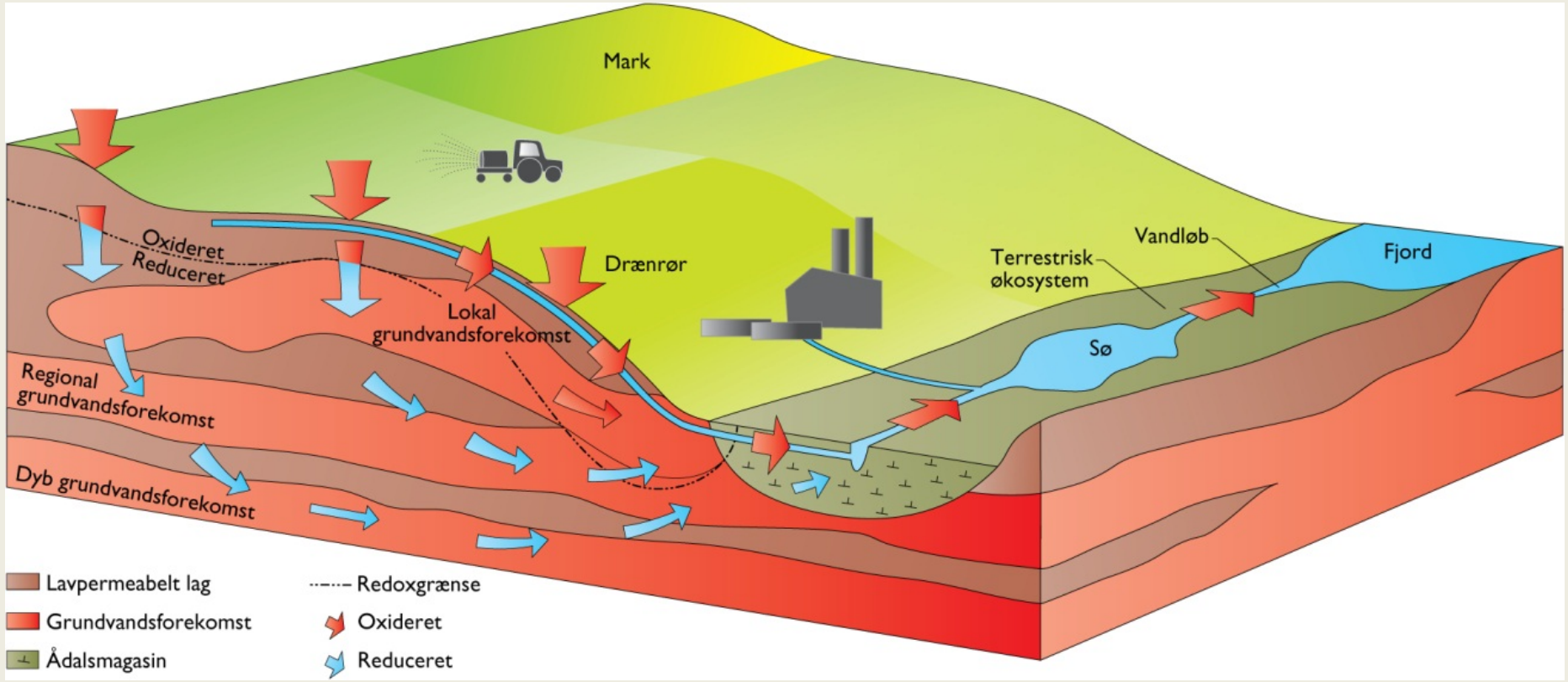


N transport and reduction from field to sea

Nationally

~ 70% of N leaching the rootzone is reduced before it reaches the marine areas

➢ **Large spatial variation in natural reduction**



Targeted regulation

2013: Danish Nature and Agricultural Commission

- Recommendation of spatial differentiated and targeted regulation
  - Required reduction determined by the **vulnerability** of the **receiving recipients** (estuaries)
  - **Less strict** regulation where the natural **removal is high**
  - **More strict** regulation where the natural **removal is low**
- Result expected to give a net increase in N-application

The national nitrogen model

GEUS and Aarhus University

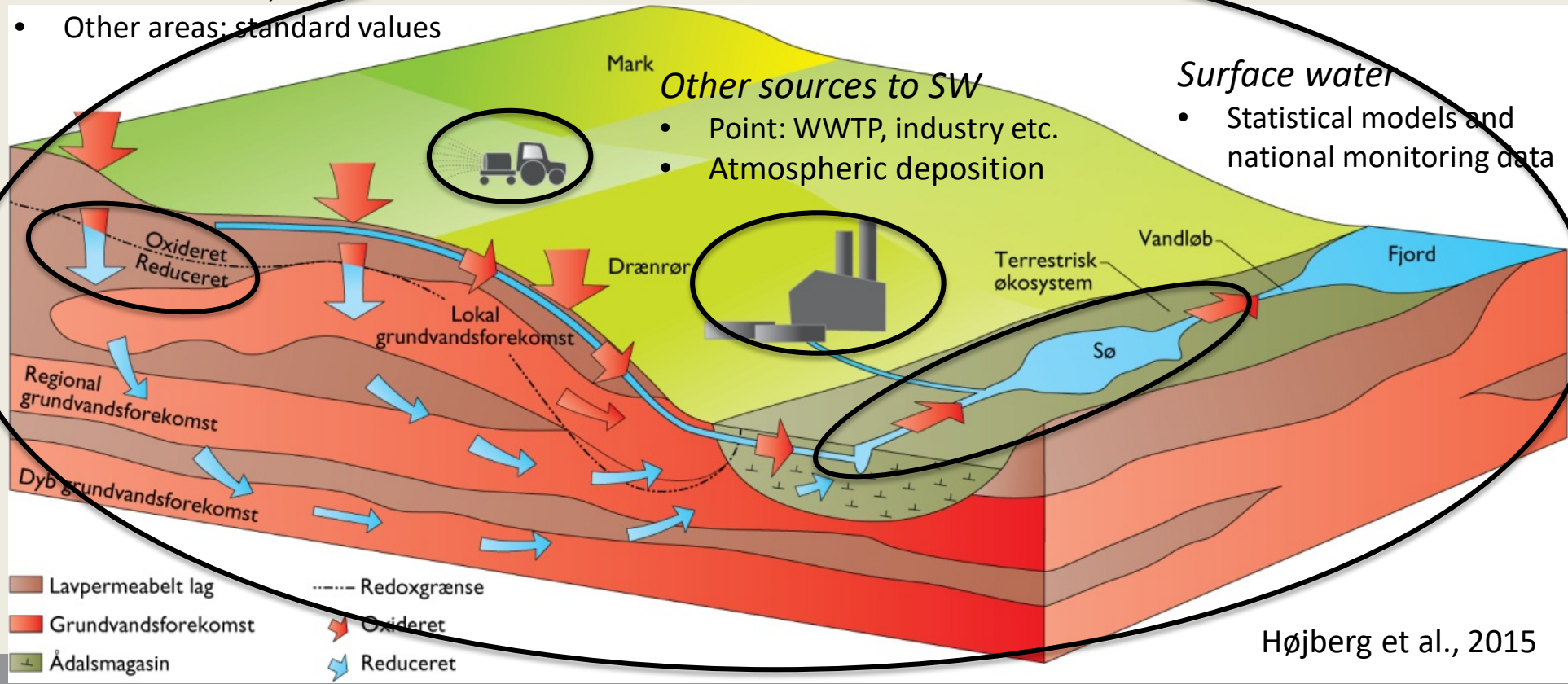
Coupled model system
- Models coupled in one-way link
- Monthly time steps
- Calibrated/validated to ~340 stream discharge stations (1990 – 2011)

N-leaching
- Farmland: NLES, statistical model
- Other areas: standard values

Groundwater
- National hydrological model (DK-model)
- Geochemistry

Other sources to SW
- Point: WWTP, industry etc.
- Atmospheric deposition

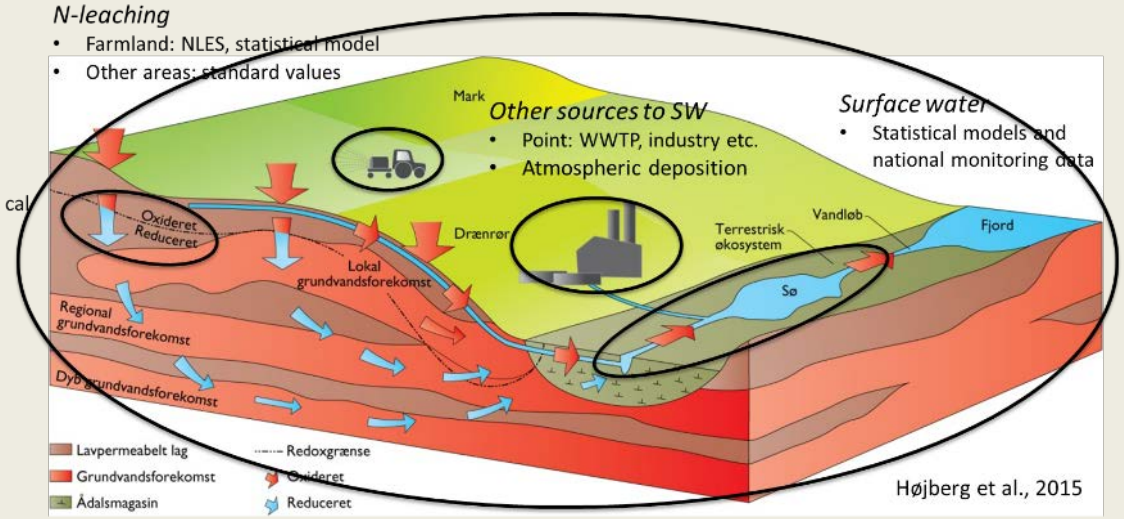
Surface water
- Statistical models and national monitoring data

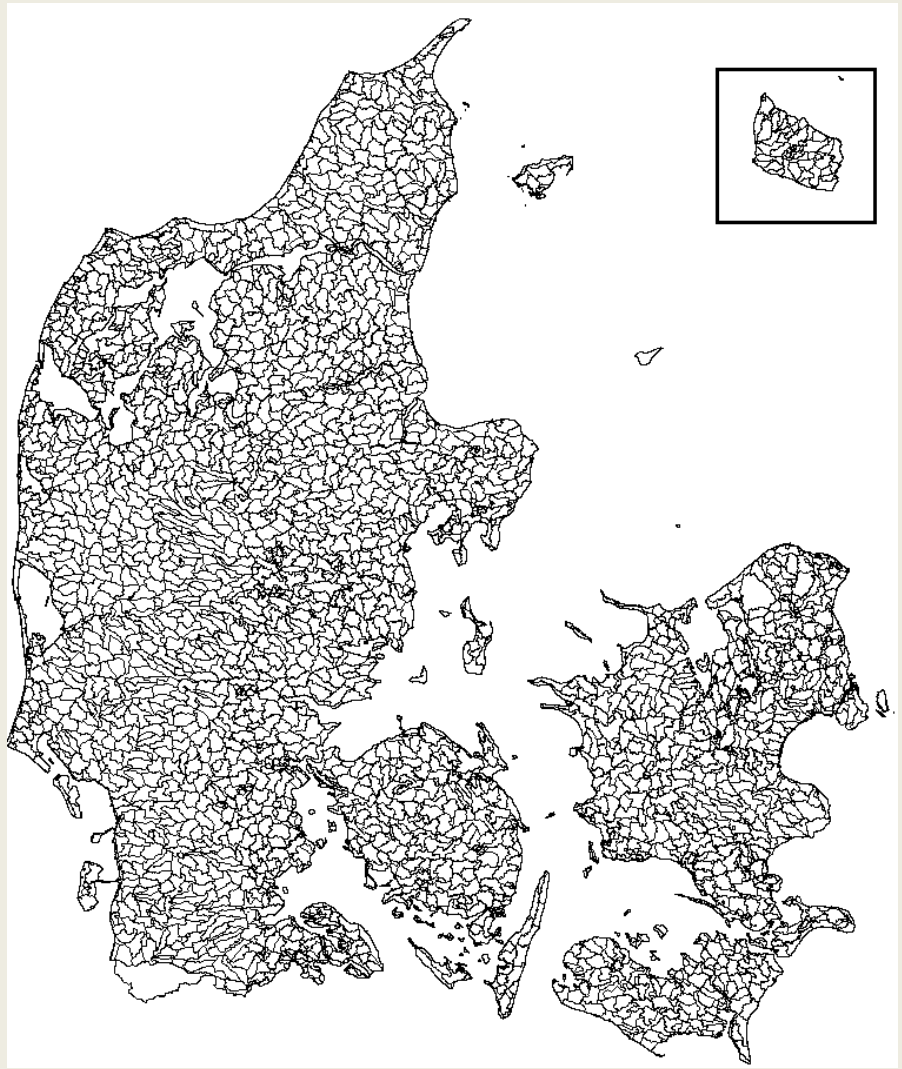


Højberg et al., 2015

The national nitrogen model

GEUS and Aarhus University, 2013 – 2015





Model constructed at 500 x 500 m grid, but tested at sub-catchment scale (~15 km^2)

- scale of observations

Model applied at 15 km^2 scale

Nitrogen retention/reduction maps

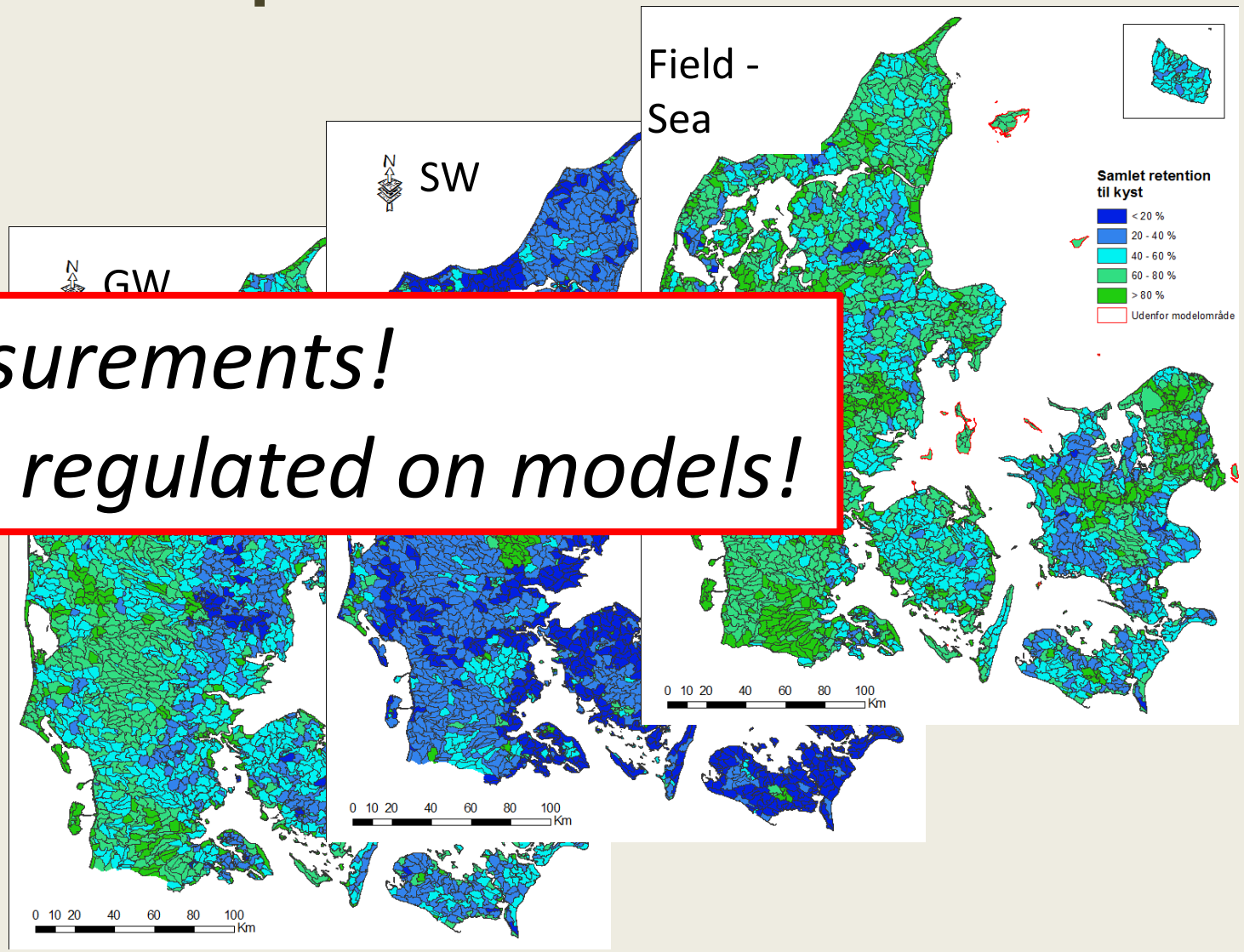
Maps for:

- Groundwater (63%)
- Surface water (25%)
- Field to sea (72%)

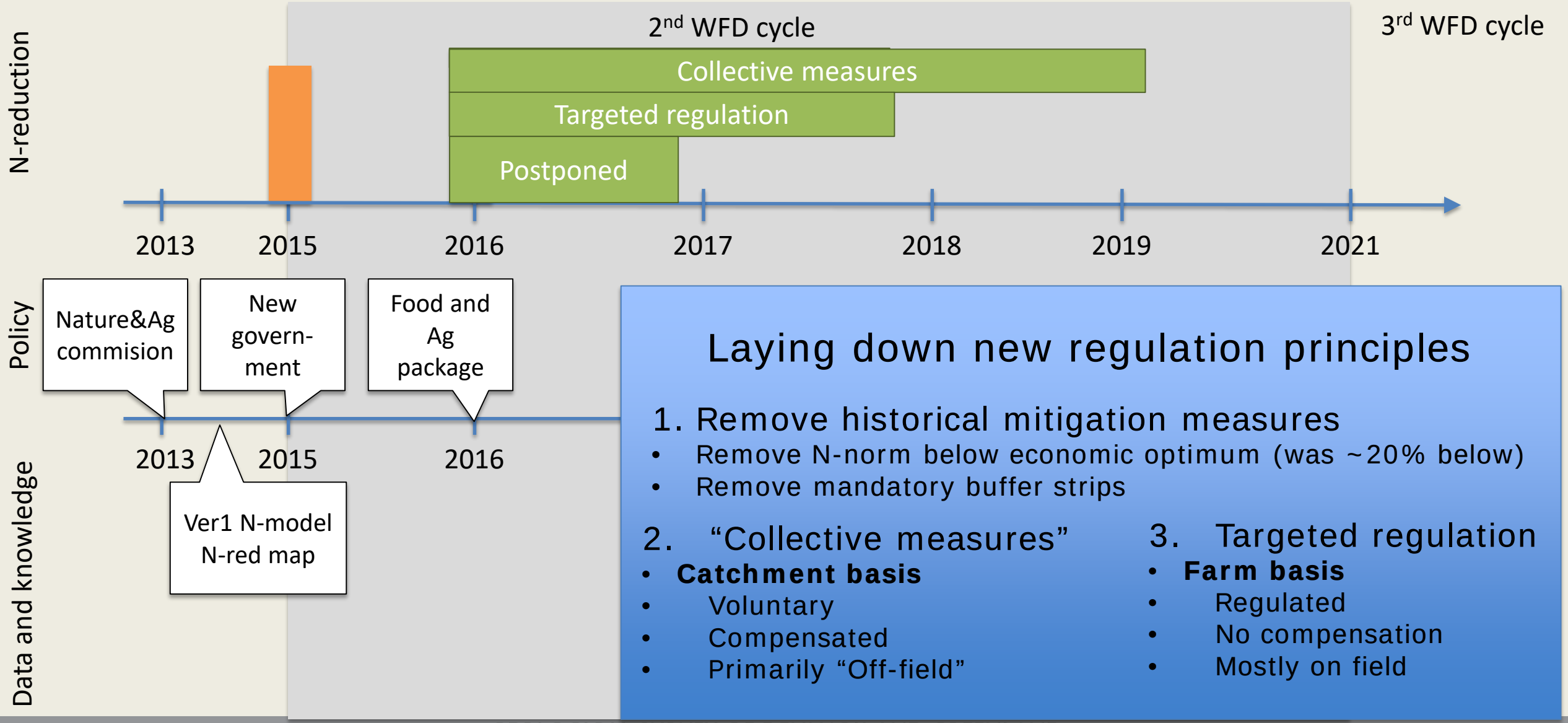
- Maps display wh
  restriction is requ
  regulation
- Not all will be winner
- Reliability of map questioned → uncertainty becomes important

More measurements!

Will not be regulated on models!



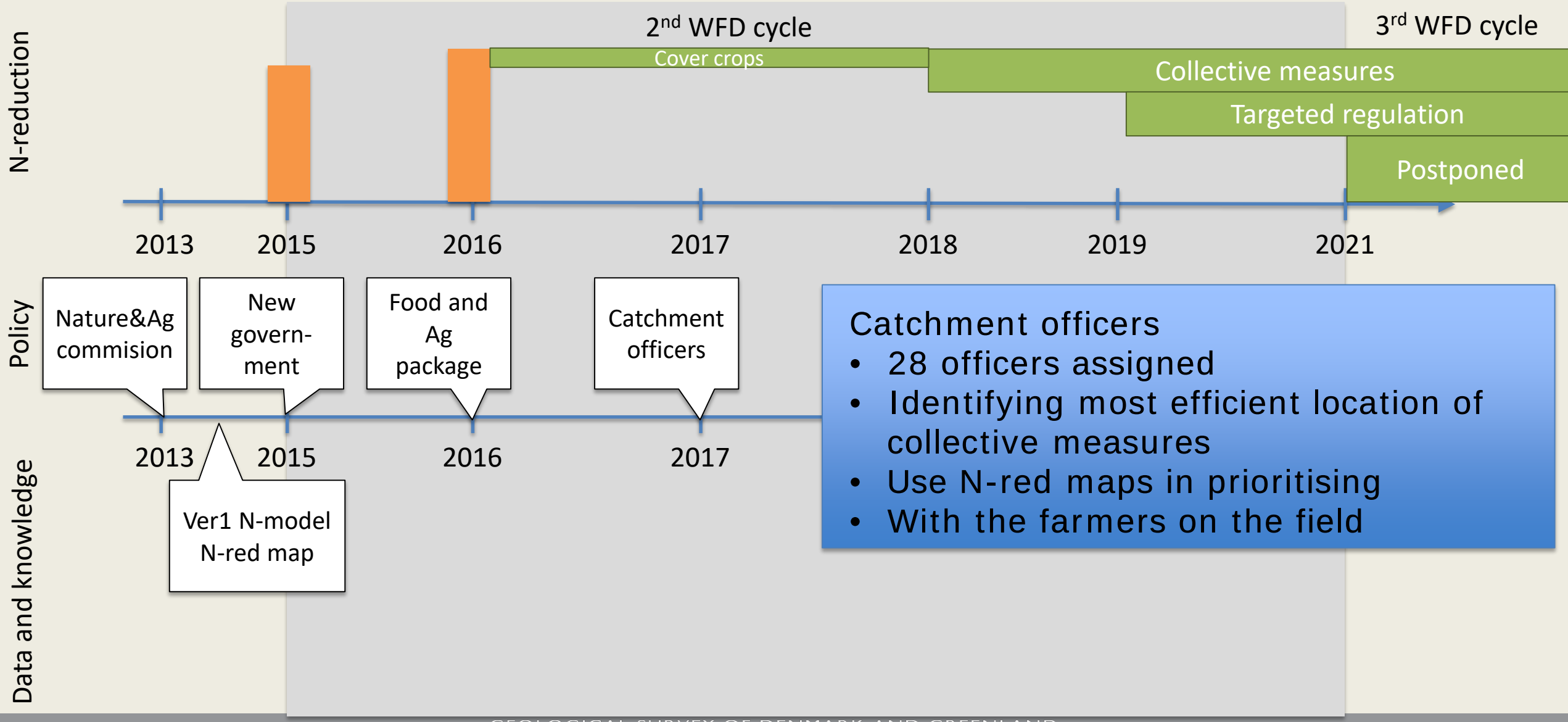
The track to targeted regulation



Laying down new regulation principles

1. Remove historical mitigation measures
   - Remove N-norm below economic optimum (was ~20% below)
   - Remove mandatory buffer strips
2. "Collective measures"
   - **Catchment basis**
   - Voluntary
   - Compensated
   - Primarily "Off-field"
3. Targeted regulation
   - **Farm basis**
   - Regulated
   - No compensation
   - Mostly on field

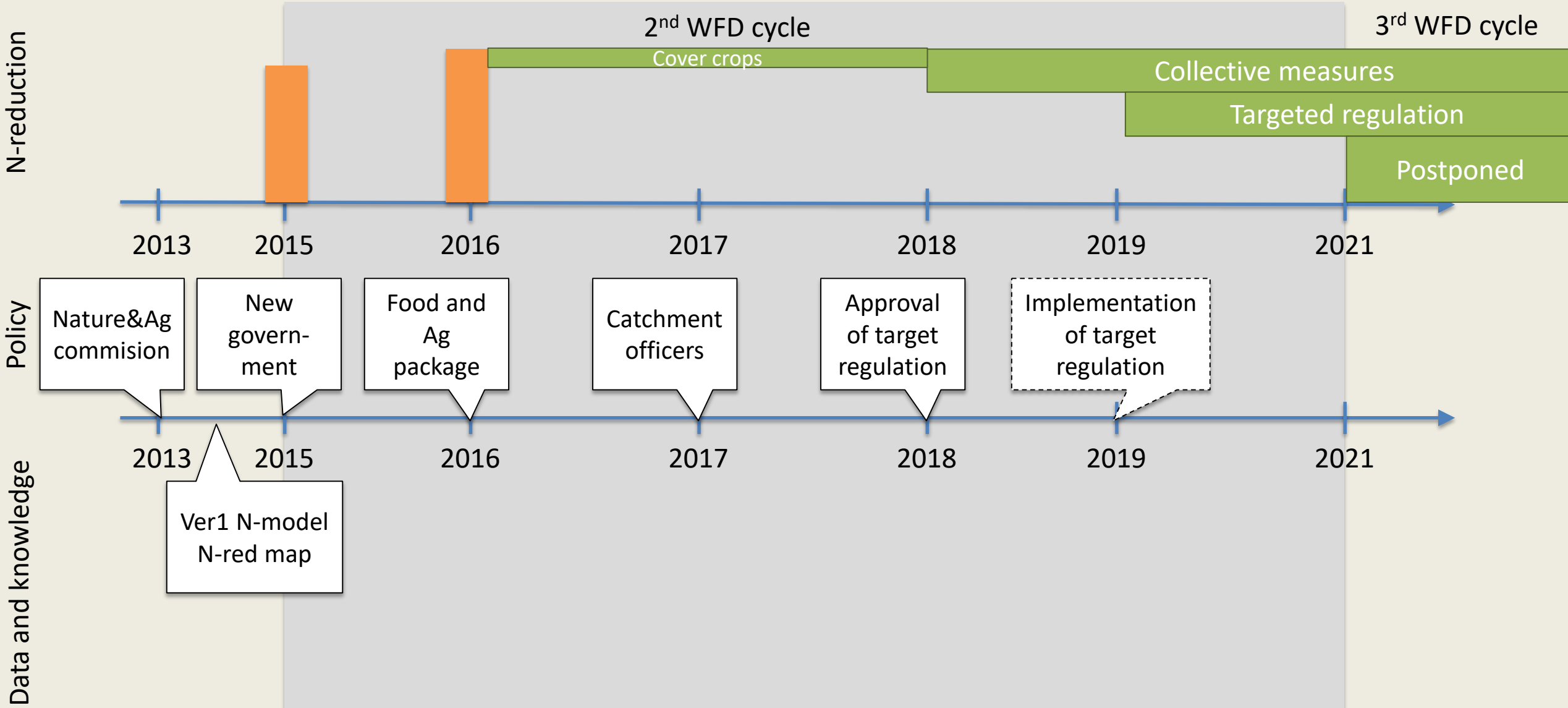
The track to targeted regulation



Catchment officers

- 28 officers assigned
- Identifying most efficient location of collective measures
- Use N-red maps in prioritising
- With the farmers on the field

The track to targeted regulation



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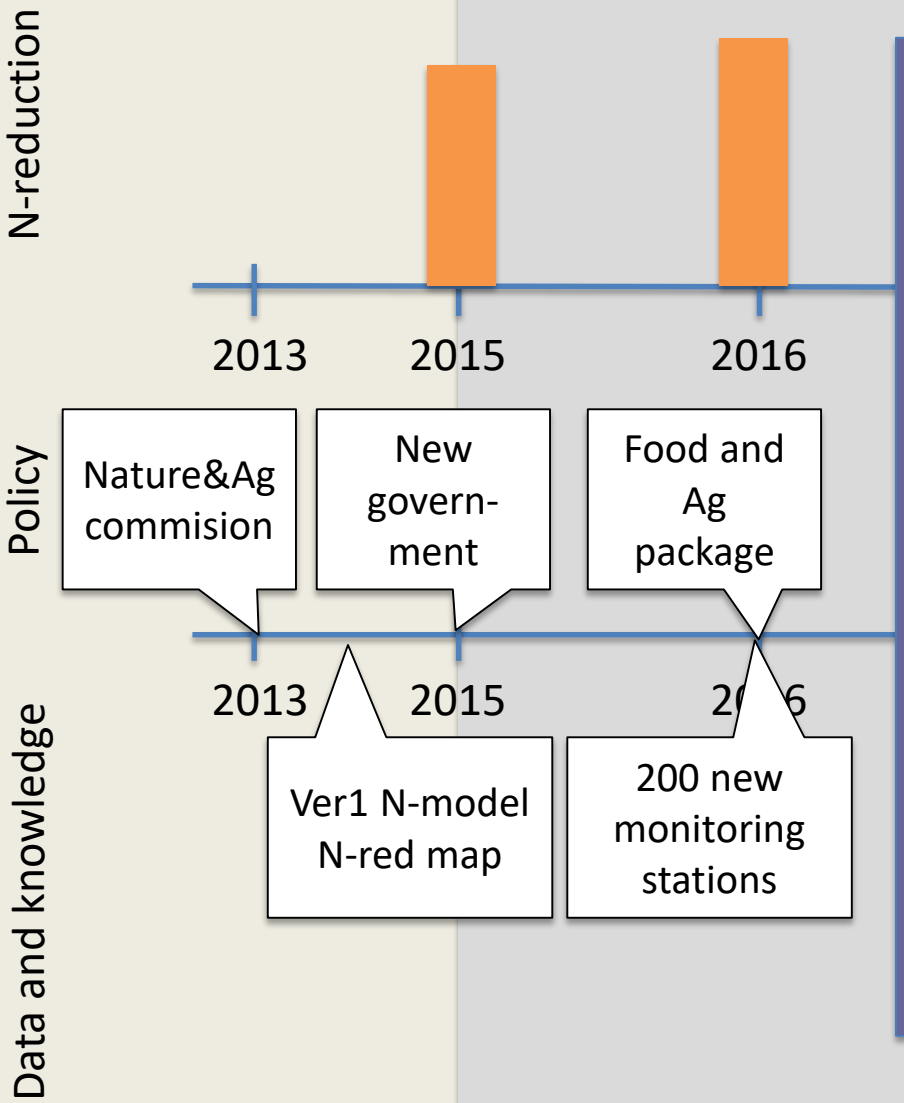

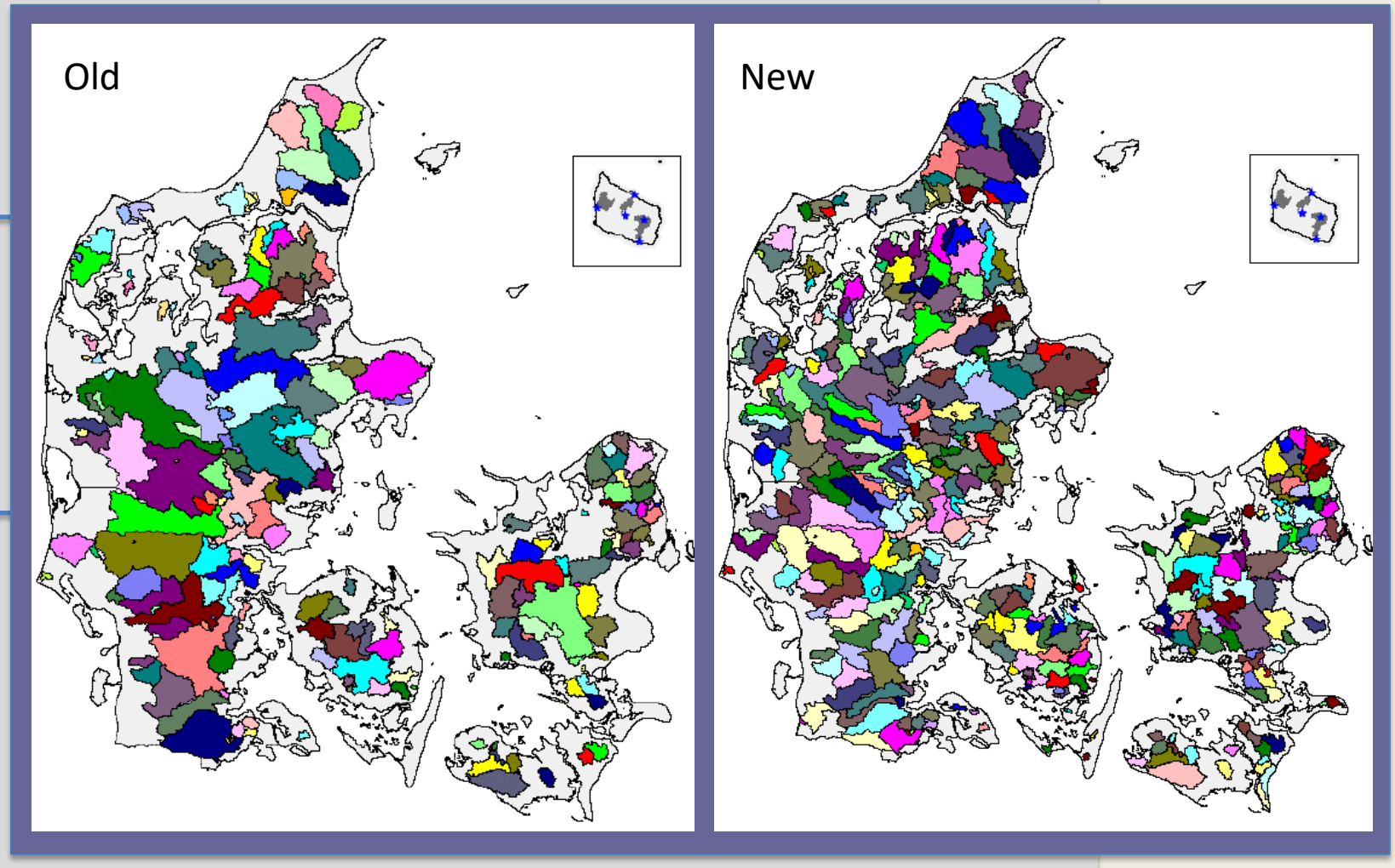

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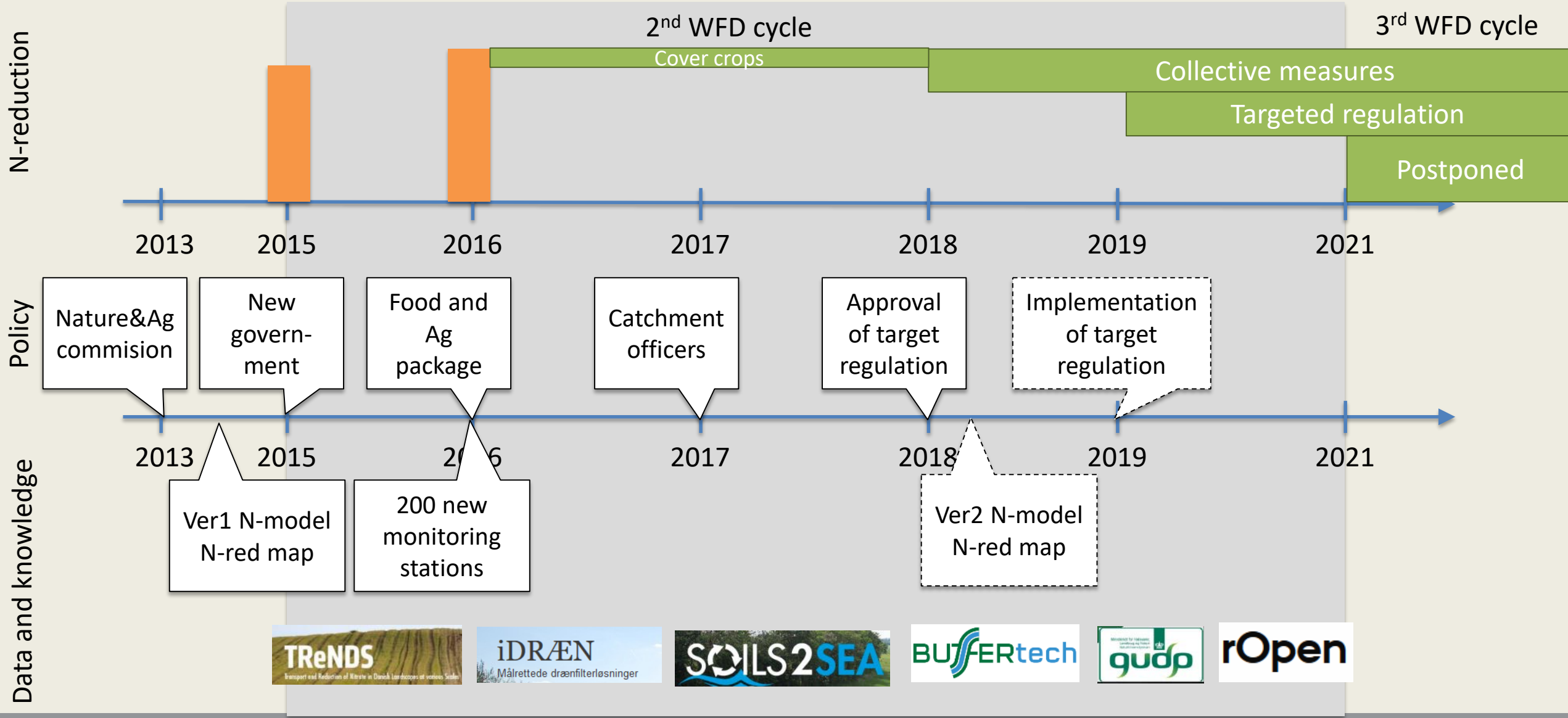
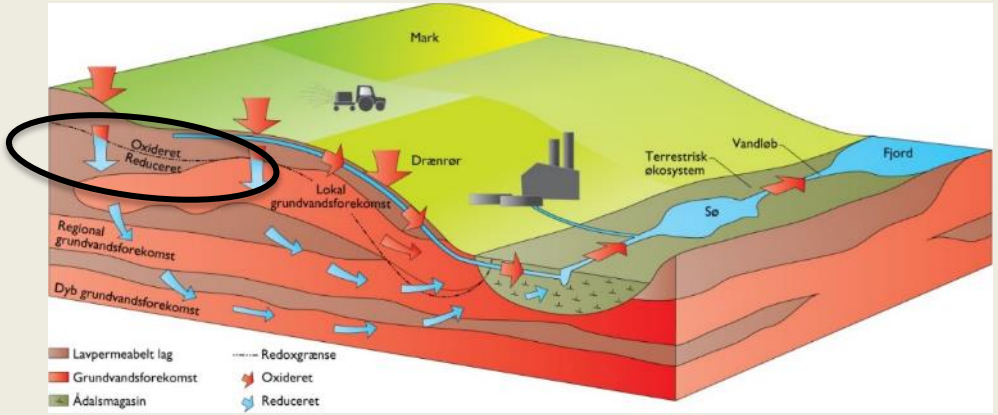
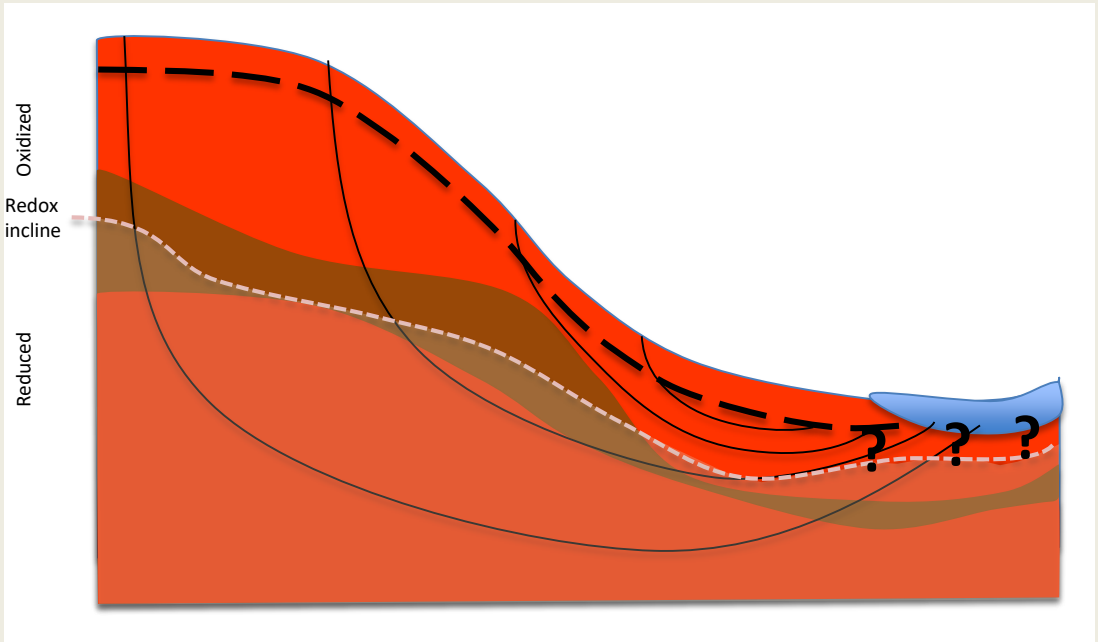


Spatial variability in N transport and reduction

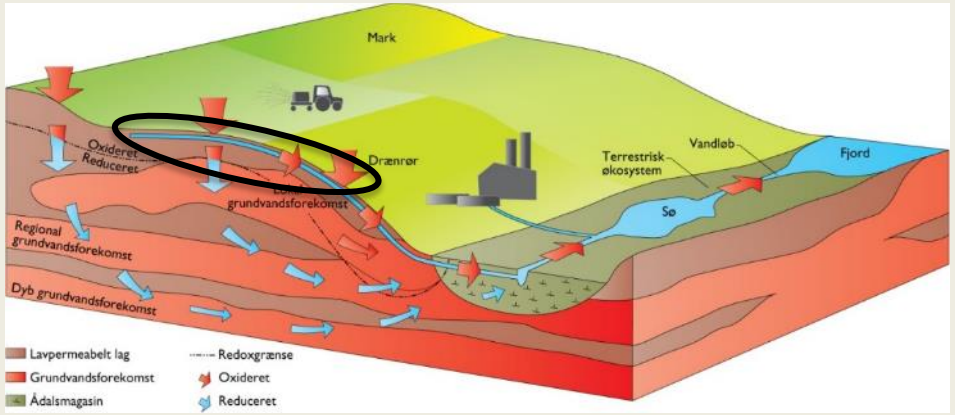


Most reduction in groundwater (~ 63%)

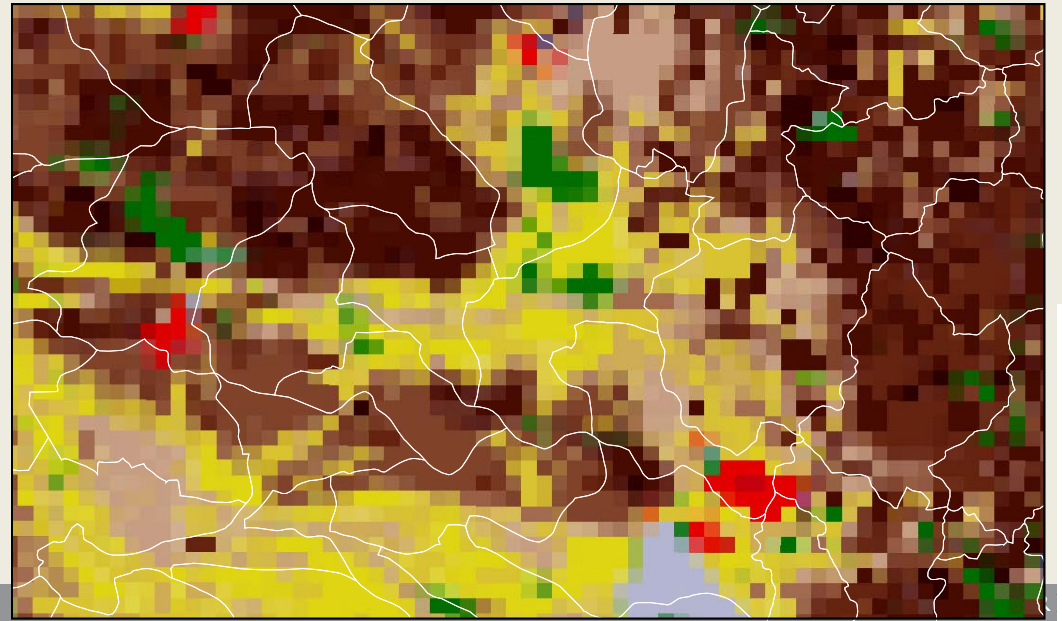


- Upper oxic, lower anoxic parts
- Controlling ”deep” groundwater reduction

Spatial variability in N transport and reduction

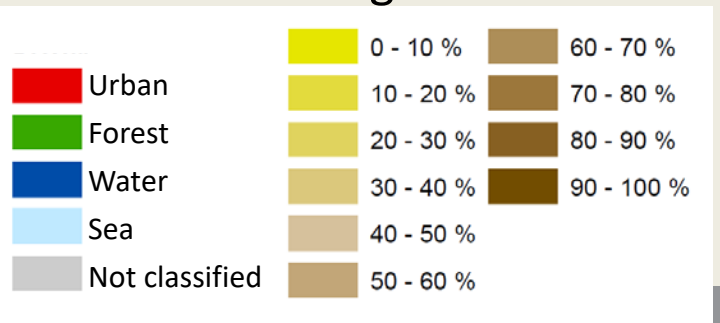


- Drainage acts as fast track to surface waters, bypassing reduced environment in subsurface
- 50% of agricultural land is drained
- Large spatial variation



- Challenges to estimate where and the fraction of drainage

Estimated drainage needs



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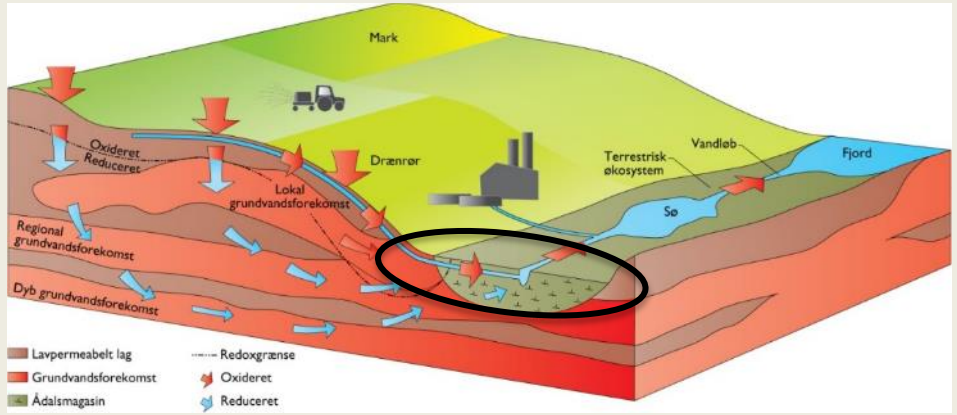
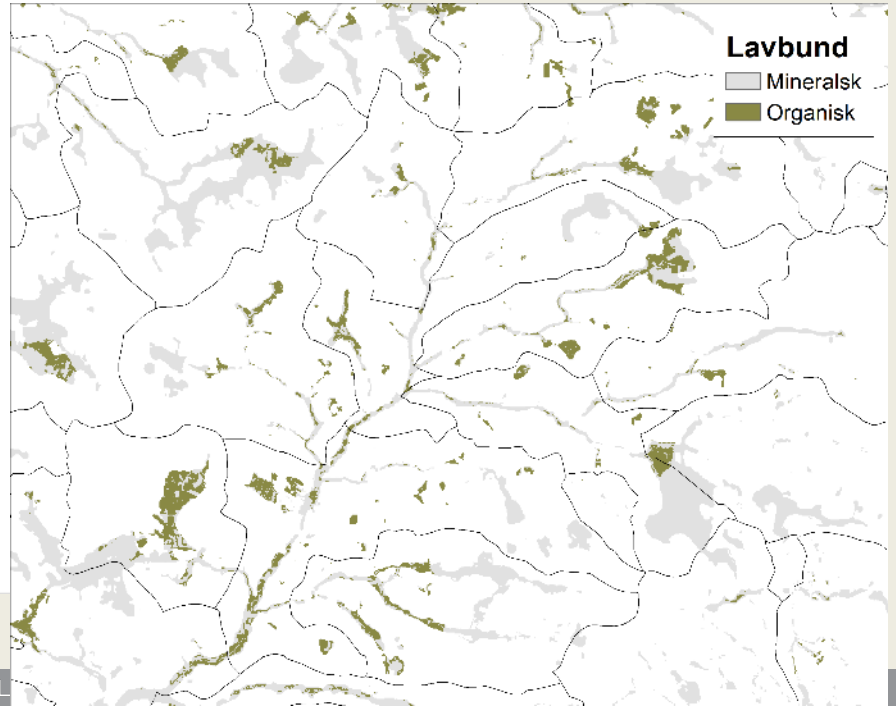




- ~ 20% of the country
- Often rich in organic carbon
- Potentially large nitrate reduction
- Complex system
- Limited knowledge and data

TReNDS – Transport and Reduction of Nitrate in Danish landscapes at different Scales

Redox interface

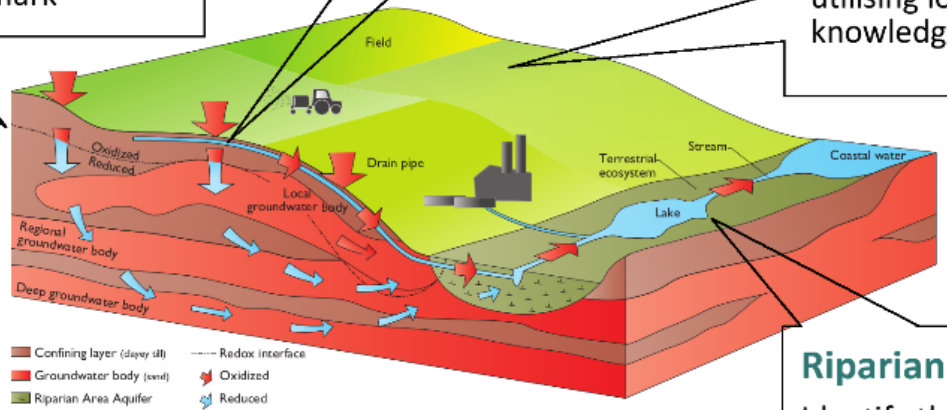
Develop a probe to locate depth to the redox interface on local scale and establish a methodology to produce an improved high-resolution national map for Denmark

Tile drains

Improve detection of drain pipe location and quantify their effects on flow dynamics and nitrate transport in the soil-groundwater zone

Emission based regulation

Develop new concepts for national regulations based on control monitoring of nitrate emissions from agriculture utilising local scale data and knowledge



Integrated modelling

Integrate local-scale drain dynamics and riparian lowland processes in large-scale catchment models required for practical use at regional and national scale water management

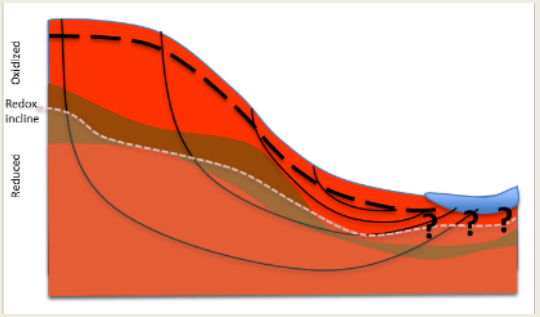
Riparian lowlands

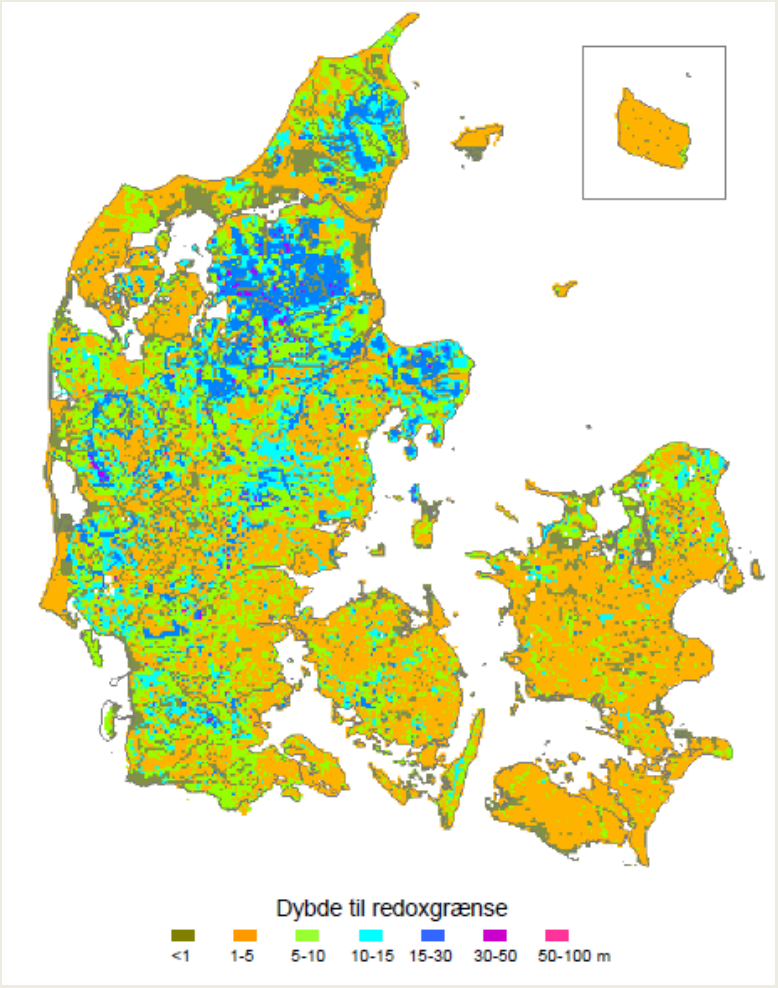
Identify the hydro-biogeochemical processes controlling nitrogen transformation in riparian lowlands and quantify their impacts on nitrate fluxes to surface waters at local scale

Improve our understanding and ***develop*** the scientific foundation, field technologies and modelling concepts for cost-effective quantitative assessments of nitrate transformation at various landscapes required for ***spatially differentiated regulation***

Innovation Fund Denmark
RESEARCH, TECHNOLOGY & GROWTH

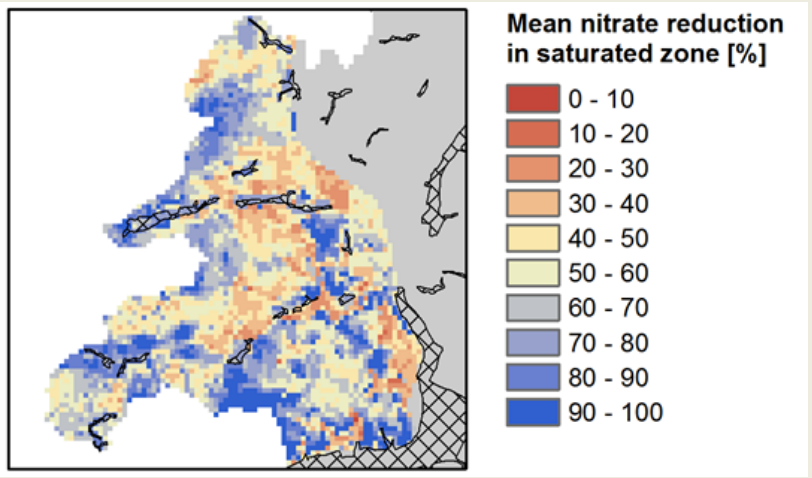
Redox interface





Ernstsen et al., 2006, 2008

- Most reduction in groundwater
- National map on redox interface, based on
  - 13.000 wells (~0.3/km²)
  - Manual interpretation
- 1 x 1 km²
- Local studies: Large variation can be found at small scale



Hansen et al., 2014

Redox conditions

- Traditional observation of redox interface by borehole
  - Time and resource demanding

- Development of new field instrument for in-situ measurements – direct push technology
  - Electric conductivity
  - Redox conditions
    - Direct redox measurement (platinum electrode)
  - Micro sample for ex-situ analysis

Ernstsen, 2013

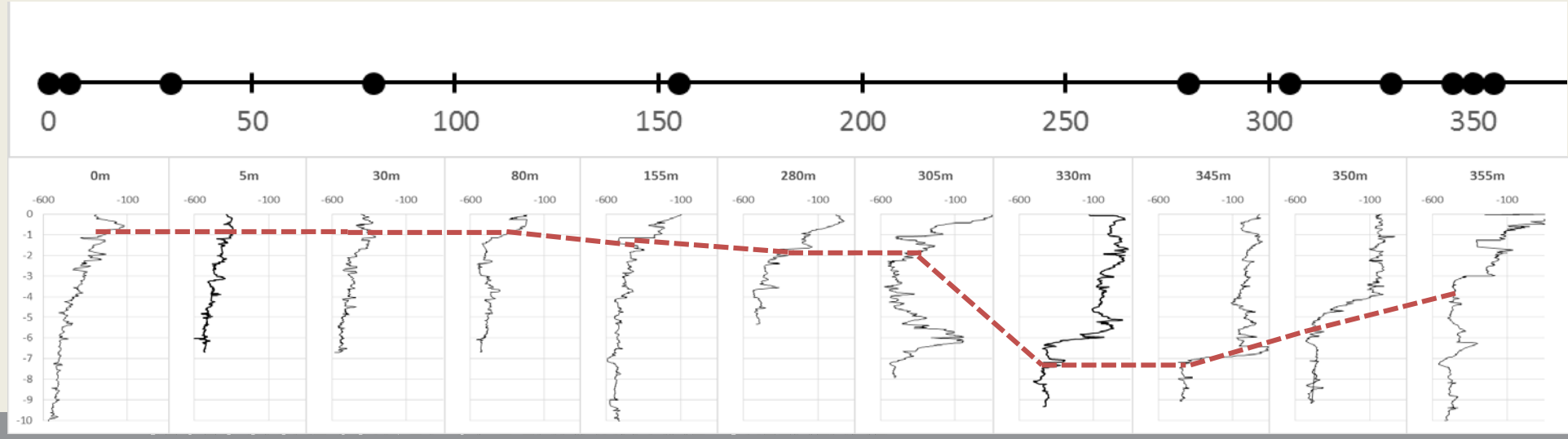
Redox measurements

- 2.5 inch
- Geoprobe 7730DT (4 tonnes)

- ~ 80m/day
- Down to ~15m

- Smaller dimension (1.5 inch) possible without water sampler

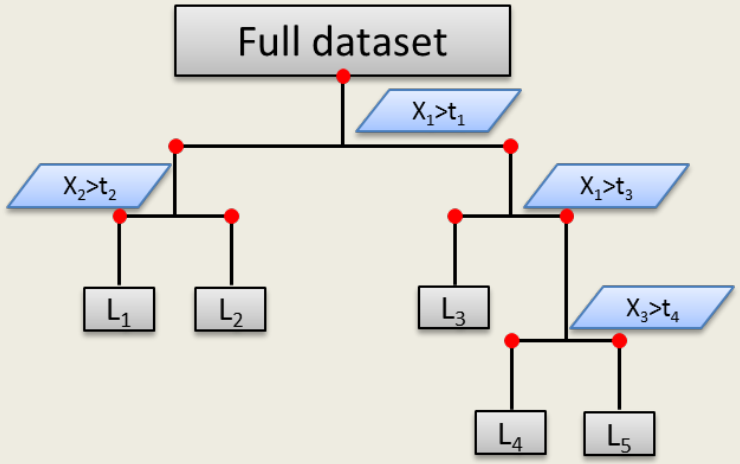
➢ Deeper and faster or smaller Geoprobe



Modelling the depth to redox interface

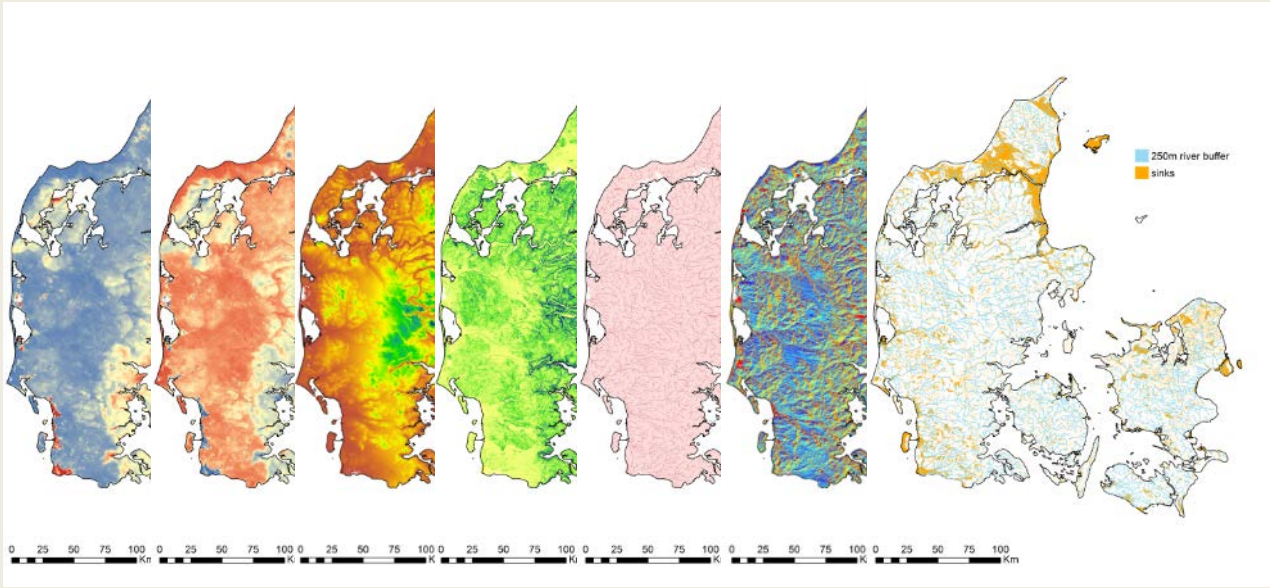
Random forest

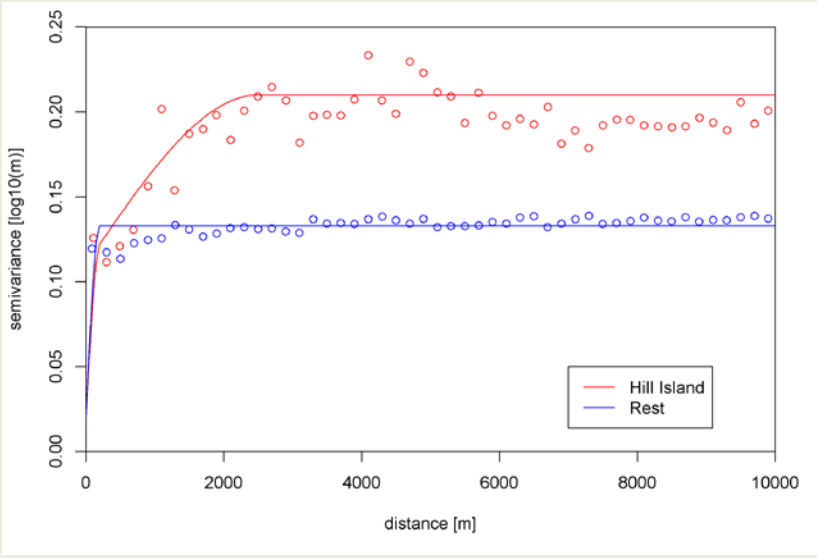
- Data driven/ Machine learning
- Explanatory variables



Residual kriging

- Conditioning to observation data
- Account for local error variance → can be updated based on new data





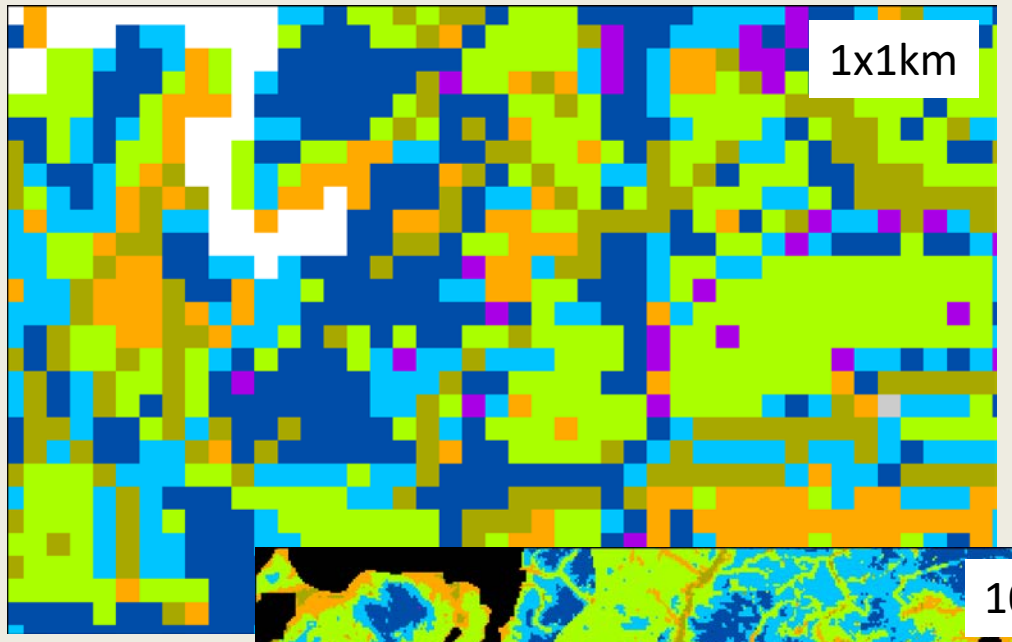
Modelling the depth to redox interface

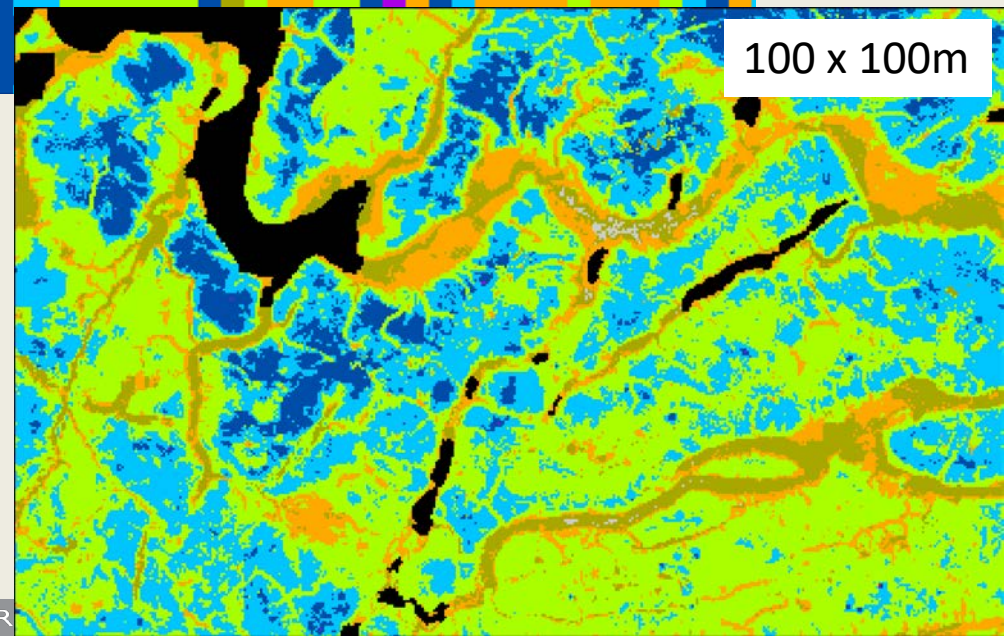
Advantages

- Makes it feasible to generate high resolution maps
- Easily updated based on local data
- Possible to generate realisations to address uncertainty

Future

- More validation in data sparse areas

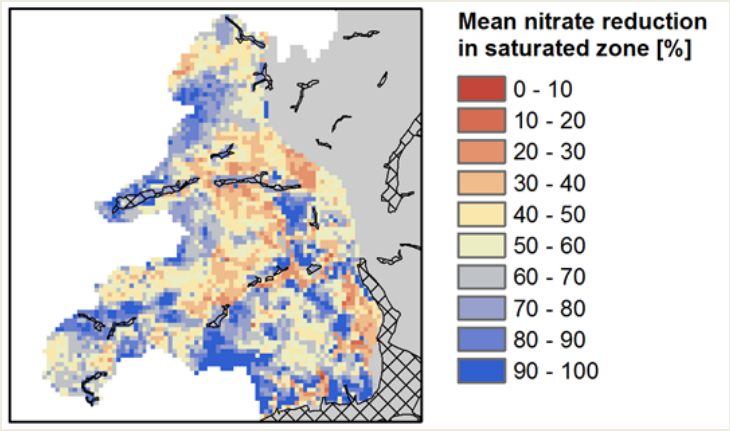




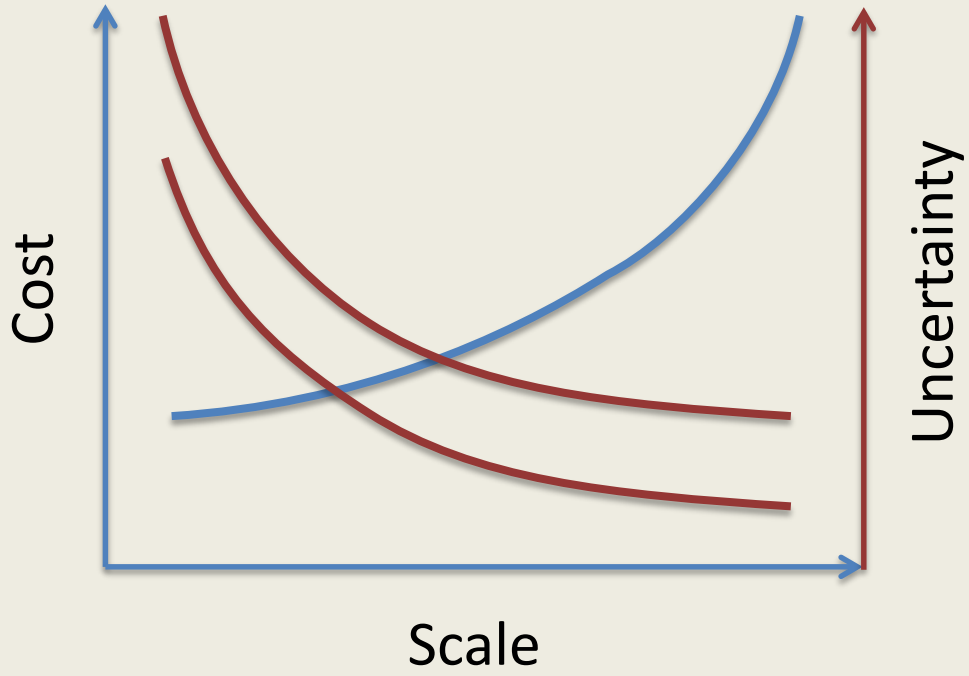
Utilising new knowledge

Two ways to go:

1. Higher resolution
   - ➢ More cost-effective
   - ➢ ...but more uncertain
2. Reduce uncertainty



Hansen et al., 2014



Targeted regulation from 2019

- (current) Principles in the targeted regulation:

1. Volunteer and compensated – in areas with highest reduction requirements (use of reduction map)
2. Mandatory not compensated (everywhere)

- Intention:
  - More differentiated
  - To a larger degree based on measurements
  - More flexibility in choice of mitigation measures
  - Local involvement

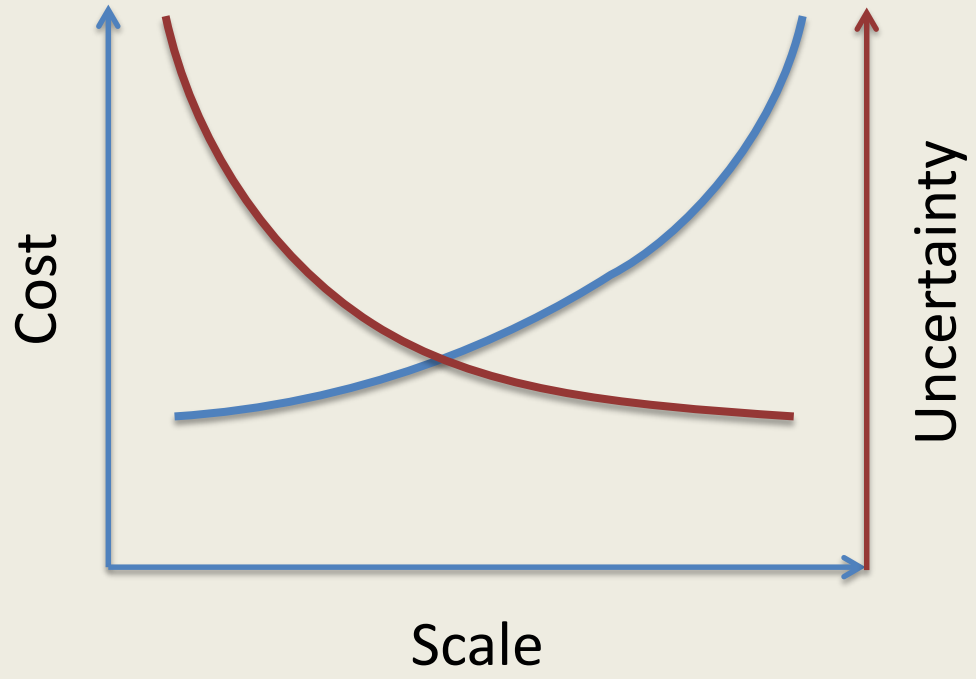
➢ Regulation to be further developed to accommodate new knowledge, data and mitigation measures

Co-governance

- From top-down to bottom-up
- Define catchment targets for control monitoring
- Freedom to manage within

- Utilising N-retention map at smaller scale (below 15km^2) for management

➢ Who carries the risk of the uncertainty



Concluding remark

- Shift in 30 years centralized, top-down and uniform regulation paradigm
- Differentiated regulation means treating people differently
  - Credibility even more important – estimation of uncertainty
  - May require new legislation
- Co-governance, building trust between parties is necessary
- Learn as we go

- Most interesting period in environmental research in my career

Thank you for your attention

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