New concept for field-scale mapping for targeted regulation of nitrogen in agriculture

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Innovation Fund Denmark

rOPEN

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Introduction

The research projects rOPEN and Mapfield funded by the Innovation Fund Denmark are developing a concept for field-scale mapping for targeted regulation of the use of nitrogen in agriculture.

The vision of the concept is to help ensure economic and environmentally sustainable development of the Danish agricultural production and at the same time to ensure that Denmark can meet the demands of EU's environmental directives.

The concept is based on the collection of large amounts of data to more precisely calculate the transport and turnover of nitrogen in the subsurface. The result is a map of the nitrogen retention in the subsurface at field level.

The new concept is developed to form the basis for a precise regulation of the agricultural use of nitrogen at field level, where the actions and mitigation measures are adapted to the nitrogen turnover in the subsurface under each field.

Nitrogen rentention
Nitrogen retention describes the amount of nitrate, which leaches from the field, and which does not reach the surface waters because of natural turnover or denitrification in the subsurface and emission to the atmosphere.

Photo: Bente Fyrstenberg Nedergaard

The concept

The concept consists of five steps:

Step 1:
Reviewing existing knowledge
Farming practices in the catchment area and requirements for nitrogen reduction are examined in relation to both groundwater, surface water and the marine environment. A preliminary overview of the subsurface and the surface water systems as well as the need for new data is created.

Step 2:
Scanning the subsurface
A newly developed scanning instrument called tTEM creates highly detailed 3D images of subsurface structures down to 100 meters below surface, which determine how the water flows in the subsurface.

Step 3:
Investigations at central locations
Water and soil samples from deep drillings are collected and analysed. The samples determine where and how nitrogen turnover takes place in the subsurface.

Step 4:
Production of nitrogen retention maps
The collected data is integrated into a 3D model of the water flow and nitrogen turnover and a map of the nitrogen retention at field level is produced.

Step 5:
Analysis of the choice of mitigation measures
The new maps of the nitrogen retention is employed and new workflows for fertilization planning and choice of mitigation measures are considered in collaboration with farmers, advisors and authorities responsible for current and future planning and legislation.

Nitrogen retention maps

Production of the nitrogen retention maps at field level takes place in step 4 of the concept, which contains 5 elements:

Element 1:
3D-model of subsurface structures
The model shows the distribution of different geological layers in the subsurface. What matters is to which extend the different layers can transport water and whether they are connected.

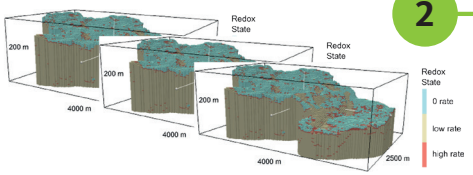
Element 2:
3D model of nitrogen turnover
The model shows the distribution of different zones in the subsurface. What matters is where and how fast nitrogen is removed in the different zones.

Element 3:
Nitrogen leaching from the root zone
Nitrogen leaching is estimated for each field for each year. What matters is the kind of crops on the fields and the farm's total fertilization application, which is distributed to each field.

Element 4:
3D flow model
The model calculates how much, how fast, and in which direction the water flows through the subsurface. What matters is the model's ability to predict the water flow in streams and drains as well as measured water levels in drillings.

Element 5:
Nitrogen retention maps
Estimation of the nitrogen retention is done with a 3D flow and nitrogen retention model, which indicates the amount of nitrogen that is emitted to streams compared to what is leached from the root zone. What matters is the agreement between simulations and measurements of the actual nitrogen transport in the streams.

3D model of nitrogen turnover



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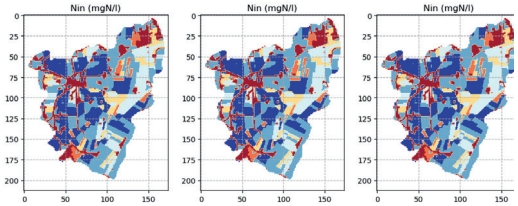
Leaching from the root zone



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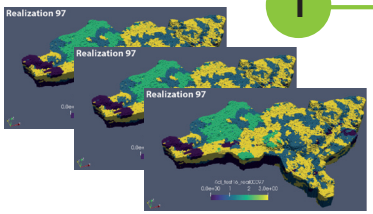
3D model of subsurface structures



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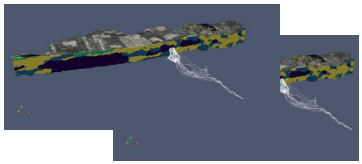
Nitrogen retention map

4

3D flow model



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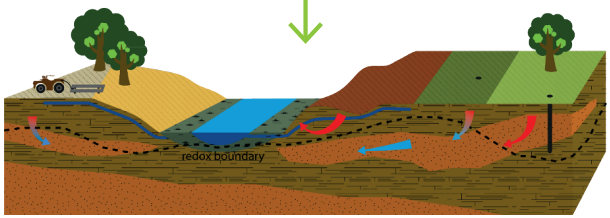


Level of detail in the nitrogen retention maps

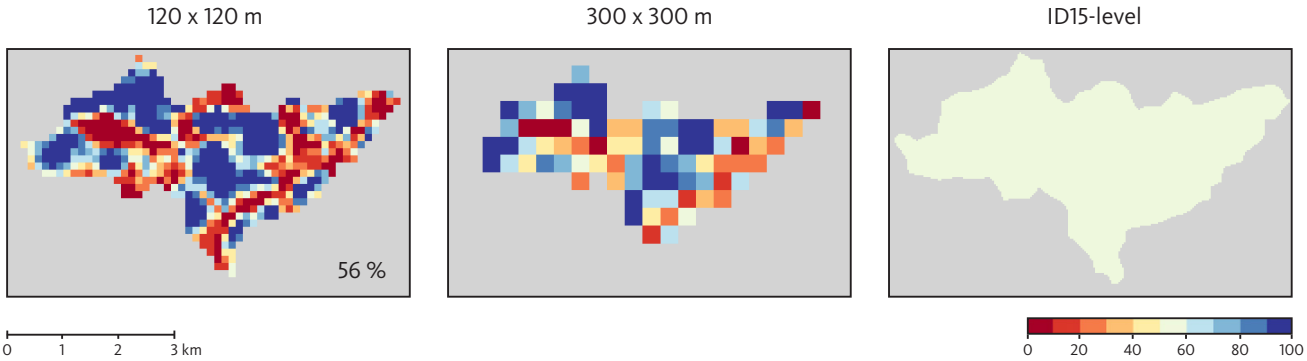
The greater the level of detail, the greater the spatial variation of the nitrogen retention
A high level of detail in the nitrogen retention map makes is possible to target the nitrogen regulation at field level, as shown in the figure on the following page.

Both a level of detail of 120 x 120 m (approx. 1,4 hectares) and 300 x 300 m (approx. 9 hectares) show a large spatial variation from 0 to 100 % while the mean for the ID15 catchment area level (approx. 1000 hectares in this case) is 56 %.

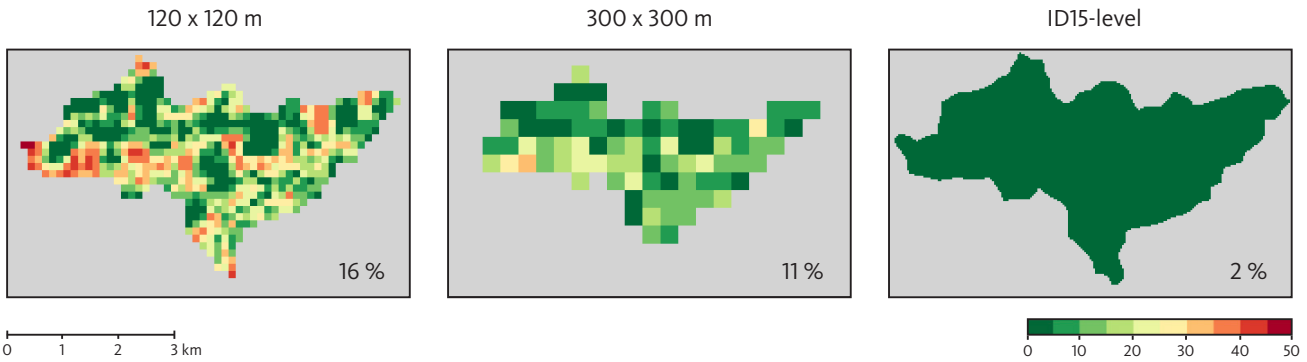
The greater the level of detail, the greater the uncertainty of the nitrogen retention
A level of detail of 120 x 120 m (approx. 1,4 hectares) gives an average uncertainty of 16 %. Uncertainty drops to 11 % with a level of detail of 300 x 300 m (approx. 9 hectares) and ID15 catchment area level respectively.

It should be noted that the uncertainty of the nitrogen turnover from the root zone is not included in the calculation of the total uncertainty of the shown maps but is planned to be included in the concept at a later point. Thus, the shown uncertainties are probably underestimated.

Nitrogen retention (%)



Uncertainty (%-point)



Optimal choice of mitigation measures

It is possible to achieve an economic gain by changing the nitrogen regulation to focus on the emission to the aquatic environment and by further targeting the nitrogen regulation on the fields. This way, the actions are implemented on a smaller area with a large environmental effect.

It is important that the nitrogen regulation is adapted to the individual farmer's crop rotations. Here the new maps of the nitrogen retention at field level can contribute to a more optimal use of mitigation measures.

The new maps can also be used at a larger scale as a basis for redistribution of the land and fertilizer use between farmers in a catchment area.

Costs

The new concept for the production of maps of the nitrogen retention at field level is matched to ID15 catchment areas (approx. 1500 hectares) and can be used in several ways. Catchment areas can be prioritised in different ways, e.g. depending on demands regarding reduction of nitrogen or uncertainties in the existing knowledge foundation.

The new concept makes it possible to only complete step 1 or step 2 in a catchment area (see page 3), if for example it turns out to be unprofitable to continue, because the subsurface is very homogeneous. In other catchment areas, it might be necessary to complete all five steps.

Preliminary calculations show that the central elements in the mapping (step 2 to 4) will cost DKK 900-1000 per hectare, while the complete mapping (step 1 to 5) will cost DKK 1150-1250 per hectare.

Groundwater protection

The concept includes a detailed 3D groundwater model calculating the nitrogen transport and turn-over in the entire hydrological cycle.

Thus, the groundwater model including nitrogen transport and turnover can also be used to make detailed assessments of the nitrate vulnerability of aquifers. This detailed knowledge can be used to point out nitrate vulnerable catchment areas and make action plans for protection of groundwater resources.

The possibility of using the concept for groundwater protection has not been completed but can be added to the presented concept.

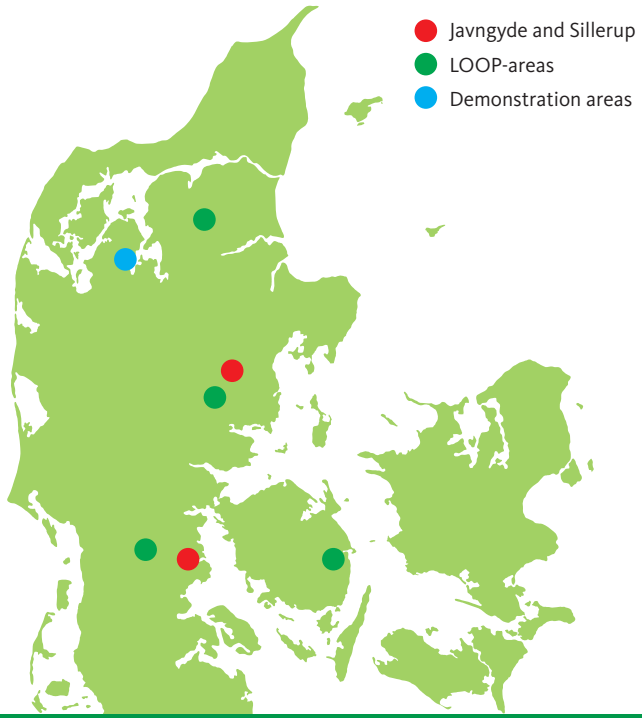
Next steps

The rOPEN and Mapfield projects focus on nitrogen turnover in the subsurface because most of the nitrogen turnover from the fields happen here.

The new concept can be expanded to also include the nitrogen turnover around drains, in areas close to streams, and in the surface water system by including knowledge from other projects. In addition, a more precise description of uncertainties on various parameters, such as nitrogen turnover from the root zone, drainage run-off and net precipitation are planned to be included.

In 2021, the concept will be validated in four small agricultural catchment areas (the LOOP areas) in Jutland and Funen, where national monitoring data in the aquatic environment is available. In addition, the concept will be demonstrated in two ID15 catchment areas with high requirements for nitrogen reduction to Skive Fjord in the Limfjord.

In the two catchment areas, draining to Skive Fjord, the new maps of the nitrogen retention at field level as well as the total nitrogen retention will be presented to farmers and advisors in the area. The maps will also be discussed with relevant authorities regarding current and future legislation as well as possible strategies for the implementation of more targeted nitrogen regulation.



Who is behind

rOPEN (2017-2020) led by Geoscience at University of Aarhus (AU), and Mapfield (2018-2022) led by The Geological Survey of Denmark and Greenland (GEUS) are both research projects under the Innovation Fund Denmark .

The projects build on the results from previous projects such as HYGEM, DNMARK, NICA and Trends. A large consortium consisting of both Danish and international partners is behind the projects.

More information can be found here: mapfield.dk or by contacting:

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