Danish review on advances in assessing: N retention in the subsurface in relation to future targeted N-regulation of agriculture

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GEOLOGICAL SURVEY OF DENMARK AND GREENLAND
DANISH MINISTRY OF CLIMATE, ENERGY AND UTILITIES

G E U S

MapField

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Task Force on Reactive Nitrogen

Innovation Fund Denmark

DE NATIONALE GEOLOGISKE UNDERSØGELSER FOR DANMARK OG GRØNLAND
KLIMA- OG ENERGIMINISTERIET

G E U S

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1. Introduction

This report is initiated in the context of the Innovation Fund Denmark project MapField.

1.1 Aim of the report

The overall aim of this report is to gather knowledge from ongoing and completed major Danish research projects and initiatives on how to assess nitrogen (N) retention in the subsurface. This new knowledge is important for implementing a more targeted N-regulation in Denmark in the future, as expressed in the political agreement from 2018 (MFVM, 2018), and the political understanding for the new Danish Parliament in June 2019 (The Danish Parliament, 2019).

The specific aim of the report is:

- To create an overview of knowledge from other projects and initiatives, which are important to implement in the MapField project

Additional aims of the report are:

- To create a general overview of knowledge important for research projects, stakeholders, and authorities
- To describe possible unmet research needs

1.2 MapField (Field-scale mapping for targeted N-regulation and management)

Period: October 2018 – December 2021
Funding: Innovation Fund Denmark (IFD)
Budget: 29.7 mill. DKK (18.9 mill. DKK from IFD)
Participants: Geological Survey of Denmark and Greenland (GEUS), Aarhus University (AU), Copenhagen University (KU), SEGES, Aarhus Geosoftware (AGS), Ministry of Environment and Food (MST), NIRAS, Central Denmark Region (CDR), the Danish Association of Consulting Engineers (FRI).
Website: http://www.MapField.dk

The vision
The vision of MapField is to develop innovative environmental technologies usable for intelligent environmental regulation of the N-management in agriculture. The generated knowledge in MapField is important for implementation of the political vision of more targeted N-regulation of Danish agriculture. MapField's technologies will ensure environmentally sustainable development of the Danish agricultural food production, meeting the demands of the EU environmental directives.

Success criteria
MapField has the following four overall success criteria:

- Danish knowledge concerning N-retention in the subsurface important for N pollution of surface waters and groundwater has been synthesized, and build into the MapField tools and concept
- A decision support tool and an implementation strategy for the MapField tools and concept has been developed, usable for future targeted N-regulation of agriculture
- Geophysical, geological, and geochemical data acquisition tools have been developed, applicable to the very detailed level needed for hydrological modelling with N-transport at a low uncertainty level on individual fields
- N-retention maps at hectare-scale have been developed for the investigated areas to be used by the individual farmers to manage their production precisely given the regulatory boundary conditions

Objectives
The overall aim of MapField is to deliver new essential research and develop a thorough N-management and regulation tool that will be the breakthrough for a future targeted N-regulation, balancing optimal economic agricultural production with low environmental N-impact on ground- and surface waters.

The following specific objectives are established to meet the overall aim:

- **Development of geophysical processing techniques** based on deep learning for improved efficiency in the data flows from the towed magnetometer (tMAG) and towed electromagnetic (tTEM) instruments

- **Development of geochemical techniques** for determination of unsaturated and saturated zone N-denitrification, and spatial distribution of redox interfaces

- **Development of integrated hydrological models with N-transport** addressing data worth and estimation of uncertainty of N-retention predictions for the decision support tool

- **Validation** of the MapField geophysical, geochemical, and hydrological tools and concept in intensely monitored and highly geologically different catchment areas

- **Demonstration** of the potential of the MapField geophysical, geochemical, and hydrological tools and concept by developing cost-effective targeted N-management and regulation together with stakeholders in typical Danish geologies and landscapes

- **Development of business models** for the implementation of MapField's tools and concept taking farmers, authorities, and companies into consideration

1.3 Related research projects

Different funding sources, including Innovation Fund Denmark, have supported a number of research projects and initiatives building knowledge for a future more targeted N-regulation and management of agriculture. These projects focus on creating detailed knowledge on the retention of N in the hydrological cycle.

In Figure 1 research projects and initiatives important for the conduction of MapField have been identified together with the synergy possibilities to the LOOP areas, part of the national Danish monitoring program, NOVANA, and agroecology projects in the DEMO sites.

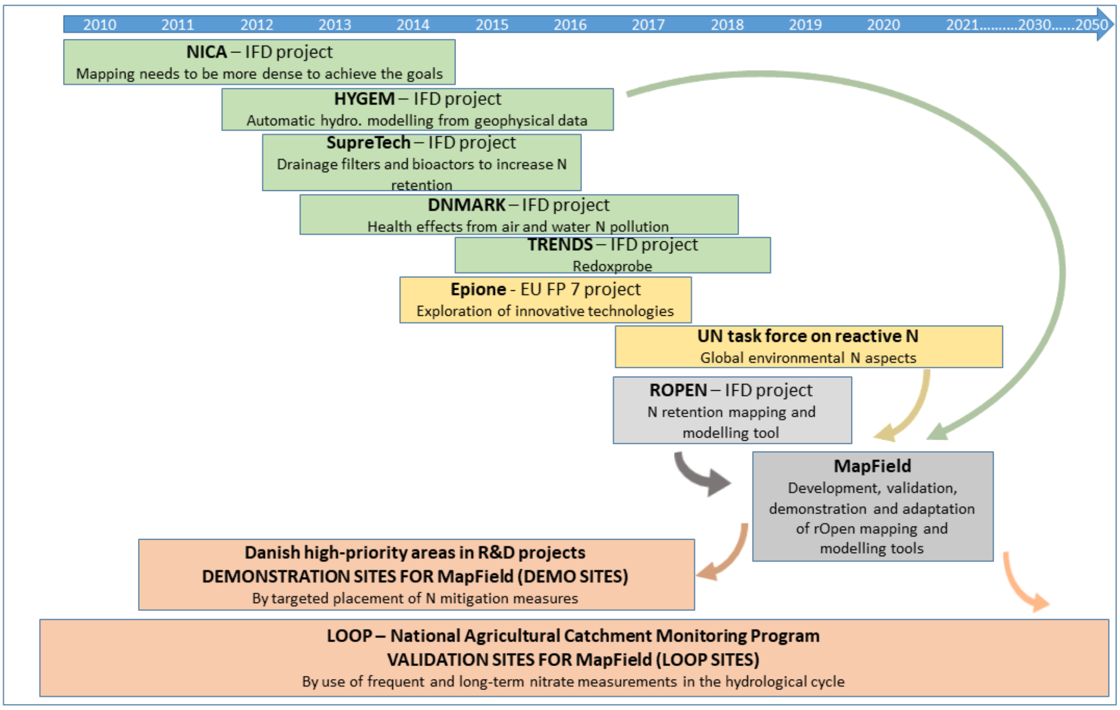

Figure 1. Illustration of how MapField (dark grey background color) intend to use knowledge from completed and on-going research projects, and how MapField will add on knowledge to ongoing projects (orange background colors). Projects with green background are earlier IFD projects. The project with the light gray background color is the ongoing rOPEN IFD project, directly related to the MapField project with darker gray background color. Yellow background colors indicate international projects/task forces related to MapField.

1.4 The April 2019 cluster workshop

On April 1, 2019 a cluster workshop was conducted within the framework of MapField and with representatives (authors of the report) from the selected projects. At the workshop the various projects were presented, and the list of ongoing and completed projects relevant for MapField was discussed and adjusted. A plan for writing this report was decided with approximately one page on each selected project written by the representative. The structure is:

- Short project description
- Main results (including 5-10 references)
- Elements relevant for MapField.

Chapter 2 of this report constitutes the synthesis of knowledge based on the descriptions of the selected ongoing and completed projects presented in chapter 4 and 5. Chapter 3 is dealing with possible unmet research needs at present (November 2019) for future more targeted N-regulation of Danish agriculture.

1.5 References

MFVM, 2018. Aftale om målrettet regulering – Et nyt paradigme for miljøreguleringen af dansk landbrug.https://mfvm.dk/fileadmin/user_upload/MFVM/Aftaletekst_om_maalrettet_regule-ring.docx.pdf

The Danish Parliament, 2019. Retfærdig retning for Danmark. Politisk forståelse mellem Socialdemokratiet, Radikale Venstre, SF og Enhedslisten. https://ufm.dk/ministeriet/regeringsgrundlag-vision-og-strategier/regeringen-mette-rasmussens-forstaelsespapir/retfaerdig-retning-for-danmark_2019-06-25_endelig.pdf

2. Synergy to MapField

Figure 2 shows the content and connections of the main six objectives of MapField and how different ongoing and completed projects are providing input to these objectives. It clearly shows the linkage between the portfolio of projects, and how the level of knowledge on N-retention methods are building up.

The specific elements of the ongoing and completed projects important for MapField can be found in the last session of the description of each project in chapter 4 and 5.

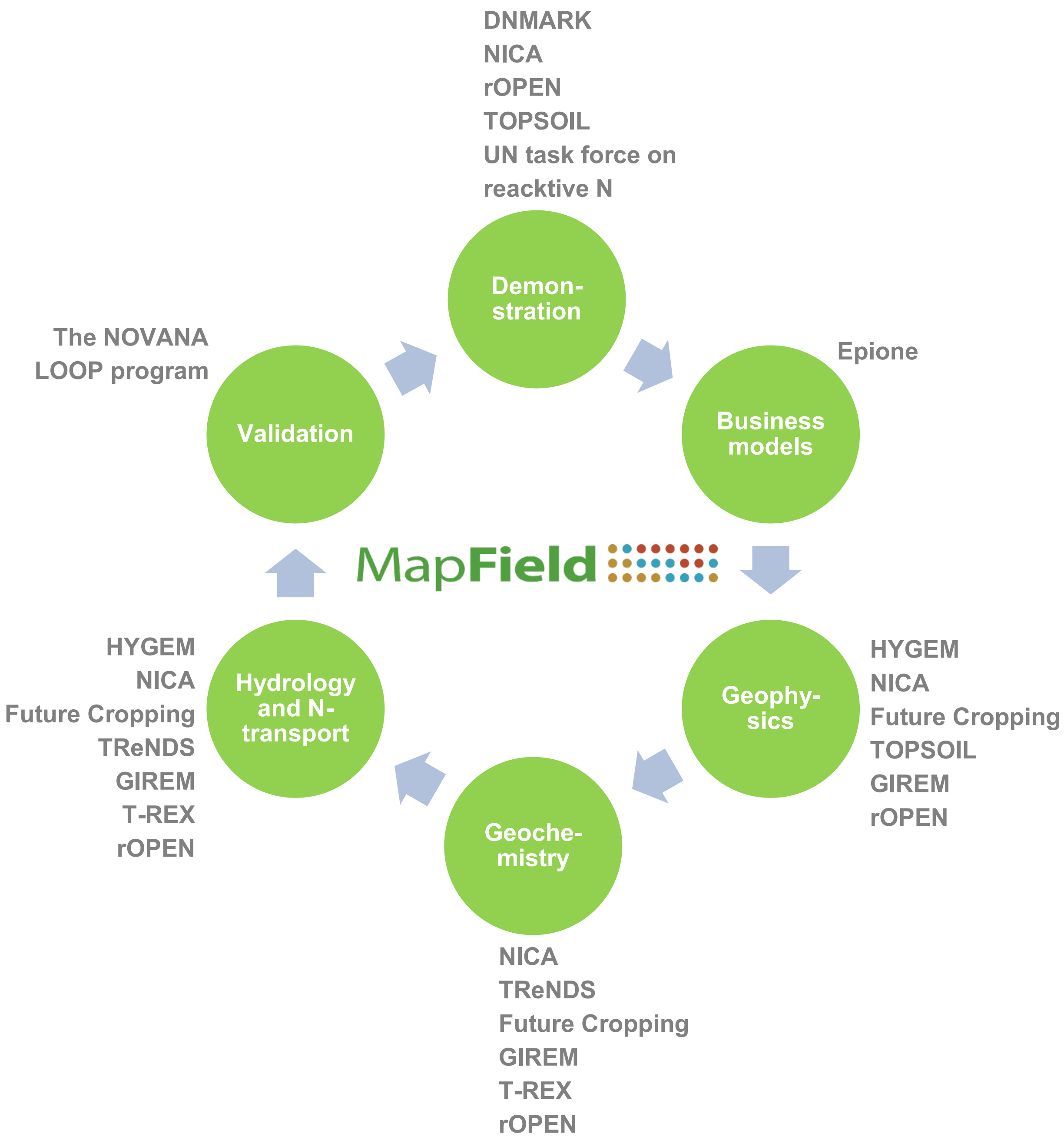

Figure 2. Overview of the projects with synergy to MapField described in chapter 4 and 5.

3. Unmet research needs

As described in the former two chapters different funding sources, including Innovation Fund Denmark, have supported several research projects and initiatives, all building knowledge for a future more targeted N-regulation and management of agriculture. These projects are focusing on creating detailed knowledge on the local retention of N in the hydrological cycle.

The question is, if the former and present research projects have been/will be able to develop technologies and approaches in order to establish a sufficiently strong scientific foundation for a more targeted Danish agricultural N-regulation in the future?

Answering this question in full is complicated, as some projects are still actively testing research hypotheses.

However, the authors of this report identify the following unmet research needs at present (November 2019):

- **Optimizing the dataflow**. The dataflow within hydrological modelling and stochastic modelling of geology and redox conditions needs to be optimized and made commercially operational. Where the data flow for the geophysical data has been developed over a decade or more, the geological, geochemical, and hydrological modelling needs to undergo a similar process in order to reduce costs and learning curves.

- **Cost-effective mapping.** Optimization of the workflow is needed in order to make the process quicker and reduce the costs required for the approach to be competitive commercially and to be used by regulators. There is a need to focus on areas with large nutrient reduction requirements and on areas where the variation in N-retention is the largest, as this is where the economic gain from using the rOPEN/MapField concept is the largest.

- **Sampling below 20 meters.** The successful Ejlskov direct push method used in MapField for geophysical, geological and geochemical core sampling from wells has a maximum reach of 20 meters below the surface. There is a need to explore and develop methods capable of core sampling from 20 – 50 meters to be used in areas with deep redox interfaces. This method should preferable have the same accuracy and possibilities as the used direct push method to 20 meters.

- **Integration of the riparian zone.** There is a need to couple the riparian zone with the concepts in rOPEN and MapField to ensure that the entire water flow and N cycle are handled, from the farm field to the stream.

- **Mapping the riparian zone.** There is a need to further develop the tTEM geophysical method so it can be used in the riparian zone. In addition, there is a need for further detailed investigations of the N-transport and reduction processes e.g. on the interaction between groundwater and surface waters and the interaction between drains and surface waters.

- **Integration of drains**. In rOPEN we have identified challenges regarding accurate modelling of flow patterns on drain affected fields. It turns out that accurate modelling of drains is very important as transit times can vary dramatically across a drained field whether a water particle “hits” a drain or not. Calibration factors can be established to mitigate the effects on the total responses, but more research is needed to gain a deeper understanding.

- **Mapping the upper 5 meters.** The drains are of vital importance, and there is a need for instruments mapping the top 1-5 meter with even higher accuracy than what the tTEM system is capable of today. Existing equipment resolves the interval, but it is clear that the instrument quality does not suffice to be used in a quantitative manner. In addition, there is a need for further detailed investigations of the N-transport and reduction processes around the drains.

- **Likelihood for drains**. There seems to be a clear correlation between the location of drains and the shallow resistivities. Together with other indirect indications of drains (e.g. aerial photos, soil types, topography, geology, crop yield, etc.) this can be used in a machine learning setup to calculate likelihood for the spatial distribution of drains on fields. In turn, this information can be included in the integrated modelling to further refine the N-retention maps.

- **Methods for stakeholder involvement and demonstration.** There is a need to test and develop research-based solutions for new, landscape scale, land use, and agricultural management practices, leading to significantly reduced nitrogen losses while optimizing synergies and avoiding tradeoffs on other ecosystem services.

- **Integration of the rOPEN/MapField concept in a national model.** There is a need to compare and integrate the concepts and N-retention maps developed in rOPEN/MapField with the existing national models. Which resolution scales are needed? Can individual areas be replaced sequentially, and which criteria should be used?

4. Overview of on-going projects

4.1 rOPEN

Period: 2017 – 2019
Long title: Open Landscape Nitrate Retention Mapping
Funding: Innovation Fund Denmark
Budget: 20.6 mill. DKK (13.1 mill. DKK from IFD)
Participants: Aarhus University (AU), Geological Survey of Denmark and Greenland (GEUS), Danish Regions, The region of Southern Denmark, Copenhagen University (KU), SEGES, Aarhus Geosoftware (AGS), Orbicon, Central Denmark Region (CDR), SkyTEM, USGS, University of Arizona.
Website: http://hgg.au.dk/projects/rOPEN/

Short description of the project

The rOPEN project vision is that more effective targeting to remediate the consequences of N-loading on farm fields can be achieved by using innovative geophysical mapping in combination with hydrogeological and geochemical modeling. This higher resolution will improve the prediction of nitrate transport in the open landscape at field scale (a few hectares). Furthermore, rOPEN seeks to deliver a transparent, data-driven decision support tool that will be cost effective on the national scale. Such improved management can lead to targeted regulation and more efficient fertilizer utilization benefiting both the agricultural sector and the environment. In short, the key objectives are to produce:

- Ground based geophysical instruments for high resolution mapping of shallow geology and location of tile drains
- Software to estimate the essential subsurface structures
- A tool for data fusion enabling a semi-automatic creation of coupled root zone and groundwater models with geophysical, hydrological, and geochemical data
- A calculation of the economic impact of suggested measures, positive and negative, for the individual farmers and on the national scale as a whole

Main results

In rOPEN most of the objectives that are listed above have been achieved. A towed Time-domain EM instrument, tTEM, has been developed (jointly with the TopSoil project) to a first production stage (Auken et al., 2018; Kallesøe et al., 2018) and two ID15 catchments have been mapped, totaling about 30 km^2. These data have been integrated into a combined modelling tool centered around a hydrological groundwater model (Vilhelmsen et al., 2019) taking inputs from root-zone leaching modelling, climate, land-use, subsurface structures (from geophysics), and detailed geochemical analyses and interpretations on redox architecture of the subsurface (Kim et al., 2019). A towed magnetometer instrument, tMAG, has been developed and tested. The tMAG development has been challenging and it remains to be concluded if drains can be detected at a larger scale. The hydrological modelling with N-transport has shown that this part could be improved by more detailed knowledge concerning water and N-transport around drains and in the riparian zone.

The maps produced are essentially maps of nitrate retention potential at a 30 m pixel-resolution, and importantly these maps are accompanied by maps showing the uncertainty at each pixel. The uncertainty map is a result of several realizations of the input to the modelling and will, in that sense, represent uncertainty factors like missing data, few boreholes, poor quality hydrological input, etc.

Elements important for MapField

In rOPEN the developed techniques and methods are tested in two pilot areas: Javngyde and Sillerup. MapField is a continuation of rOPEN, brings the technologies and methods developed in rOPEN closer to implementation, and uses the results from rOPEN on:

- Development of the tTEM and tMAG geophysical processing technologies
- Development of N-retention rates analytical methods
- Assessments of subsurface redox conditions in 3D by integration of geophysical, hydrogeological, and geochemical data
- Development of hydrological modelling tools with N-transport for N-retention map production

References

Kallesøe, A.J., Pedersen, J.B., Sandersen, P., Høyer, A.-S., Jørgensen, F., Christiansen, A.V., Auken, E., & Hansen, B., 2018. Ny geofysisk metode inviterer til detaljeret geologisk kortlægning. Vand og Jord, Maj 2018. https://northsearegion.eu/media/6802/appendix-20.pdf

Auken, E., N. Foged, J. Larsen, K. Lassen, P. Maurya, S. Dath, and T. Eiskjær, 2018. tTEM — A towed transient electromagnetic system for detailed 3D imaging of the top 70 m of the subsurface, Geophysics, E13-E22. https://doi.org/10.1190/geo2018-0355.1

Kim, H., Høyer, A.-S., Jakobsen, R., Thorling, L., Aamand, J., Maurya, P.K., Christiansen, A.V. & Hansen, B., 2019. 3D characterization of the subsurface redox architecture in complex geological settings. Science of the Total Environment. Accepted.

Vilhelmsen, T.N., Auken, E., Christiansen, A.V., Barfod, A.S., Marker, P.A. & Bauer-Gottwein, P., 2019. Combining clustering methods with MPS to estimate structural uncertainty for hydrological models. Frontiers in Earth Science, section Hydrosphere. doi: 10.3389/feart.2019.00181.

4.2 **DNMARK** research alliance

Period: 2013 – 2019
Long title: Innovative solutions for a sustainable management of nitrogen in agriculture
Funding: Innovation Fund Denmark.
Budget: 30.9 mill. DKK (20 mill. DKK from IFD)
Participants: Aarhus University (AU), Copenhagen University (KU), Geological Survey of Denmark and Greenland (GEUS), SEGES, Alterra Research Institute (NL), Aalborg Water Supplies Ltd, Alectia, ARLA Foods, Association of Recycling of Organic Waste in Agriculture, Conterra Lts, Danish Nature Agency, Horsens Municipality, Jammerbugt Municipality, Odsherred Municipality, SEGES Pig Reserch Center, Skive Municipality, Varde Municipality & YARA Danmark Ltd.
Website: http://dnmark.org/

Short description of the project
Both too little and too much nitrogen (N) is a problem. Lack of nitrogen causes reduced food production while too much nitrogen causes damage to the environment, climate, and public health.

DNMARK is a multidisciplinary research alliance proposing new solutions and ideas to optimize the use of N. The result is a list of targeted initiatives available to consumers, farmers, farm advisors, politicians, and other decision makers in the private and public sector. The potential economic benefit can be large, as the cost of current unsustainable use of N is estimated to 5000 DKK/capita/yr. Therefore, a number of EU, OECD and UN initiatives with significant interest to DNMARK are promoted.

Read the Danish N alliance brochure at
dnmark.org/wp-content/uploads/2016/03/DNMARK_UK_tryk1_4.pdf;
or watch the translated N video via: dnmark.org/?p=3083&lang=en.

A full list of publications is available from http://dnmark.org/wp-content/uploads/2019/05/0603-00517B-publications-DNMARK-2019.pdf and includes 578 publications and dissemination entries.

Main results
The key findings from DNMARK are:

- Policies for agricultural nitrogen management - trends, challenges and prospects for improved efficiency in Denmark (Dalgaard et al., 2014).
- Groundwater nitrate response to sustainable nitrogen management (Hansen et al., 2017).
- Ammonia, ammonium and the risk of asthma - A nationwide case-control study in Danish preschool children (Holst, 2018).
- Nitrate in drinking water and colorectal cancer risk: A nationwide population-based cohort study (Schullehner et al., 2018).
- Using landscape scenarios to improve local nitrogen management and planning (Andersen et al., 2019).

Elements important for MapField
The main elements of relevance to MapField are:

- The solution scenarios around geographically targeted nitrogen management and landscape scenarios to improve local nitrogen management and planning (see e.g. Andersen et al. 2019)
- The results on the relation between nitrate in drinking water and colorectal cancer risk, which will be used in an assessment in MapField.

Key references

Andersen PS, Andersen E, Graversgaard M, Christensen AA; Vejre H and Dalgaard T, 2019. Using landscape scenarios to improve local nitrogen management and planning. Journal of Environmental Management, Volume 232, 15 February 2019, Pages 523-530. https://doi.org/10.1016/j.jenvman.2018.11.023.

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Holst G, Thygesen M, Pedersen CB, R.G. Peel, J. Brandt, J.H. Christensen, J. Bønløkke, O. Hertel, and T. Sigsgaard (2018) Ammonia, ammonium and the risk of asthma - A nationwide case-control study in Danish preschool children. Environmental Epidemiology: September 2018 - Volume 2 - Issue 3 -p e019. https://journals.lww.com/environepidem/Fulltext/2018/09000/Ammonia,_ammonium,_and_the_risk_of_asthma__A.4.aspx.

Schullehner J, Hansen B, Thygesen M, Pedersen CB, Sigsgaard T (2018) Nitrate in drinking water and colorectal cancer risk: A nationwide population-based cohort study. International Journal of Cancer 143: 73–9. https://doi.org/10.1002/ijc.31306.

4.3 TopSoil

Period: December 2015 – December 2021
Funding: Interreg North Sea Region. European Regional Development Fund. European Union.
Budget: 8.453 mill. EURO
Participants: Region Midtjylland (DK), Region Syddanmark (DK), GEUS (DK), AU (DK), Herning Kommune (DK), Horsens Kommune (DK), Vlaamse Mileumaatschappij (B), Bundesanstalt für Geowissenschaften und Rohstoffe (G), Dachverband Feldberegnung Uelzen (G), Landeamt für Bergbau, Energie und Geologie Niedersachsen (G), Landesmat für Landwirtschaft, Umwelt und ländliche Räume Schleswig-Holstein (G), Landwirtschaftskammer Niedersachsen (G), Leibniz-Institut für Angewandte Geophysik (G), Oldenburgisch-Ostfriesischer Wasserverband (G), Universität Bremen: Geologischer Dienst für Bremen (G), Provincie Drenthe (NL), Waterschap Hunze en Aa's (NL), Waterschap Hunze en Aa's (NL), Durham University (GB), Essex & Suffolk Rivers Trust (GB), Norfolk Rivers Trust (GB), Northumbrian Water Limited (GB), The River Trust (GB).
Website: https://northsearegion.eu/topsoil/

Short description of the project
Climate change affects the hydrological cycle, and we now experience more heavy rains, prolonged droughts, and increasing sea levels. The changes in climate also affect the groundwater aquifers, and the TOPSOIL project explores the possibilities of using the upper soil layers to solve current and future water challenges concerning both water quantity and quality. TOPSOIL looks beneath the ground surface, predicts and finds solutions for climate related threats like groundwater flooding during wet periods and droughts during summer seasons.

The overall objective of the project is the joint development of methods to describe and manage the uppermost 30 m of the subsurface, in order to improve the climate resilience and protect the environment of the North Sea Region. Across the North Sea in Northern Europe we share different challenges within groundwater and climate change. In the 4-year TOPSOIL project, five shared challenges are addressed via geological, geophysical and hydrological investigations, stakeholder involvement, and changes in management. In 16 pilot areas, in the North Sea Region, in the involved countries, TOPSOIL has developed and tested solutions for managing the uppermost 20-30 m of the subsurface.

Main results
The identified challenges we share across the North Sea Region within groundwater, surface water, and climate changes are: 1) Groundwater flooding, 2) Saltwater intrusion, 3) Groundwater buffering, 4) Soil conditions, and 5) Pollutants and nutrients.

The project is built on the following elements:

Stakeholder involvement: Key stakeholders at pilot and project level are identified and involved in the project activities. A framework for planning both stakeholder participation and critically evaluating the success of each pilot and the project of involving stakeholders has been developed. All pilots have produced a strategy for stakeholder involvement, detailing the key stakeholders that need to be involved in the pilot and how they will be involved. Production of the strategies was supported by a TOPSOIL stakeholder involvement guidance, produced early in the project. At project level, stakeholders have actively participated in project meetings and workshops, providing expert knowledge and contributing to discussions on the key challenges of the Topsoil project.

<u>Field investigations and technical development:</u> Taking groundwater, salinization, groundwater levels, soil, interaction between the vadose zone and the saturated zone into consideration in simulation models. Especially, geophysical, technical dedicated workflows are needed to learn more about the subsurface. These special techniques and field investigations have been applied in the various pilot areas. The acquired data contribute to geological and hydrological 3D models. Overview measurements like SkyTEM have been carried out in some pilots to show the distribution of freshwater and saltwater in the aquifers, while other pilots use pre-existing results from airborne electromagnetic measurements by BGR (Federal Institute for Geosciences and Natural Resources).

The development, testing, and deployment of different investigation methods has been carried out to map the upper soil layers and their properties in all 16 pilot areas. This includes an electromagnetic time-domian system, tTEM (Auken et al., 2018; Kallesøe et al., 2018), which can be used for detailed, three-dimensional hydrological and geological mapping of the subsoil layers.

<u>Interpretation and modelling:</u> Hydrological and geological tools are applied and developed to prepare the basis for the new management needed. This includes further development of methods that can map and model the hydrogeology in the shallow subsurface. The data on geology, groundwater and surface waters have been analyzed and models of varying complexity are constructed to analyze the data and hydrogeological systems in question. With the modelling tools, flooding and inundation in urban and rural areas and the potential to use groundwater reservoirs as buffers to store water in periods of excess rainfall is investigated. The expected increasing problems with saltwater intrusion into coastal freshwater reserves are also being investigated. Further, changes in degradation capacity of nutrients, and other hazardous pollutants in the near-surface layers are being investigated in the project.

<u>Governance:</u> To solve present and future water challenges, strong governance is needed if the different interests at different levels are to be unified. Here, governance is defined as the way the management of water resources is organized, comprising all technical, organizational, legal, financial, and political aspects, and the totality of interactions and collective actions taken by authorities and stakeholders. Based on the results from the above mentioned activities, TOPSOIL develops regional roadmaps towards an optimal governance setting within the region. A European governance assessment toolkit for topsoil climate change adaptation is under development.

<u>New management regime:</u> For all pilots a new water management plan will be developed based on the new knowledge. The management will emphasize the focus on a strong climate resilient management. The goal is to describe new ways of managing our surface-near groundwater to find resilient and sustainable management regimes, including: Development of new management in each pilot, synthesis of the roadmaps and their impact on policy challenges per catchment area, identification of measures, which have been particularly effective, and development of recommendations for addressing the European barriers for implementing locally efficient measures.

Elements important for MapField

The element of TOPSOIL most important for the objectives of MapField is the tTEM method. The method was developed partly in TOPSOIL and partly in rOPEN. The results and experiences from its implementation in several of the TOPSOIL pilots can be directly transferred to the development in MapField. This includes the experiences with geological interpretation of data and how to use these for subsequent groundwater modelling. In some cases, the tTEM mapping in the TOPSOIL pilots was related to nitrate leaching issues, but in most cases, it was used for other purposes, e.g. mapping of groundwater resources or flow pathways.

Knowledge on involvement of stakeholders, development of new management in each pilot area, impact on policy challenges and identification of measures might be useful in MapField as well.

References

Kallesøe, A.J., Pedersen, J.B., Sandersen, P., Høyer, A.-S., Jørgensen, F., Christiansen, A.V., Auken, E., & Hansen, B., 2018. Ny geofysisk metode inviterer til detaljeret geologisk kortlægning. Vand og Jord, Maj 2018. https://northsearegion.eu/media/6802/appendix-20.pdf

Auken, E., N. Foged, J. Larsen, K. Lassen, P. Maurya, S. Dath, and T. Eiskjær, 2018. tTEM — A towed transient electromagnetic system for detailed 3D imaging of the top 70 m of the subsurface, Geophysics, E13-E22. https://doi.org/10.1190/geo2018-0355.1

4.4 Future Cropping

Period: 2015 – 2020
Funding: Innovation Fund Denmark.
Budget: 100 mill. DKK (50 mill. DKK from IFD)
Participants: SEGES, Aarhus University (AU), GEUS, Copenhagen University (KU) Novozymes, YARA, Rambøll, Ejlskov, Orbicon, FOSS, Teknologisk Institut, Agro Business Part and Agrointelli.
Website: https://futurecropping.dk/

Short description of the project
Future Cropping is a large research project financed by Innovation Fund Denmark. The overall aim of the project is to utilize the potential benefits of precision farming and data communication by integrating large amounts of data from agro- and environmental technologies with area and climate data. One of the principal aims of the project is to bring Danish agriculture closer to the shift towards a differentiated environmental regulation. The project contains nine different work packages dealing with different aspects (machinery, soil management, fertilization, microorganisms, weed, etc.). This chapter will focus only on work package nine (WP9) in the project with the title "Differentiated N-regulations and drainage filter technologies" since this is closely linked to the activities in MapField. In WP9, solutions to reduce the transport of nitrogen from field to the aquatic environment are being developed.

Main results
A redox probe for in situ measurements of the redox potential has been developed by Ejlskov in a collaboration between Future Cropping and the TReNDS project also financed by Innovation Fund Denmark. The probe provides information on the redox potential in the subsurface more cost-effectively than traditional drilling and analysis of sediment cores (Ernstsen et al. 2019). In order to secure the availability for future analysis, the developed probe can be used in a new system to update a newly developed map of the depths to the redox interface where the redox probe logs are stored in GEUS's geophysical database GERDA.

Mapping of tile drain structures has been studied using a ground penetrating radar (GPR). The study has shown that the tile drains can be mapped with variable success depending on local soil and hydrological conditions (Iversen et al. 2019). WP9 also focuses on the development of a drainage model describing the water flow to drains and groundwater on a national scale. This model integrates hydrogeological data as well as near surface properties and is supported by detailed studies of drainage dynamics in small tile drain catchments that have been monitored with respect to water discharge and nutrient transport at a field level. Detailed computer modelling has been carried out where developed pedotransfer functions have been used for the parameterization of the model (Varvaris et al. 2019a,b). In the same tile drained catchment, studies are carried out with respect to the nitrate redox dynamics in the vadose zone. An important task in the project is to test optimized drainage filter technologies. Here, monitoring is ongoing at four different tile drained catchments where constructed wetlands with filter matrices are used to mitigate nutrient losses (Skovgaard et al. 2018).

Elements important for MapField
Most elements in Future Cropping relate to MapField, however especially:

- The mapping of the depth to the redox interface.

- The mapping of the tile drain structure. Mapping tile drains with GPR is part of a PhD study where several other techniques are used. This involves drone technologies with the use of different kinds of cameras (visible, near-infrared, thermal infrared, etc.) as well as the use of a magnetometer, tMAG developed in rOPEN and MapField by Geoscience at Aarhus University.
- The study of the flow processes.
- The study of the possibilities for nitrate reduction in the vadose zone.

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4.5 GIRem

Period: 2018 – 2021
Long title: Guided Injection Remediation
Funding: Innovation Fund Denmark.
Budget: 24.2 mill. DKK (16.8 mill. DKK from IFD)
Participants: Ejlskov, Airborne Instruments and Aarhus University (AU)
Website:

Project description
The GIRem project is centered on a societal challenge as well as a business case for the company Ejlskov. Contamination with hydrocarbons, chlorinated solvents etc. pose a major threat to the environment all over the world. Well-known examples from Denmark include contaminated soil below gas stations, the waste deposits in Kærgården Klitplantage, and the factory site in Grindsted. Traditionally, excavation and off-site treatment or storage of the contaminated soil has been used for remediation, but this is costly and has a huge impact on the infrastructure, which must often be removed or shut down for extended periods. Hence there is a need for efficient on-site clean-up technology, which is applicable while the site remains in operation or with a minimum of down-time. One such method, injection remediation, is successfully used by Ejlskov. Here remediation products are injected into the soil where they break down the contaminants. Unfortunately, for the time being, the injection cannot be monitored in real time, and the remediation success is measured with follow-up studies, e.g. groundwater samples. The aim of GIRem is to develop a geophysical method based on induced polarization (IP), providing real-time monitoring of the injection. This will lead to a cost-efficient installation of the expensive remediation products and it can be ensured and documented that the entire contaminated volume has been treated.

Main results
The project started October 1, 2018 and involves two companies, Ejlskov and Airborne Instruments and two Aarhus University departments, Geoscience and Engineering. No main results have been delivered yet (May 2019). Planned main results are new multi-electrode pipes installable by direct push, a new multichannel instrument for IP measurements, automated data processing, inversion code, and visualization tools all implemented in one fast workflow. Scientifically, it is expected that the project will bring new understanding of induced polarization, e.g. models of the 3D volume effects that cause exotic, non-exponential decays in cross-borehole IP data.

Elements important for MapField
So far three potential applications of instruments or methodology developed in GIRem have been identified to be important for MapField:

- The machine learning based methods for automated data processing, e.g. noise reduction and anomaly detection
- The IP method for recording lithology to be used in geological interpretation and modelling. This is related to scenarios where it is not possible to use gamma logs to record lithological information in MapField, i.e., fragile gamma log instruments cannot be used with direct push technology. Lithological information can instead be obtained from IP data.
- The IP method for recording hydraulic conductivity to be used for hydrological modelling.

- The IP method for recording redox conditions. This is an open research question. Is it possible to infer knowledge on the redox environment in the subsurface from IP data? To answer this question, detailed studies of the correlation between redox measurements and IP data needs to be performed in a variety of redox conditions.

4.6 T-REX

Period: 2019 – 2021
Long title: Near surface redox and retention mapping for a targeted differentiated mitigation within ID15 sub-catchments
Funding: GUDP, PAF
Budget: 13.0 mill. DKK
Participants: SEGES, Aarhus University (AU) and GEUS
Website:

Short description of the project
The overall objective of T-REX is to develop new technology, mapping, and modeling tools for a differentiation of N-retention classes within ID15 sub-catchments to achieve a more targeted and cost-efficient N-mitigation strategy. The project focuses on clay till areas, where the drainage transport of N is generally dominating, and where the water table dynamics can lead to spatial and timely variations in the vadose zone N-reduction. Two clay till and drainage dominated ID15 sub-catchments, situated within the Norsminde Fjord and Horsens Fjord catchments, have been selected as study sites. Within the two ID15 sub-catchments, tile-drained field sites with variable geological, topographical, and pseudo-gley characteristics have been selected for the detailed T-REX investigations.

The specific objectives include:

- Further development of the Ejlskov redox-probe from the existing groundwater application to vadose zone application in tile-drained fields
- To combine new geophysical mapping tools and drain geometry for mapping spatial geology and water table dynamics in the upper soil profile to develop hydrological models describing climate normalized water-table, drainage discharge, and redox dynamics
- To develop an operational, scalable model for mapping spatially differentiated N-retention classes across landscape elements within ID15 sub-catchments, and demonstrate the effect and cost-efficiency of variable scenarios for a targeted, differentiated N-mitigation strategy within ID15 sub-catchments.

Main results
The project started in January 2019. The expected main results will be to develop:

- Technology and methods for mapping field-scale redox-potential in the vadose zone (0-3 m)
- Operational methods for mapping field-scale hydro- and redox-regimes and related N-retention
- Operational models for mapping spatially differentiated N-retention classes across fields and landscape elements within ID15 sub-catchments
- Develop a new optimized N-mitigation strategy targeting differentiation within ID15 sub-catchments.

Estimated effects for a differentiated targeted mitigation strategy based on the T-REX approach for representative clay till ID15 catchments will be an increased N-effect on marine N-loads from field and drainage measures. The potential N-reduction increase corresponds to >80-100% increased efficiency for field-scale N-measures such as catch crops and set-a-side, and >60-75% increased efficiency for drainage filters such as surface-flow constructed wetlands and bioreactors. The estimated economic gain depends on the type of measure, and ranges for a target area of 162.000 ha from annually 36-53 mio DKK for drainage measures up to 206-315 mio DKK for set-a-side as the most expensive N-mitigation measure.

Elements important for MapField

The following elements in T-REX can support the activities and catchment modelling in MapField:

- Water table, redox and N-reduction dynamics in the upper 0-3 m (vadose zone and shallow groundwater) in moraine clay drainage discharge dominated catchments
- Mapping differentiated N-retention across landscape elements especially including the influence of riparian lowlands intercepting tile drained uphill agricultural areas.

4.7 UN task force on reactive N

Website: http://www.clrtap-tfrn.org/

Short description of the project

The Task Force on Reactive Nitrogen (TFRN) is formed under the Working Group on Strategies and Review (WGSR) of the UNECE Convention on Long-range Transboundary Air Pollution. TFRN is led by Denmark and is co-chaired by Tommy Dalgaard (Aarhus University, Denmark), Mark Sutton (Centre for Ecology and Hydrology, United Kingdom), and Claudia Marques-dos-Santos Cordovil (University of Lisbon, Portugal).

The Task Force reports to the WGSR, holds plenary meetings at least once a year, and coordinates the work of the related expert panels (see http://www.clrtap-tfrn.org/). This includes the Expert Panel on Mitigation of Agricultural Nitrogen (EPMAN), the Expert Panel on Nitrogen Budgets (EPNB), the Expert Panel on Nitrogen and Food (EPNF), and the Expert Panel on Nitrogen in countries of Eastern Europe Central Caucasus and Asia (EPN-EECCA). These panels can meet more often than the TFRN, work on specific issues, and provide input to TFRN.

Main results

Some of the main results include the contribution to the ongoing Global Nitrogen Assessment (http://www.inms.international/), following the previous European Nitrogen Assessment from 2011 (http://www.nine-esf.org/node/204/ENA.html; e.g. Cellier et al. 2011), and national background research assessments like the Danish dNmark.org and the Portuguese NitroPortugal projects. Main results are listed in annual reports and guidance documents to the UN and international bodies, as seen in the list of references (Dalgaard et al., 2018; Dalgaard et al., 2016; Sutton et al., 2015; Oenema et a., 2014 & Cellier et al., 2011).

Elements important for MapField

Important ongoing activities in relation to the Task Force on Reactive Nitrogen, of special relevance to MapField, include:

- Contributions to the regional demo region studies under the http://www.inms.international/, and in particular the current work for The European Commission on targeted nitrogeN-regulation at the landscape scale (see Dalgaard et al. 2011, above)
- The planned international workshop on integrated sustainable nitrogen management (https://ec.europa.eu/info/events/workshop-integrated-sustainable-nitrogen-management-2019-sep-30_en), which will also refer to results from MapField.

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5. Overview of completed projects

5.1 NICA

Period: 2010 – 2014
Long title: Nitrate reduction in geologically heterogeneous catchments – a framework for assessing the scale of predictive capability of hydrological models
Funding: Danish Council for Strategic Research
Budget: 20.2 mill. DKK (14.5 mill. DKK from IFD)
Participants: GEUS, KU, AU, SEGES, Laval University, Alectia, Municipality of Aarhus, Municipality of Odder, SkyTEM and DHI.
Website: http://nitrat.dk/about_us_uk/main.html

Project description
The project title was "Nitrate reduction in geologically heterogeneous catchments – a framework for assessing the scale of predictive capability of hydrological models (NICA)". The Purpose of the project was to develop new methodologies and tools for preparing maps with a fine spatial resolution of the percentages of the nitrate leaching from the root zone that will be reduced before reaching the streams. Furthermore, the aim was to quantify the uncertainties on such maps and address the potential for using such information to the development of cost-effective strategies for spatially differentiated regulation of agricultural activities. The project ran from 2010-to 2014 with GEUS (Jens Christian Refsgaard) as project leader (Refgaard et al., 2016).

Main results
New geophysical methods
A new version of the SkyTEM system, referred to as Mini-SkyTEM or SkyTEM101 was created (Auken et al., 2014 and Schamper et al., 2014). The carrier frame was constructed with an aerodynamic profile giving a small drag in the air, thus making the system easy to fly in a nominal altitude of 30 m. SkyTEM101 was successfully tested and applied in a flight campaign over the two project areas (5 km^2 Lillebæk and 101 km^2 Norsminde catchments) in June 2011. The software for data processing was updated, and the data analyses and tests against field data showed that the data were of unprecedented high quality. The Magnetic Resonance Sounding (MRS) instrument has been tested and field measurements have been carried out in the Norsminde area. The major scientific novelty of the work has been an optimization of the data processing software, resulting in significant improvements of the signal/noise ratio and hence allowing shorter measurement periods in the field.

Heterogeneous geology and hydrological models
Based on data from existing and new boreholes drilled within the project and the comprehensive SkyTEM geophysical dataset, a total of 20 alternative geological models have been established using the geostatistical software package TProGS. The flow paths for each model were then simulated using particle tracking. We have therefore developed and tested a new concept for estimating the depth to the redox interface, based on the hypothesis that the depth to the redox interface can be explained by the oxidation of geological deposits due to transport of oxygen from the land surface since the last glaciation age.

Predictive uncertainty and spatial scale - RES

Based on the 20 geological/hydrological models and the 3 redox models a total of 60 models were established for simulation of flow paths and nitrate reduction for the western part of the Norsminde catchment. For each of the models the percentage of particles leaving each 100 m cell that passes the redox interface is calculated (Hansen et al., 2015 and He X, 2015). The uncertainties in flows and nitrate reduction at grid scale due to the geological and redox uncertainty is characterized by the standard deviation between the 60 models (Figure 3). By aggregating the simulation results to spatial units larger than the model grid (100 m) the relation between predictive uncertainty and spatial scale is assessed (Figure 3). The value of the SkyTEM data for reducing the prediction uncertainties are clearly seen on both figures. If policy makers can specify an acceptable level of prediction uncertainty, Figure 3 tells the minimum scale at which the model potentially has predictive capability. This new methodology is denoted the RES (representative elementary scale) concept.

Economic aspects, agricultural regulation, and water management strategies

Economic calculations for 10 farmers in the Norsminde catchment show that there would be an economic gain if the regulation could be spatially differentiated and farmers allowed to make use of the information in maps like Figure 3a. This economic gain comes from utilizing spatial differences in nature's own nitrate reduction. In the project, the new estimations have been translated into nitrate reductions for each field. The analysis shows a gain of 100 DKK per ha based on targeted measures and current N-norms, but the gains are higher if optimal N-application is allowed or if the N-reduction target is higher and the targeting is combined with new measures such as mini-wetlands (Jacobsen and Hansen, 2016). The findings also suggest that not all farmers can use these options for more targeting due to crop rotations etc. The analysis of carrying out the NICA exercise is estimated to be an investment of around 400-800 DKK/ha or roughly 50-70 DKK/ha/year.

If the regulation is based on reduction maps that show average values for larger areas (e.g. ID15 catchments of 1500 ha), the economic gain will be less that in the NICA mapping showing differences at ha scale (Figure 1). On the other hand, the uncertainties at 100 m scale (Figure 2) is very large and will be reduced significantly by aggregating results to e.g. 500 m (25 ha) scale or more. This dilemma, which is a key issue in developing water management strategies, cannot be adequately evaluated without involving local farmers and other relevant stakeholders.

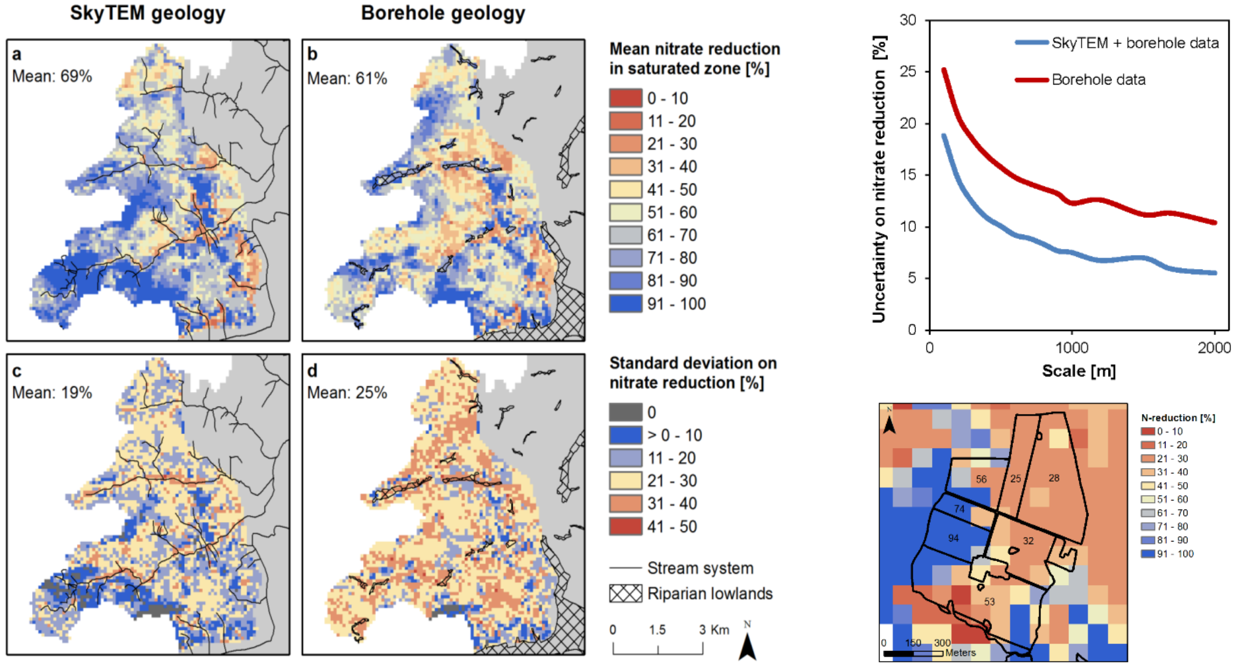

Figure 3. Left side figures: Spatially distributed average nitrate reduction potential and associated uncertainty. (a) Average nitrate reduction for SkyTEM geologies; (b) average nitrate reduction for borehole geologies, (c) and (d) standard deviations for nitrate reduction for the SkyTEM and borehole geologies, respectively. Right side upper figure: Uncertainty on percentage nitrate reduction as a function of the length scale at which the results are aggregated before standard deviations are calculated. Right side lower figure: The retention for a case farm divided into fields.

Elements important for MapField

NICA was the first project providing knowledge for targeted regulation of agriculture, and many of the achievements have been carried on and further developed in subsequent projects. Some of the important elements for MapField are:

- Geophysical mapping of the subsurface together with borehole data can provide information to reduce uncertainty in groundwater modelling
- Understanding the importance of knowledge on spatial variation in the redox conditions for N-retention modelling
- Production of N-retention maps as a useful tool for communication with farmers and authorities on targeting mitigation measures. This has also highlighted the variation in adaptability between farmers as well as a focus on the costs of producing the maps compared to both the economic gain for the farmer and the increased knowledge, which the maps have produced.
- For the approach to be developed, the process from mapping to production of retention maps must be faster and cheaper. Also, the approach must be able to deal with a large variation in local conditions. Therefore the next steps in both rOPEN and MapField are to gain more experience with both more precise and faster mapping technologies.

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5.2 HyGEM

Period: 2012 – 2016
Long title: Integrating geophysics, geology, and hydrology for improved groundwater and environmental management
Funding: Danish Council for Strategic Research
Budget: 28 mill. DKK (15.4 mill. DKK from IFD)
Participants: AU, GEUS, Aarhus Geophysics, SkyTEM, Alectia, Aarhus Vand, DTU, CSIRO, TNO & USGS.
Website: http://hgg.au.dk/projects/past-projects/hygem-2016/project-description/

Short description of the project
In HyGEM the purpose was to create tools for improved groundwater resource management. This was done by construction of hydrological models for knowledge-based groundwater resource management through direct and automatic integration of spatially dense geophysical and sparse geological and hydrological data.

The research included:
1. Development of automatic methods for parameterization of a hydrological model based on geophysical, geological, and hydrogeological data;
2. Use of statistical methods to describe the correlation between the geophysical data and lithological/hydrological data and to assess the uncertainties from the automatic methods;
3. Demonstrating the benefits of spatially distributed geophysical data for improving groundwater models in terms of their increased predictive power and ability to represent the natural system at levels not achievable by other methods.

The results were anticipated to have a significant scientific and societal impact. Better management of groundwater resources is of major interest to society, and model-based decision support for groundwater resources management is a critical need. The development and application of the individual elements will bring substantial insight into integration (particularly automatic integration) of large geophysical datasets into groundwater models. The outcome will be of high value to Danish end-users (municipalities, regions, consultants) as well as a valuable export article in the form of superior expertise in the industry

Main results
The main results of HyGEM was a hydrological modelling concept allowing for incorporation of very detailed geophysical model information and calculation of hydrological prediction uncertainties. The geophysical results were a new electromagnetic SkyTEM system with calculation of early time primary response allowing for a hitherto unseen resolution of the shallow geological layers. This was accompanied by a new data processing and inversion algorithm. The geophysical models were translated into hydrostratigraphical models by transforming them into clay fractions followed by a clustering into 3 – 5 units. Multiple point statistics were then used to create multiple realizations of the hydrostratigraphical models allowing for calculation of prediction uncertainty. In addition, a large effort was spent on calculation of data worth, i.e. which data are most important for the prediction parameters.

Elements important for MapField

The research in HyGEM was essential for both rOPEN and MapField in many ways:

- HyGEM convinced us that it is both possible and necessary to use high resolution geophysical data in order to calculate realistic uncertainties on N-retention. Because the ambition has been to be able to predict on the hectare scale in rOPEN/MapField, it was also clear that sufficiently detailed images of the subsurface could only be obtained by a scaled down version of the technique behind SkyTEM, namely what has become tTEM. Development of the tTEM system involved electronics, hardware, and an efficient data interpretation environment.
- HyGEM showed that the hydrological modelling environment had to be automated in order to calculate retention uncertainties where hundreds of realizations of the hydrostratigraphical and redox models are simulated. This has resulted in a lengthy development of a Python scripting environment, allowing for automated executing of hundreds of realizations of the hydrological model. The usage of geostatistical methods like multiple points statistic and training images has proven to be invaluable for the rOPEN and MapField modelling concepts.

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5.3 TReNDS

Period: 2015 – 2018
Long title: Transport and Reduction of Nitrate in Danish landscapes at various Scales
Funding: Innovation Fund Denmark
Budget: 20.2 mill. DKK (15 mill. DKK from IFD)
Participants: GEUS, KU, AU, SEGES, Ejlskov, Sorbisense, Rambøll, Laval University, US Depart. of Agriculture, University of Melbourne, Illinois University, Odder Municipality & Danish Nature Agency.
Website: http://trends.nitrat.dk/about_us_uk/main.html

Short description of the project
The overall objective of TReNDS has been to improve our understanding and to develop the scientific foundation, field technologies, and modelling concepts for cost-effective quantitative assessments of nitrate transformation in various landscapes to support the implementation of a spatially differentiated regulation and locally based solutions. This has been realized through a set of specific objectives: 1) improving the detection and understanding of the impact of drainage systems on nitrate transport for different hydrogeological settings, 2) improving the understanding of the source-sink functioning of riparian lowland as hydrobiogeochemical transformation zones, 3) developing and testing a tool for local scale measurements of the redox conditions and develop a methodology for establishing a high resolution map of the redox interface, 4) developing upscale approaches for utilizing local scale processes in catchment and national scale hydrological modelling, 5) developing new management concepts with improved engagement of local stakeholders and utilizing local data and knowledge. The means to achieve TReNDs objectives have been detailed field studies combined with detailed and catchment scale modelling.

Main results
Nitrate reduction in anoxic environments in the subsurface is responsible for the vast majority of the nitrate being naturally reduced. Thus, knowledge on the redox conditions in the subsurface is vital, as these can be spatially very variable. A redox probe was developed by Ejlskov in TReNDS by which the subsurface redox conditions can be obtained much faster and cheaper than with traditional drilling. In order to fully utilize these data at a national scale, a new methodology to estimate the depth to the upper redox interface was developed, and a new national map of this interface produced. Subsurface reduction only occurs if nitrate is transported to the reduced conditions, and not transported directly to the surface water system by drains, where reduction is generally very limited or absent. Quantifying drain flow is thus vital in assessing nitrate reduction, which at the same time is extremely variable from field to field. Using drain data from TReNDS and related studies in catchment scale modelling, clearly illustrated that quantifying the drain flow is a standing challenge, and that the challenge of representing this in catchment scale models is even larger. Detailed studies in TReNDS lowlands demonstrated that these areas can act as both N sinks and sources, which confirmed previous studies that a key factor in understanding the function of these systems is an understanding of the various flow paths in the lowland areas, which are very complex. Quantifying transport and reduction in these areas can have profound effect on the total reduction associated with uphill fields, as nitrate may leach from the field, but later be captured and reduced in the lowland during transport.

Elements important for MapField

Many elements of the TReNDS project are important for MapField:

- The redox probe developed in TReNDS and Future Cropping is a powerful instrument for screening the redox conditions in the subsurface.
- Understanding the split between drain flow and water infiltrating the groundwater is extremely challenging, but vital in estimating the nitrate reduction.
- It is important that an integrated approach is taken when estimating the nitrate reduction, i.e. accounting for the entire transport pathway to the final recipients, as nitrate leaching from a field may be reduced along the transport path, e.g. in riparian lowlands.

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5.4 Epione

Period: 2013 – 2017
Long title: Natural sensory feedback for phantom limb modulation and therapy
Funding: EU FP-7-HEALTH
Budget: 8.022 mill. EURO
Participants: 12 partners from Europe and the US **i**nvolving clinical, industrial and academic institutions
Website: https://cordis.europa.eu/project/rcn/109345/factsheet/en

Short description of the project
Epione aimed at the development of innovative solutions and technologies for the treatment of phantom limb pain.

The herein described work package focused on the question "*How is it possible to make money from the technological solutions and related IP generated through the EPIONE project?"* (Nielsen et al., 2017a, p. 3). Thereby, it addressed the objective of identifying the innovation and exploitation possibilities for EPIONE's technologies. As described in Nielsen et al. (2017a), this specific work package was articulated in sequentially articulated steps, starting with a thorough mapping of the potential competitive landscape to understand the industrial setting in which the developed technologies would eventually be deployed.

The following step focused on the intellectual property (IP) created in EPIONE and on evaluating the technologies' and solutions' potential value for end-users and customers as well as potential corporate stakeholders. The work package accompanied the clinical development since its early stages in the project, and the insights about possible models for the exploitation were fed back into the actual clinical developments in several iterations, e.g. during the project's status meetings.

Main results
The later phases of this work package were eventually focused on the business model (BM) configurations applied by competing companies and from there to identify potential business models and their underlying value drivers for the exploitation of EPIONE's technologies. In concrete terms, 80 companies have been identified in the industry landscape mapping, and their specific business model configurations have been derived using an innovative data capturing methodology as described in Montemari et al. (2017 and 2019).
This data analysis constituted the basis for identifying potential innovation routes and the profiled similarities and deviations of these configurations were discussed in the light of BM innovation as opposed to BM imitation strategies (Montemari et al., 2019).
The results were presented in the form of three concrete exploitation strategies and a preliminary outline of the steps required for their implementation (Nielsen et al., 2017a).
Besides the previously mentioned articles, the results of the analysis have also formed the empirical base of another conference article attempting to construct BM configuration specific key performance indicators (Thomson et al., 2017).

Elements important for MapField

The EPIONE project provided relevant background and potential insights/lessons learned on the exploitation and dissemination strategy of MapField as well as an appropriate methodological toolbox, which encompasses the following:

- A mind map approach for structuring a competitive landscape (described in Nielsen et al., 2017a) combined with a project-specific value proposition canvas approach;
- Validation of potentially relevant data capturing methodology, based on a questionnaire-based mapping tool (Nielsen et al., 2017b) built on the business model taxonomy developed in Taran et al. (2016), to identify appropriate and relevant business model configuration strongholds and their respective value drivers.

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