Interreg North Sea
Co-funded by the European Union
Blue Transition

Blue Transition

How to make my region climate resilient

MIDTERM REPORT

SEPTEMBER 2024

Foreword

The impact of climate change is a pressing issue that poses significant challenges to various aspects of our environment, economy, and society as a whole. One of the critical areas affected is ground water resources. These are indispensable for drinking water, agricultural irrigation, and maintaining natural ecosystems. Alterations in precipitation patterns and the increased frequency of extreme weather events can disrupt the natural recharge of groundwater reserves, leading to potential shortages and affecting water quality.

Agriculture, a cornerstone of human existence and economic activity, is particularly vulnerable. Climate change can cause shifts in growing seasons and intensify drought conditions. These changes can threaten food security and livelihoods, necessitating the development of adaptive strategies and resilient agricultural practices. Moreover, nature reserves - vital for preserving biodiversity and ecosystem services - face significant stress due to climate change. Rising temperatures, changing precipitation pattern and cultivated land use changes can lead to habitat loss and fragmentation, endangering many plant and animal species.

Land use plays a crucial part in this complex interaction. Urbanization, deforestation, and agricultural expansion can exacerbate the impacts of climate change on groundwater, agriculture, and natural habitats. Effective land use planning and sustainable management practices are essential to mitigate these adverse effects and promote environmental resilience.

Overarching European policies play a vital role when dealing with the above. However, convinced that we need to start with place-based solutions, and then create a (transnational) setting to facilitate upscaling innovative solutions. This is central to the Blue Transition project which now reaches all across the North-Sea-Region - from Sweden to south of France.

Blue Transition targets a systemic change, by integrating water and soil management to better adapt to climate change, securing and improving groundwater resources. We aim to ensure the future availability of good-quality water while helping to revitalise natural habitats and reduce CO_2 emissions.

With this brochure, we want to share our progress, and the current status of all our pilots. This includes an overview of the methods applied, the results already achieved and the road ahead.

We hope you enjoy the read!

The Blue Transition Partnership

Summary

The Blue Transition project is set up with 16 pilots. Each of these pilots connect gathering new knowledge (e.g. through geophysical measures and modelling or mapping), with practical application, such as testing field measures or developing short- and long-term strategies. We develop transnational solutions for water boards, farmers, authorities and citizens to enable land-use change in urban areas, forests, farming land, wetlands, peatlands and nature protected areas.

The Blue Transition pilots are structured around three central types of landscapes. However, an important aspect of the project is the consideration of the interaction between these landscapes and their correlation to climate change.

- Urbanisation is a major development in coastal areas worldwide. In four pilots we deal with vulnerable dune areas and sustainable land-use, improving rainwater infiltration, developing protection against heat and floods, understanding the interaction between lakes and groundwater and supporting the development of a green economy park.
- It appears that secure food production is difficult in combination with the preservation of soil, groundwater and natural areas. In six pilots we deal with rewetting peat land to reduce carbon emissions, humus oriented organic farming, balanced groundwater extraction for irrigation, salinization and fresh-water conservation and land-use conflicts.
- Protecting natural areas to preserve biodiversity, their ecological state and ecosystem performance is a central target from many perspectives. In five other pilots we deal with rewetting of peatlands, finding a compromise between groundwater use for municipalities or agricultural purposes and natural areas, and understanding the impact of land-use change for lake water.

Blue Transition started in October 2022, and we are now half way through our project. We have acquired a huge amount of new data, reviewed existing data and tested innovate techniques and measures ranging from geophysical surveys and hydrological measurements to the installation of new weirs. Building models and simulating scenarios is currently an important task in most pilots - early results are already available In parallel and closely related to the context of data and governance in each pilot or region, the consortium is developing strategies where the pilots' water balance is central, to create climate adaptation measures using water and soil as guiding principles.

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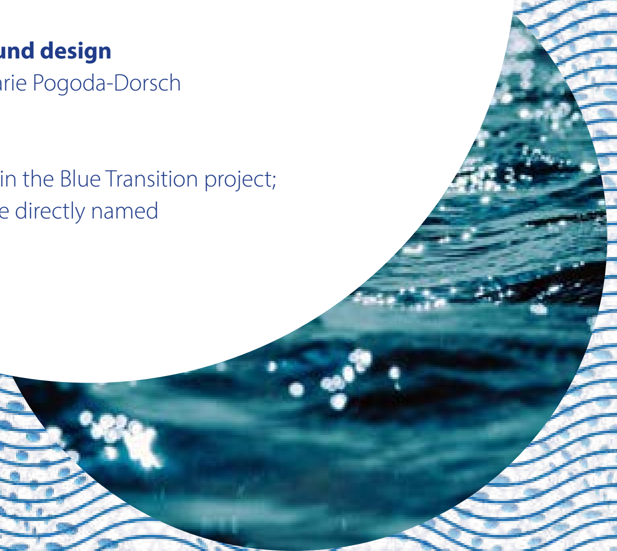


Content

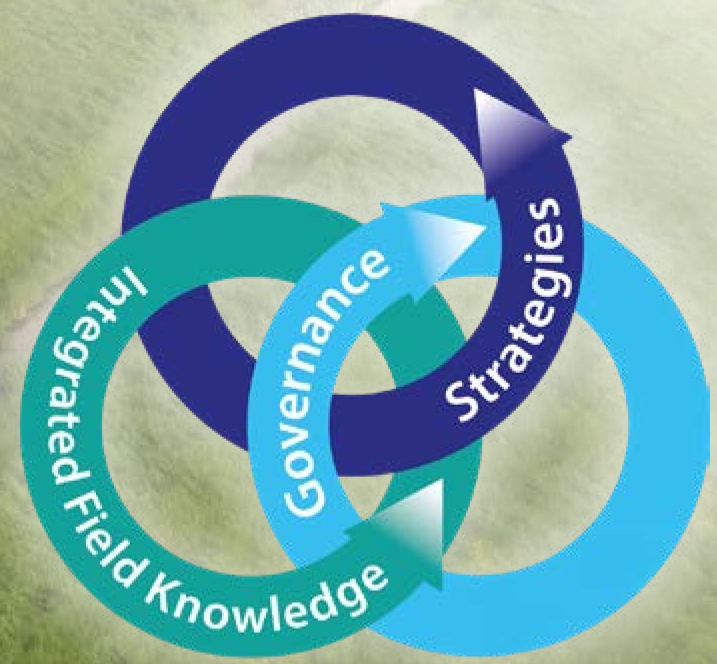
Our Approach

Picture taken by Daan Stemgée ©

Our approach: to gain integrated field knowledge, learn on governance structures and develop strategies to implement and upscale our results.

Why do we connect field knowledge and governance?

Successful short and long-term strategies are implemented only if they foster integration of technical expertise and societal needs and context. Adaptation to climate change is not only fact based but always needs to balance different interests and needs: How can we protect nature, groundwater and local farming?
Why is this important in comparison to local health services or business parks?
Policy makers have to integrate diverse goals. They can only consider new insights on groundwater and soil if they can accommodate them in their governance context.

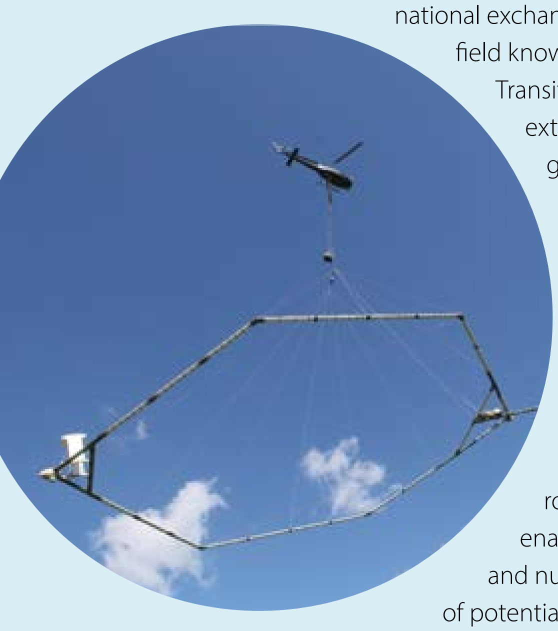


Integrated field knowledge – data, modelling and measurement technologies

Objective: New integrated field knowledge is developed with available and new data and models to foster transition in land-use towards integrated, balanced activities in urban, agricultural or natural areas.

Activities

We use geophysical data, (simulation) models, and innovative techniques for monitoring and intensive transnational exchange to develop new field knowledge. As part of Blue Transition available data is extended by new data generated by innovative geophysical mapping techniques on the ground and airborne, drilling, direct-push methods and (ground) water sampling. All data feeds into hydrological models that enable scenario analyses and numerical assessments of potential measures. Using dedicated workshops (online and during partner meetings), we discuss shared challenges, such as best practice and suitability of different methods or modelling practice (e.g. model uncertainties or long-term analyses). Special focus is kept on the different landscapes. As a result, a report will summarise the new integrated field knowledge reports for each pilot and landscape.



What have we achieved so far

Internal workshop on data and model demand: Right at the start, Blue Transition partners discussed in an internal workshop the variety of demands for data as well the various tools used for modelling. This exchange resulted in comprehensive knowledge of the available broad expertise within the group. Partners created transnational plans for joint fieldwork. In particular, the geophysical groups at Aarhus University and LIAG closely share expertise when conducting novel NMR measurements.

Internal online peer-reviews: In addition to the half-yearly partner meetings, we have organised in Blue Transition additional online exchange to enable quick feedback and sufficient time to introduce novel methods and ongoing developments. We meet in between every partner meeting to discuss current datasets and development and to coordinate joint activities.

Datasets: In the last two years Blue Transition partners have conducted various field campaigns to collect the necessary data.

This includes

- Geophysics: more than 7 km of seismics, SkyTEM, 20 km^2 of tTEM + sTEM, 10 km of floatTEM, 10 km of ERT, 25 ha of GPR, 70 surface NMR soundings
- Drillings and sampling: shallow drillings were conducted and groundwater monitoring wells (DK1, DK3, NL1, NL4) are installed and in particular borehole measurements (e.g. logging-NMR) were conducted. Soil samples were taken and analysed in the labs
- Monitoring: loggers were installed in five sites (DK1, DK3, NL1, NL4, FR1) and geophysical monitoring has been set up at two sites (SE2, FR1)
- Environmental monitoring: fDOM, TOC, PFAS, Temperature, etc (SE1, FR1?)
- Models: Essential part to developing strategies that enable a climate resilient future is a hydrological model and the simulation of climate scenarios. Within Blue Transition, hydrological models have already been set-up (10), this is to be finished soon (DK1, DK2, DK3, GE1, GE2, GE4, NL1, NL3, NL4, FR1).

Challenges

Climate change is not only affecting our groundwater and soil, it is also affecting our data acquisition. The wet and rainy winter/spring 2024 made access to fields almost impossible. As data is based on building prediction for the future some of the measurements were postponed and thus modelling is delayed.

Engaging with stakeholders and ensuring their involvement is crucial, but it requires significant time and trust-building. Setting up monitoring stations in areas with multiple landowners is particularly challenging and time-consuming. Additionally, initial technical issues when using new methodologies and instruments often take more time to resolve than initially anticipated.

Another challenge is data sharing. Aggregating all theoretically available data from various open-source databases is difficult due to different data formats. Furthermore, essential information, such as water usage data for hydrogeological modelling, is unexpectedly unavailable in some areas and must be gathered through time-intensive surveys.

Strategies towards climate resilient land use

Objective: Strategies, goals and measures are developed and tested to achieve a long-term and short-term climate resilient transition in land use, incorporating field knowledge and governance structures

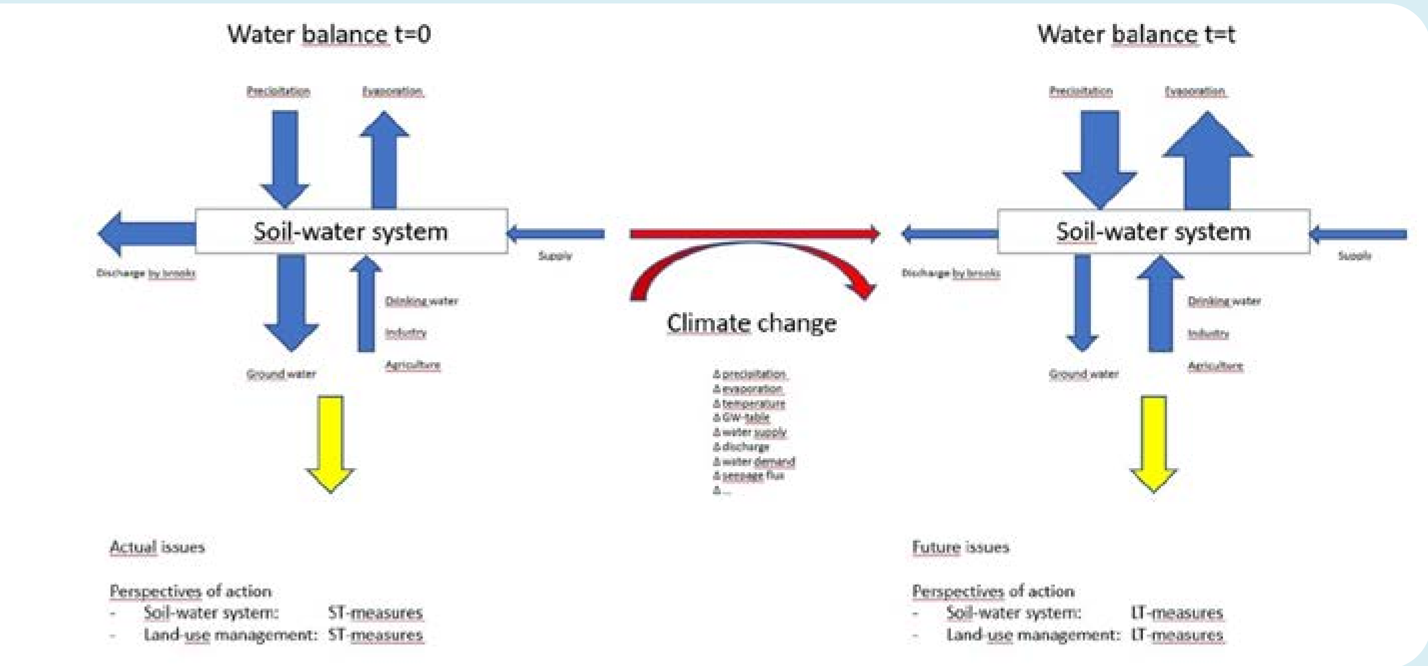
Activities

Climate resilient land use is about developing and testing local strategies, goals and measures for climate-proof land use, both in the short and long term. A supported view by the different stakeholders in an area is crucial in this respect. Therefore, the impact of climate change and possible measures are discussed with stakeholders in the different pilot areas, using knowledge of the subsurface and the influence of water management on land use functions. Three types of landscapes are distinguished in this process – agricultural land, natural areas and urban land - where the connection and influence on the environment is taken into account. The aim is to arrive at a short- and/or long-term strategy for each pilot and describe the influences on existing user functions.

What have we achieved so far

As a first step, we discussed in a transnational meeting, whether using the water balance, as a tool will lead to a better understanding of the effects of climate change and the possible effects of interventions. This resulted in a roadmap to increase insights consisting of:

- A detailed water balance with a high resolution of the growing season, focussed on the issues per pilot
- Impact climate change on water balance
- Perspectives to change the elements of the water balance by adapting hydrological and/or land management measures at distinctive steps
- Effectiveness of measures over a period of time
- Organizing the steps to develop a strategy in a coherent timeline



Schematic approach of the role of the water balances of the soil and water system to define short term and long term measures as function of climate change

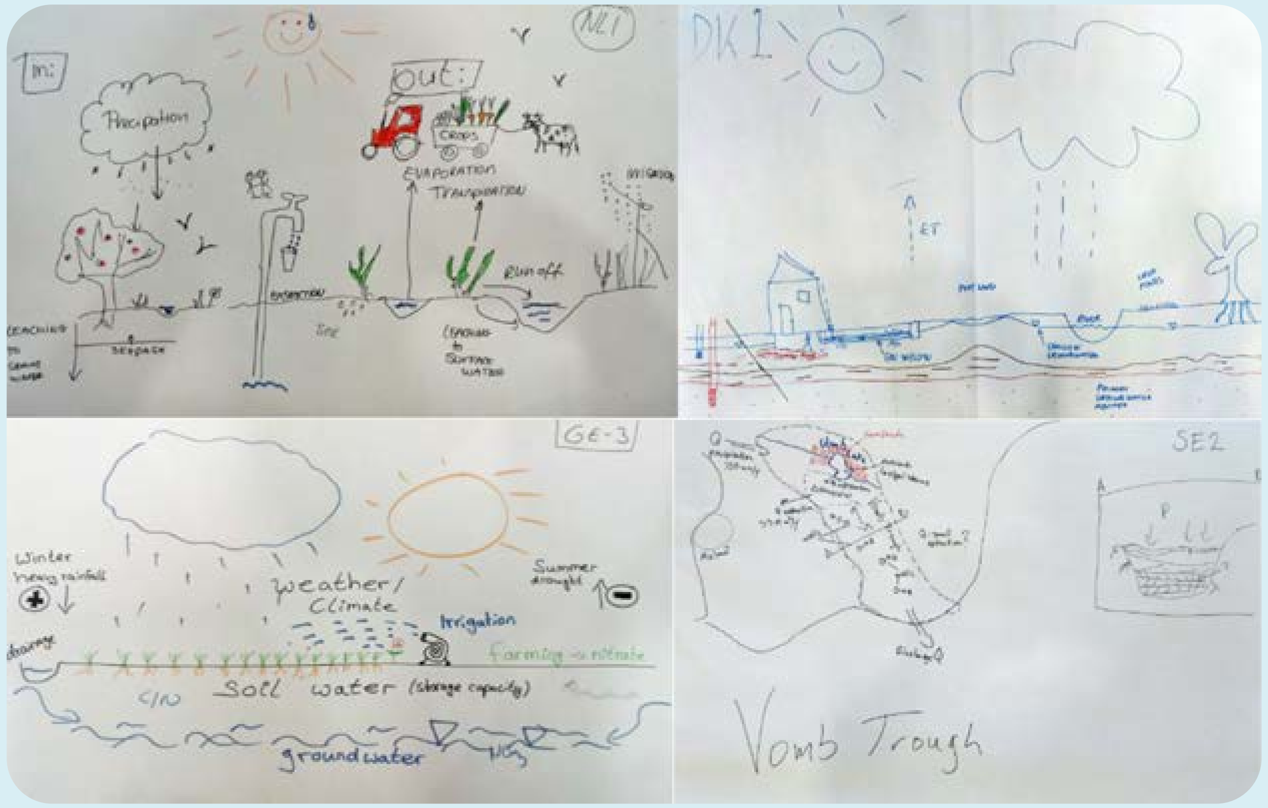
OUR APPROACH

In the various pilot areas, the effects of climate change and possible measures are being discussed with stakeholders. A number of measures have already been tested or they are currently under investigation. However, they are evaluated not just for effectiveness but also for user support.

During the partner meeting in Horsens, Denmark, the water balance concept was introduced and the case study leaders sketched the water balances for their individual pilot. During this session, partners also discussed the use of water balance as vehicle to structure the strategy.

As a follow-up, various approaches to design a long-term strategy were discussed during the partner meeting in Drenthe, The Netherlands. As a result, the concept of 'letting water and soil guide the development of climate adaptation measures' was highlighted at different levels and from different points of view. At the policy event with regional politicians and national policy advisers and stakeholders, for example, it became evident that making decisions for the long term is still a long way off. The threats are clear but the consequences for existing land use are still difficult to translate into actual measures or intentions.

Together with Wageningen University, we translated 'water and soil as a guiding principal for future strategies' into a European perspective, zooming in on the various regions. Below are some of these future perspectives, visualizing the potential impacts of a long-term strategy.

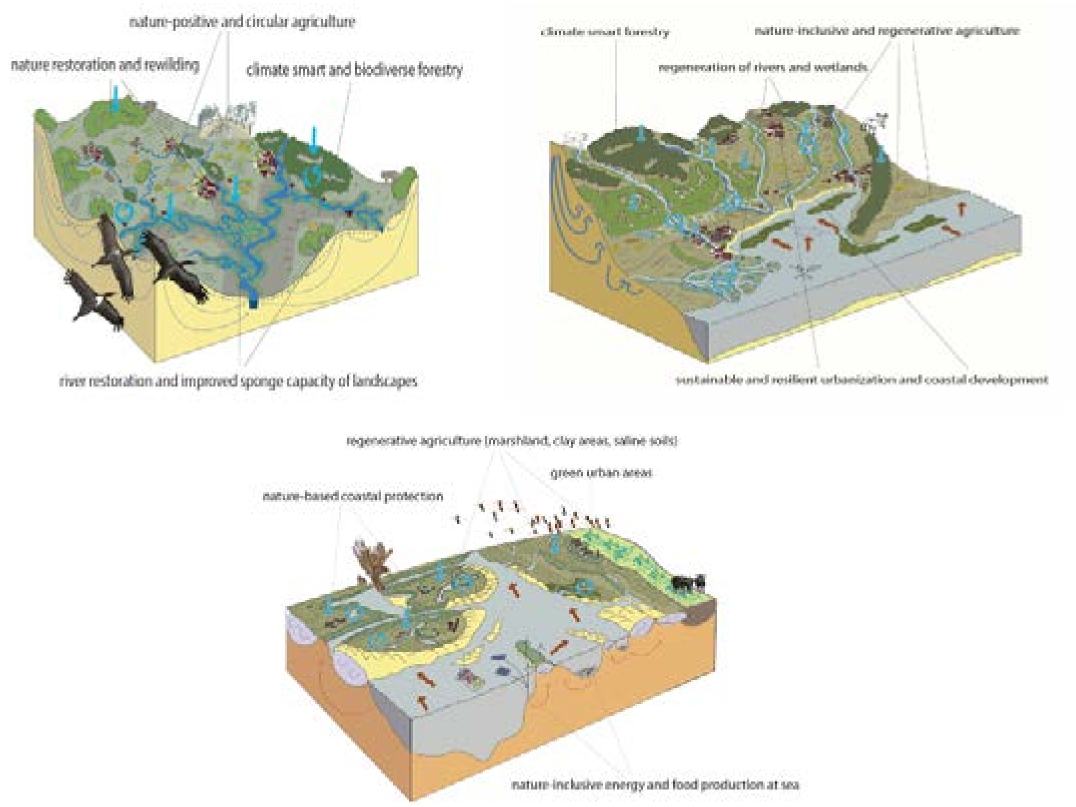


Impression of the drawn water balances

OUR APPROACH

Challenges

The main challenge is to translate an initial short-term vision into an enduring one that also involves a shift in land use. This requires administrative, decision-making courage, together with a long-term perspective. At the upcoming partner meetings, the Blue Transition consortium will discuss how to proceed towards a future-proof vision that allows for climate change.

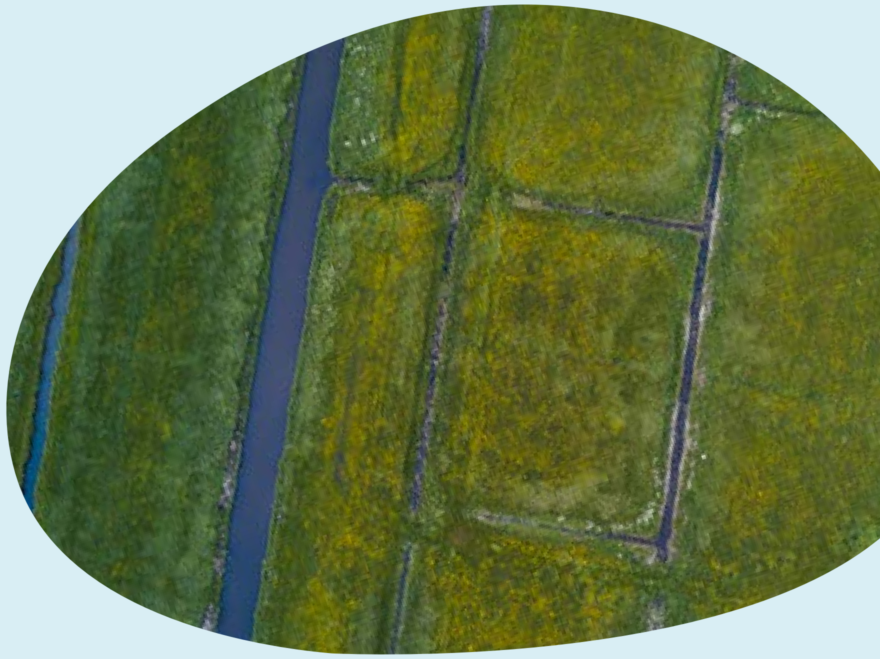


Future perspectives North Sea Region (picture from: "Imaging a nature –based future for Europe in 2120", Wageningen University & Research)

OUR APPROACH

Governance and Capacity building

Objective of WP3: Transnational exchange and learning on governance structures is achieved which foster the implementation of solutions for land use transition strategies for urban, agricultural or natural areas.



How can the solutions be most effective for local groundwater and land management?

Next to innovative measuring and modelling activities on groundwater, soils, and their complex connections, we fully appreciate that climate change adaptation is not only about understanding complex data and identifying technical solutions. Our solutions will only be implemented if they comply with the governance context, such as policy and administrational processes are successfully integrated. Thus, we relate our studies to current governance challenges and involve relevant stakeholders and decision makers to make project results more applicable and targeted for local water managers.

To build the capacity of our partners in dealing with these issues on governance, we dedicate a major part of the transnational partner meetings towards learning on governance structures and challenges in the form of simulations/trainings on stakeholder involvement and World Café setting e.g. to reflect on developing successful strategies. At the Kick-off meeting (Feb. 2023) partners identified shared governance issues and prioritized the collected topics to select workshop themes. In two partner meetings in Denmark and The Netherlands (2023/2024), we worked on stakeholder involvement and shaping the strategy for further uptake after the project.

This contributes to a successful implementation of the pilot level activities related to stakeholder involvement such as a stakeholder workshop to discuss our new data in all pilots and, at a later stage, another workshop in each pilot to foster support for new solutions for climate change adaptation.

Fostering European learning, we arrange "policy events" at each project partner meeting, to raise awareness for climate adapted water and soil management and invite regional policy makers and address their issues. In autumn 2024 in France, we start the process of shaping transnational issues and identifying lessons relevant for the European level. Until the end of the project, we will synthesize insights from all pilot and transnational activities in the form of two strategies to:

1. better link climate change adaptation into European Directives and a climate resilient soil- and groundwater management in the North Sea Region.

2. improve capacity building for future water/soil managers building on lessons learnt from the BT "summer" schools. This will strengthen the regional/local benefits on the project results.

Capacity building for (future) water managers

Building capacity in our partnership, we set up technical workshops dedicated to issues related to geophysics or modelling. Workshops have also been arranged on strategy development and governance issues in combined sessions to make sure that their projects address and are related to local governance challenges. Our governance workshops have included a training on connective negotiation, and a serious game on stakeholder negotiation in urban development that have been requested by the partnership to learn about new approaches for stakeholder involvement.

In addition, we involve future water managers in four "summer schools". These summer schools aim to provide additional training to students and young professionals to expand their experience toward better integration of soil and groundwater in climate change adaptation. They include training on geophysical methods but also interdisciplinary approaches (see table below).

	TOPIC / Approach	Participants	When (Approx)
Sweden (LU, SGU)	"Water from Source to Tap ensuring the health of water bodies. Why is this important?"	**About 20 international students**	**2-3 days in Spring 2025, linked to partner meeting**
Germany (GDfB)	"A Mini Blue Transition"- morning with input, afternoon with practical field work, excursions and modelling exercise. All BT issues (data, modelling, governance/strategy) are present.	**About 30 local students**	**One week in Spring 2025**
The Netherlands (Hunze en Aas /PD)	NL1/ Drenth'sche Aa: "Maintaining Crops/ Improving Land Use Practices". NL3/ Veenkolonien, similar but with Wageningen University Students	**About 3*5 Dutch students learning and young professionals**	**Parallel learning process, started early 2024, until end of 2024**
Denmark (AU)	Geophysics: applied field methods, link to BT via pilot (same methods)	**10-24 international students enrolled in AU**	**8-12th April 2024 (5 days)**

How can the relevant solutions and strategies get the required attention at European and other policy levels?

We are convinced that many of our solutions can be relevant to other regions, or could be up-scaled.

As described above we involve and interact with policy and decision makers both at pilot and at project level to make our work known and more relevant for solving current needs and challenges, and to ensure applicability of the project results. At this point partners and project communicate mainly via LinkedIn, and we attend several conferences and networking opportunities where we present Blue Transition work.

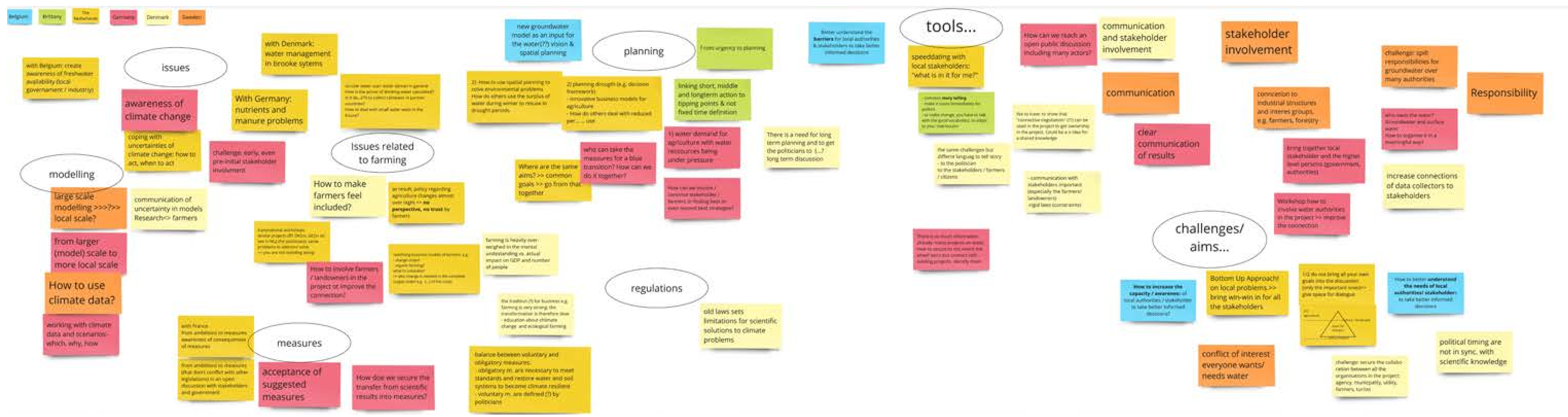
One central activity will also be our final event in Brussels (March 2026) during which we will not only show our results from the pilots but also provide strategies and policy recommendations on how to improve soil- and groundwater management, and how to achieve a "blue transition" for the North Sea Region.

What have we achieved so far/ Highlights

- Identification of project relevant governance issues
- Governance Workshop with Training in Connective Negotiation (Partner Meeting Horsens)
- Governance Workshop with Training in Climate Resilient Urban planning with a serious game approach

Challenges

At this point in the project, most partners are busy with generating new data and knowledge to inform stakeholders at a later point on climate adaptation opportunities. The different character of governance and technical processes poses challenges to some of the pilots- how to deal with important but not interested stakeholders, how to communicate that the focus of the results may not reflect the recently changed priority of the stakeholders? Our results compete for attention with many other relevant projects. We will further strengthen our communication efforts both in the pilots and at project level, and we have to continue integrating governance and technical aspects of our work.



Our Pilots

The 16 pilots share transnational issues to link climate change mitigation with adaptation for groundwater and soil management and integrates different land-scapes to foster a climate resilient North-Sea-Region.

The following table gives an overview of shared issues and landscapes in the respective pilots.

No	Pilots Short Name	Focus on climate change regarding …			Focus on changes in …		
		Mitigation (7*)	Adaptation for GW/Soil Management		urban area (5*)	agriculture/ forestry (10*)	nature/ forests/ peatlands (14*)
			Quantity (15*)	Quality (14*)			
BE1	Urbanized Dunes		x	x	x		x
BE2	Meirdam Urban Wetlands	x	x	x	x		x
DK1	Aabenraa/ Bylderup-Bov		x	x	x		x
DK2	Åstrup kær	x	x	x		x	x
DK3	Island Endelave		x	x		x	x
FR1	Guidel Compromise		x	x			x
GE1	Luneplate	x	x	x	x		x
GE2	Geest Adaptation	x	x				x
GE3	Humus		x	x		x	
GE4	Waterfarmers		x			x	x
NL1	Climate Proof Drenthe Aa		x	x		x	x
NL2	Polder Flushing		x	x		x	
NL3	Climate Proof Veenkolonien	x	x	x		x	x
NL4	Freshwaterconservation		x	x		x	x
SE1	Bolmen Brownification	x		x		x	x
SE2	Vomb Trough System	x	x	x	x	x	x

BlueTransition links climate change mitigation with adaptation for groundwater / soil management and integrates different landscapes to foster a climate resilient North Sea Region. The table below provides an overview on which pilots addresses which issue and what the character of the study/management area is.

Changes in urban area

Urbanisation is a major development in coastal areas worldwide.

On the one hand it impacts on our freshwater and soils resources while on the other hand urban areas are impacted by climate change and sea-level rise.

In four pilots we deal with vulnerable dune areas and sustainable land-use, improving rainwater infiltration, developing protection against heat and floods, understanding the interaction between lakes and groundwater and supporting the development of a green economy park.

Foto: Pixabay, Janos Bencs

OUR PILOTS

BE1 Urbanized Dunes

Focus on

- **Changes in Urban Areas**
- Changes in Agricultural Areas
- Changes in Natural Areas

Dealing with

- **Water balance**
- **Water quality**
- **Land-Use**

Management of fresh groundwater in an urbanised dune area under a changing climate

Coastal dune areas have multiple functions: they protect the low-lying polder area against flooding and salinisation, offer touristic and ecological values and are an important freshwater resource for drinking water supply. The coastal dune area in Belgium is highly urbanised which has led to a decrease in natural groundwater recharge and an increase in groundwater extraction. In addition, climate change and sea level rise threaten the availability of freshwater in these areas.

To protect these freshwater resources, understanding the impact of urbanisation, climate change and sea level rise is necessary. Groundwater modelling can predict the evolution of the fresh-salt water distribution and indicate which part of the dune area is more vulnerable to urbanization, climate change and/or sea level rise.

Together with stakeholders, the potential of different measures will be investigated. The project will lead to a cooperative and sustainable management of freshwater resources in the dune area.

Our strategy to foster a Blue Transition

The results of the groundwater modelling will indicate which part of the coast is more vulnerable to urbanization, climate change and sea level rise. We will investigate which measures can lead to a sustainable management of freshwater resources. Possible solutions are protection of open space, a sustainable transition in land-use, improvement of rainwater infiltration and proper management of groundwater extraction. This will also impact the future water balance and lead to a better protection from salinisation.

These measures should be implemented by local and regional authorities, spatial planning authorities, water and coastal managers. Main barriers are the limited physical space in the coastal zone, the process of innovation adoption, social acceptability of land-use change, authorisation procedures and agreements between stakeholders. All necessary stakeholders will be involved by workshops and meetings.

What we achieved so far

We informed our stakeholders about the Blue Transition project during a stakeholder consultation. This helped us to define the main needs and to dampen the expectations of the participants about the modelling. Next step was a market consultation by written and oral consultation. This gave us an idea of new developments, the model framework needed, the feasibility of the project and the possible risks. All these steps were key elements to prepare the necessary documents for the public procurement.

What is to be done

We will start up the public procurement for the modelling and field work. Stakeholders will be involved during this process.

Impression of the stakeholder meeting

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Johan Lermytte, Flanders Environment Agency (j.lermytte@vmm.be)

BE2 URBAN WETLANDS

Focus on
- **Changes in Urban Areas**
- **Changes in Agricultural Areas**
- Changes in Natural Areas

Dealing with
- **Water balance**
- **Water quality**
- Land-Use

Drought and flood mitigation by restoring the water buffering capacity of an urban wetland

Next to the city of Dendermonde lies Meirdam, a historic meander of the river Scheldt, right at its confluence with the river Dender. Meirdam is a polder with mostly wet meadows interspersed with forested patches. A pumping unit and drainage ditches have been keeping the land artificially dry for agriculture (hay meadows) and houses, thereby damaging wetland habitats and undoing their water buffering function. Effects of climate change have become increasingly tangible with more frequent and longer droughts and, conversely, regular floods affecting the Dender valley. Moreover, due to drought-induced ground water level decreases, a shallow peat layer risks degradation, reverting from carbon sink to source. In collaboration with partners and stakeholders Natuurpunt aims to restore natural water levels to boost resilience to climate change. Controlled increase of water levels by e.g. installing weirs could buffer an additional 30 million litres of water per year and renders the ecosystem less drought-sensitive. Agriculture will benefit from amongst others improved water quality and hay for cattle. Restoring ecohydrological values will make the urban environment more liveable through drought, heat and flood protection, support recreation and bring nature closer to people.

Our strategy to foster a Blue Transition

The philosophy of removing water to make Meirdam useful is deeply ingrained in current management practices. Given the issues of flooding and the old pumping unit, elevated water levels are met with panic, so it takes patience to maintain a constructive dialogue with all stakeholders. This is enhanced thanks to dedicated local partners that help push a more sustainable agenda. All stakeholders have been offered an opportunity to be involved from the beginning of the project. Natuurpunt (pilot lead) is joined by the city of Dendermonde, the province of Oost-Vlaanderen, the Flemish Agency for Nature & Forests, regional water managers ("Polderbestuur"), the University of Antwerp (Curieuzeneuzen, ECOPLAN model), Eurosite – European Land Conservation Network, local and regional businesses working on sustainability, office for Regional Landscape Schelde-Durme, volunteers and local residents. Stakeholders are actively involved through group meetings, in targeted field visits, or ad hoc in case of technical support. [STEP1] A sound scientific basis is built for identifying the most effective, safe and desirable interventions to improve water balance and quality [external study with input from partner discussions on which scenarios must be studied]. [STEP2] Partners and stakeholders together define which targets and actions are to be prioritised during meetings, and those actions are executed by the most appropriate partner. During this phase, we must anticipate (often long) waiting periods during the administrative process for e.g. obtaining permits. [STEP3] Results are reported to a broader audience using various channels, and follow-up plans are developed for upscaling efforts. For instance, regional action plans in the Scheldt and Dender basins are solidifying to restore natural flooding zones, thereby attenuating flooding risks in sensitive zones downstream. At a national level, the Meirdam project can be used as leverage for these initiatives, as well as benefit from their implementation. At international level, the INTERREG umbrella provides a framework for collaboration and exchange of knowledge/best practices,

What we achieved so far

- An ecohydrological study for Meirdam has been finalised (26/02/2024), which provides crucial support to motivate which actions are needed [STEP1].
- A monitoring system has been set up with 11 wells with divers in Meirdam, previously controlled by the province but now updated, managed and analysed by Natuurpunt. This will allow us to closely follow the changes in water levels resulting from planned hydrological interventions [STEP1], facilitate adaptive management [STEP3] and support reporting [STEP3].
- The University of Antwerp (Prof. Jan Staes) provided analyses on ecosystem services (ECOPLAN) from restoring wetland habitats in Meirdam [STEP1]. Also, potential gains in water storage have been modelled based on different restoration scenarios (Sumaqua) [STEP1]. These quantitative estimates of restoration benefits can be used when informing a broader audience and (potential additional) partners [STEP3].
- The INTERREG framework created opportunities to attract additional financial support. Funding has been obtained from Google (for i.a. hydrological restoration works). A subsidy application has been submitted to the Flemish government in anticipation of the hydrological restoration works (April 2024) [STEP2/3].
- Results of the ecohydrological study were shared and discussed with stakeholders during a constructive meeting (3/06/2024). The most urgent action agreed upon during the meeting is the installation of weirs at specific locations [STEP2].

Digital elevation model

What is to be done

- Drawing up the action plan and course of the strategy [OVERARCHING PROJECT GOAL].
- Permit application for placing weirs is in progress [STEP2], installation planned by end of 2024.
- Broad information session with local residents prior to installation of weirs [STEP2].
- The functioning of the pumping unit relies on regular repairs and one shutter continues to leak. This situation is not tenable but renewing the pumps will take several years. Although its replacement is not a direct objective in this pilot, its context has an important effect on the sense of safety of residents and on the accuracy with which overall water levels can be managed. Hydrological restoration success thus relies on informing and involving all stakeholders during the process. The situation is an opportunity as well, however, to learn from the system's response to more irregular fluctuations in water levels [STEP1/2].
- Water level agreements are to be negotiated for Meirdam. As a basis for negotiations, we will use the recommendations from the ecohydrological study and data from the water level monitoring system. Similarly, sewage works are necessary to improve water quality [STEP3].
- Upscaling of efforts and strategies, where Meirdam is taken as an example for related wetland restoration projects under the framework of related incentives from Natuurpunt, different organisation levels of the government and other partners/stakeholders [STEP3].

Pictures taken by Daan Stemgée ©

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DK1 Aabenraa city and town of Bylderup-Bov

Focus on

- **Changes in Urban Areas**
- **Changes in Agricultural Areas**
- Changes in Natural Areas

Dealing with

- **Water balance**
- **Water quality**
- **Land-Use**

Climate-hydrological models for flood and contamination protection in the urban area

DK1 focuses on developing a holistic approach in climate adaptation projects using groundwater modelling for the entire water catchment in order to achieve the most optimal solution. Climate changes, such as increased precipitation, flooding and rising groundwater level affect the water cycle. The pilot area Bylderup-Bov is especially vulnerable with its originally extremely high groundwater level. Episodes with inundated basements and overloaded local sewage systems are frequently occurring. In the Aabenraa city pilot there is an additional risk of affecting the groundwater flow at contaminated sites.

Many factors affecting the water cycle demand a holistic approach in climate adaptation, and therefore it is essential that an integrated water management is based on modelling that includes all elements of the water cycle. This approach requires modelling within the entire water catchment area. In both pilot areas, one of the solution is change of land use. Nature based solutions (NBS) as climate actions adds extra value: increased biodiversity and recreation. Conversion of e.g. agricultural areas back to its previous natural state can play a substantial role because the retention of water upstream can prevent fast drainage to downstream areas. NBS can also with success be applied in urban areas of Aabenraa city. Inviting the water into the city and creating blue-green areas mitigates flooding and generates recreational areas, which positively effects mental health.

Seismic measurements in the Bylderup-Bov pilot.

Information meeting for citizens in Bylderup-Bov.

Our strategy to foster a Blue Transition

Holistic approach means that all elements of water cycle determining water transport are taken into account: geology, hydrology, climate and land use. Holistic approach means also that all authorities must cooperate and supplement their data and competences in terms of achieving the common goal. The goal which is better water management and the most optimal and robust solution in climate adaptation strategy. The approach is to be implemented by municipalities and waste-water companies.

The challenge in water management in DK are the regulations, as they treat each element of the water cycle separately and refer to different authorities. That's why the cooperation is so important. Our partners AU Geoscience, LIAG and GEUS are research institutions who have the expertise on fieldwork and modelling, Central Denmark Region cooperates about socio-economic assessments and Aabenraa Municipality, together with waste-water company ARWOS, deals with the climate challenge in the pilot areas.

What we achieved so far

- An information meeting for the citizens and farmers in Bylderup-Bov took place.
- Several geophysical methods have been applied in order to improve the knowledge about the underground in the pilot.
  - Seismic measurements: ~7 km profile (5,5 km in Bylderup-Bov and 1,4 km in Aabenraa)
  - tTEM measurements: ~837 ha (792 ha in Bylderup-Bov and 45 ha in Aabenraa)
- Shallow boreholes have been drilled: 14 boreholes (5 in Bylderup-Bov and 9 in Aabenraa)
- IoT sensors have been Installed: 12 sensors (5 in Bylderup-Bov and 7 in Aabenraa)
- The existing water infrastructure, which can affect groundwater flow has been investigated

What is to be done

In the forthcoming period the rest of tTEM measurements in Bylderup-Bov (~110 ha) will be conducted. The hydrostratigraphic 3D model will be developed and made ready for the groundwater model and climate scenarios. We will arrange a second information meeting for the citizens in the pilot area and share the preliminary results with them. Furthermore, the assessment of the socio-economic impact of the nature-based solutions on the agricultural and urban areas will be developed.

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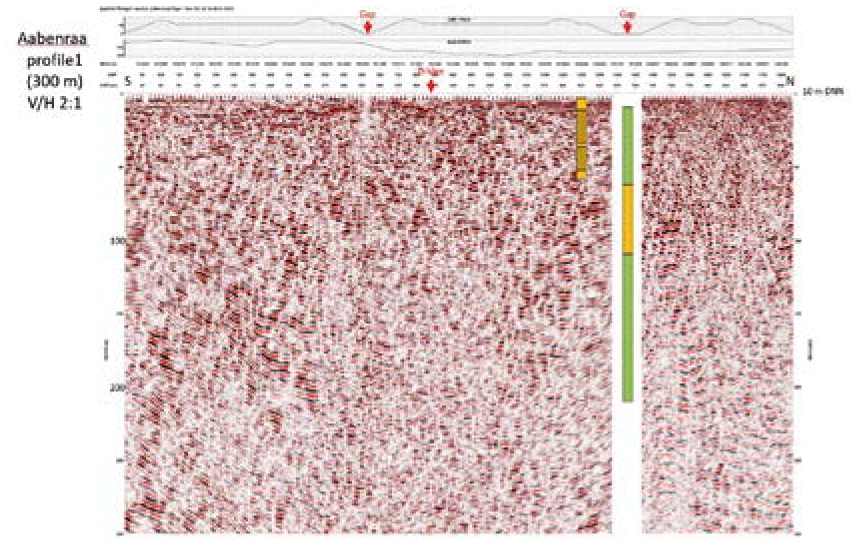
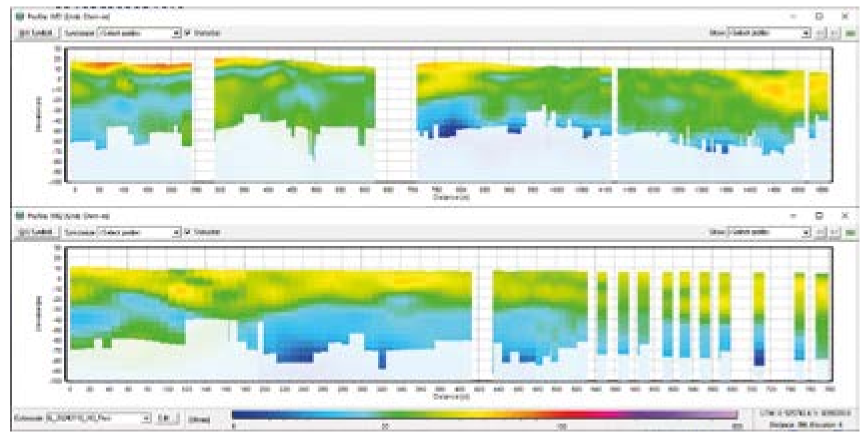
Seismic measurements in the Bylderup-Bov pilotv.



Preliminary results of seismic measurements in Aabenraa..



Preliminary results of tTEM measurements in Aabenraa.

IoT-sensor installed in Bylderup-Bov area

GE1 Luneplate

Focus on
- **Changes in Urban Areas**
- Changes in Agricultural Areas
- **Changes in Natural Areas**

Dealing with
- **Water balance**
- Water quality
- **Land-Use**

Climate adapted water management to prevent saltwater intrusion and dessication of organic loam with the associated CO_2 submission at the Luneplate

The Luneplate in southern Bremerhaven hast been proved within TOPSOIL to be the most sensitive area of Bremerhaven with respect to saltwater intrusion. In the nature protected area with an organic rich alluvial loam extensive farming takes place. In the northern part an area of economic activities is located.

Soon this will be expanded by a green business park with a climate-neutral approach. This gives the opportunity to join the challenges of climate change for both areas. The focus will be on water management and the use of excess rainwater (more intense rain events are predicted) to prevent saltwater intrusion. Measures (rainwater infiltration / storage for irrigation) will be simulated in a model and their effects measured by permanent groundwater monitoring wells and geoelectrical methods where possible.

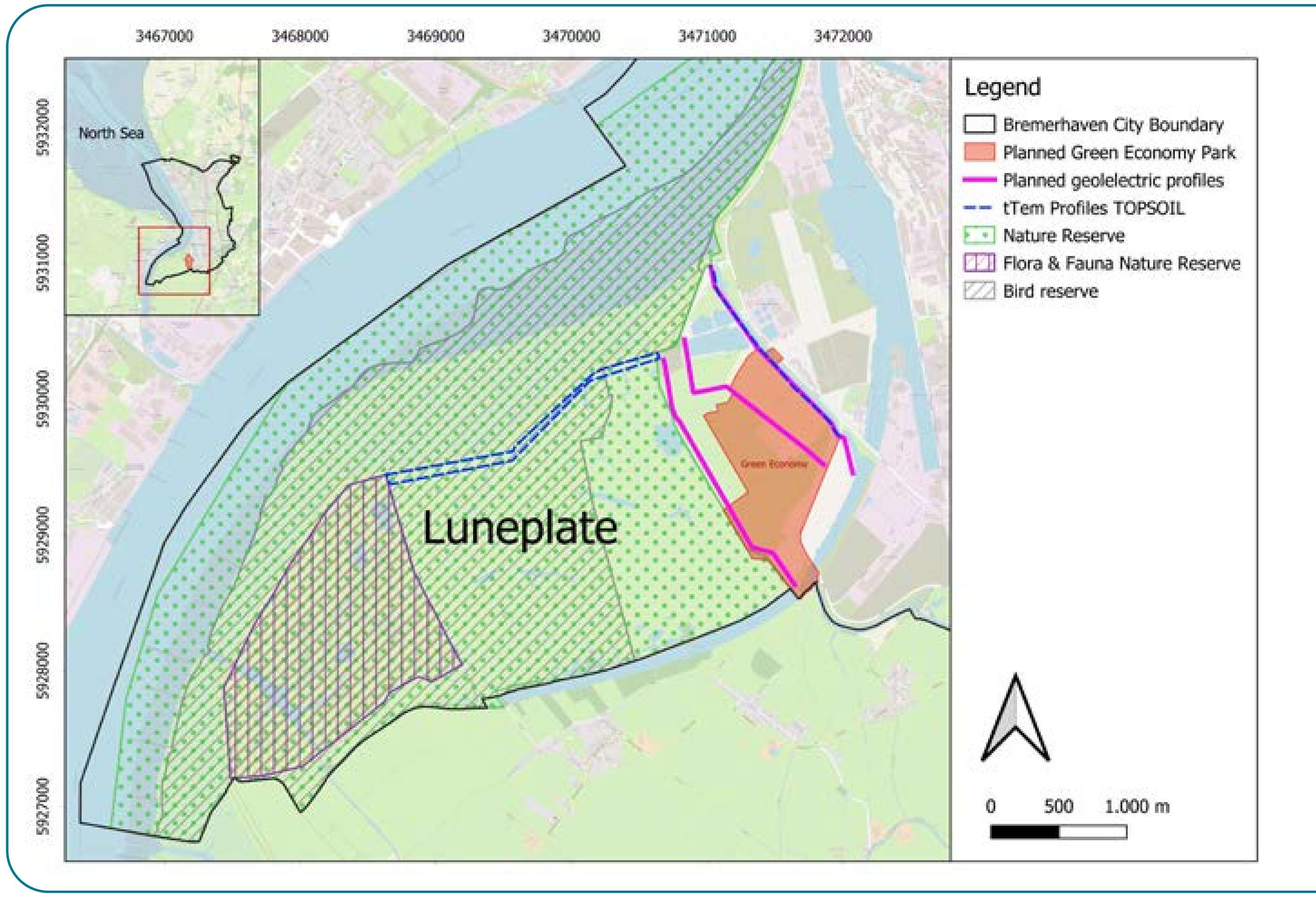
Our strategy to foster a Blue Transition

Our strategy for a blue transition is to enrich the groundwater supply. The focus of the project activities here is on water management and the use of additional rainwater to reduce the further progression of saltwater intrusion into the aquifer and the drying out of the organic-rich clay and the associated CO_2 emissions.

In order to see effects on the salt-freshwater interface, we measure salinization on three profiles once or twice a year using electrical resistivity tomography (ERT) measurements with our project partner Leibniz Institute for Applied Geophysics (LIAG) from Hanover.

We are also in contact with the Bremerhaven Society for Investment Promotion and Urban Development (BIS), which is building the industry park. They are also interested in sustainability and want to create a dedicated water cycle for the park, so there is a lot of potential for symbiosis with our project. One Strategy for effective ground water management could be the installation of infiltration wells.

We are in regular contact with our stakeholders and partners to plan various things and move the project forward.



What we achieved so far

- We learned new and effective way to infiltrate rainwater through "Düsen-Saug-Infiltration" by Hölscher Wasserbau
- After one test measurement day (Nov 23) to get to know the ERT (electrical resistivity tomography) measurements, we did two successful days (Apr 24) of measurements to get information's about the underground
- Building a strategy plan to manage all tasks in the right order
- Started planning a summer school

What is to be done

- Regular ERT measurements (monitoring the salt-water-freshwater interface)
- Plan next stakeholder meeting
- Create a plan with BIS for a sustainable water circle
- Start implementing the new ERT data together for 3-dimensional underground model, which will be the basis for the groundwater flow model

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SE2 Vomb Trough water resources

Focus on

- **Changes in Urban Areas**
- Changes in Agricultural Areas
- **Changes in Natural Areas**

Dealing with

- **Water balance**
- **Water quality**
- Land-Use

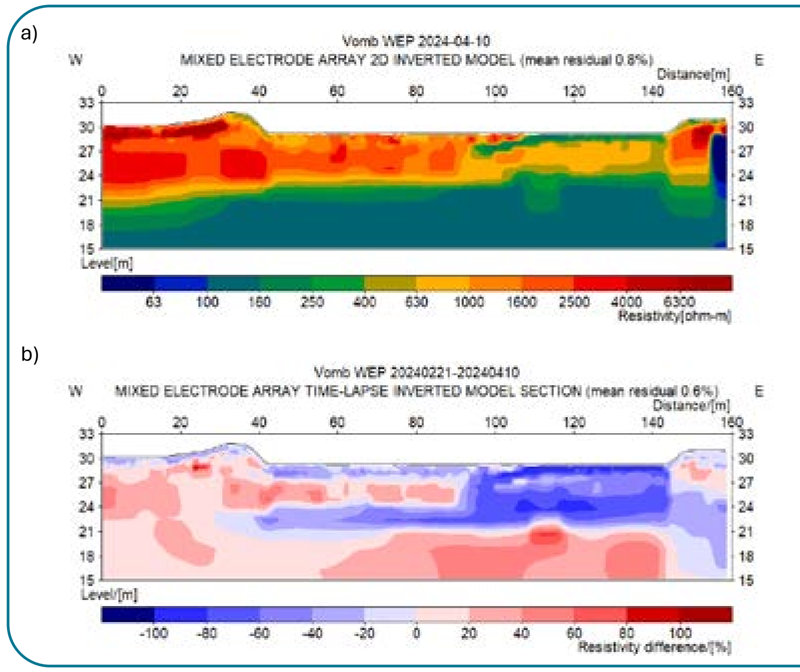
Optimization of infiltration for nature and drinking water

Facing future scenarios of climate change, the southern Sweden area will likely be challenged with droughts, heavy rain events and temperature extremes in the upcoming years. The Vomb Trough constitutes an important groundwater reservoir and is one of the largest aquifers in Southern Sweden. The Vomb Trough also includes valuable wetlands and lakes, including the Klingavälsån Valley and Lake Vomb. Possible increasing surface and groundwater extraction in combination with climate changes will likely have an impact on the water supply, biosphere and the biodiversity of the region.

The project aims to enhance the understanding of the hydrogeological connections between the Vomb area's aquifers, wetlands, and lakes. It seeks to improve the processes of artificial infiltration and groundwater extraction in the managed aquifer recharge (MAR) plant. Additionally, the project aims to develop a conceptual model and establish a water budget to manage resources more effectively.

Installation of electrode spreads for geoelectrical monitoring intended to give an increased understanding of the processes below the water-filled infiltration pond. In the picture we see personnel from Engineering Geology, Lund University, deploying electrodes and cables in a trench that was backfilled afterwards.

Example results from the west-east line through the infiltration pond from 2024-04-10; a) resistivity, and b) change in resistivity relative background measurement.



Our strategy to foster a Blue Transition

A better understanding of the water resources of the Vomb Trough will allow to manage it in a long-term sustainable way. The locally available water resources will be augmented by water from Bolmen, and the pilot provides a baseline for how to balance it. By monitoring a MAR infiltration pond, we will achieve better understanding of the processes and how to optimise these for increasing demands.

What we achieved so far

- Background hydrogeological data were collected and will be used to create a hydrogeological conceptual model of the Vomb Trough with focus on the area around Vomb.
- A monitoring system that is acquiring daily geoelectrical tomography data along 3 transects was installed in a MAR infiltration pond in the Vomb water works plant.
- Hydrogeological properties such as hydraulic conductivities were estimated from the sieve and sedimentation analysis conducted on soil samples collected in and around the infiltration pond during the installations of the monitoring system. We have observed changes in the water spread area's groundwater level, resistivity, and chargeability.
- We conducted GPR data collection covering pond area before and after the water inflow. This revealed a clear groundwater level and a washed sand layer with intermediate soil layers in the unsaturated zone. Additionally, water conductivity and temperature sensors have been installed near the pond inlet, and we plan to install soil moisture sensors soon.

What is to be done

- IP lab measurements and validations of the hydrogeological parameters
- We will achieve results showing water quality improvements during the early stages of groundwater infiltration.
- Effects of groundwater mounding will be measured and visualized, aiding infiltration pond management for increased groundwater quantity.
- The results from the pilot will change existing management strategies and the monitoring of the pond will actively be used for groundwater quality and quantity optimization.
- Continuation of monitoring of the infiltration pond for long term development and seasonal variation.
- Evaluation of infiltration pond management strategies after the whole management cycle of the pond is complete; maturation, water production increase and decrease (pond clogging).
- Development, adaptation and implementation of infiltration pond management strategies based on the pilot results.

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Changes in agricultural area

Foto: Pixabay, NickyPe

Securing food production while preserving soil, groundwater and natural areas in times of climate change appears to be a difficult task.

Agricultural land-use demands healthy soils and sufficient amounts of water thus; it is affected, among others, by droughts and salinization of groundwater. On the other hand, it impacts as a changing factor on landscapes, soil use and groundwater resources that can be in conflict with demands of natural protected areas or tourism.

In six pilots we deal with rewetting peat land to reduce carbon emission, humus oriented organic farming, balanced groundwater extraction for irrigation, salinization and fresh-water conservation and land-use conflicts.

DK2 Åstrup kær

Focus on
- Changes in Urban Areas
- **Changes in Agricultural Areas**
- Changes in Natural Areas

Dealing with
- **Water balance**
- Water quality
- Land-Use

Multifunctional land use and carbon sinks in peats soils

The objective of the Danish pilot, DK2 Åstrup kær is to examine how rewetting of peat soils affects emission of Green House Gasses (GHG) and land subsidence.

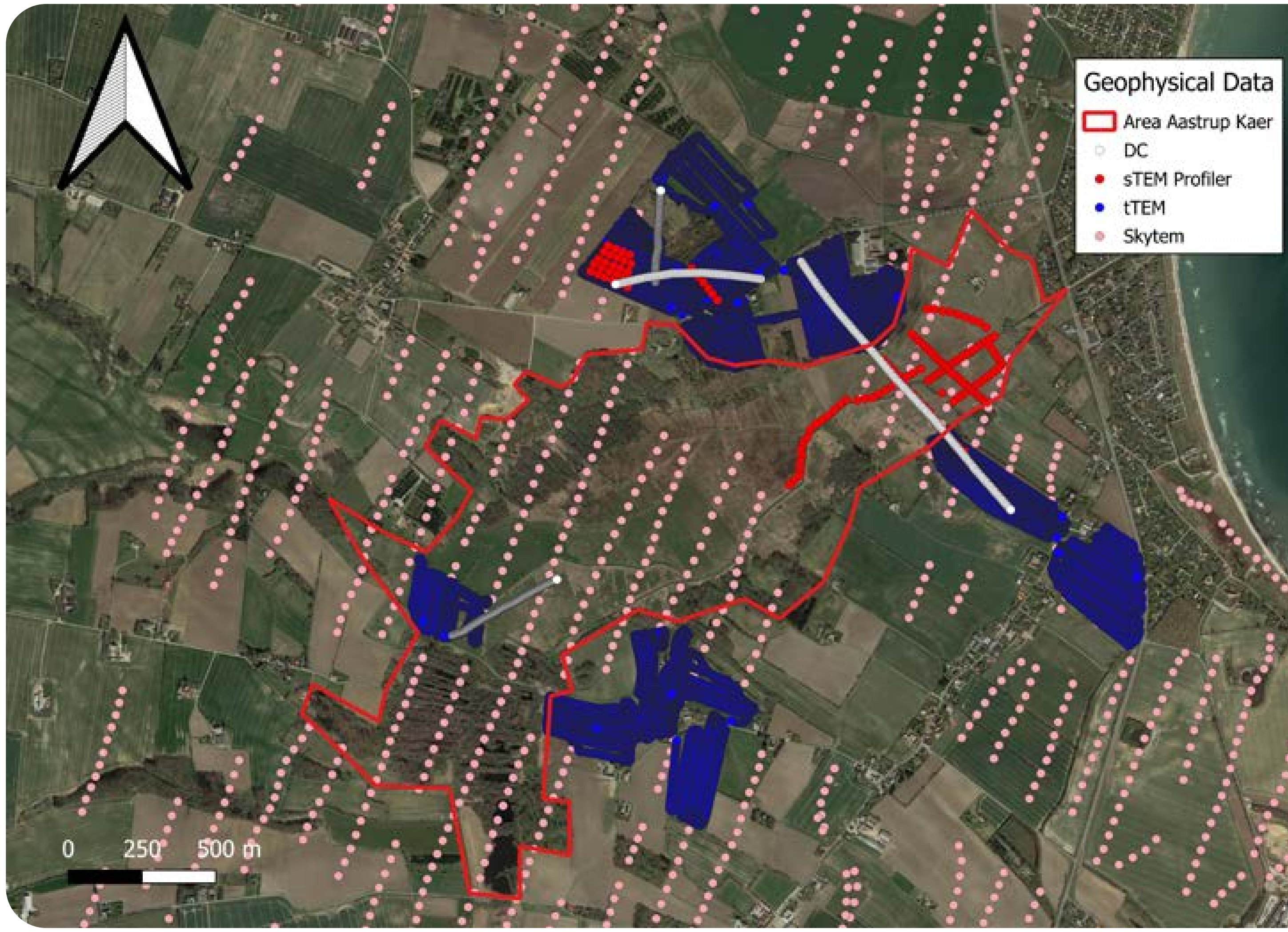
In Denmark the National Nature Agency (NNA) is currently working on a national initiative about rewetting peat soils to reduce GHG emissions. Most peat lands are placed in low lying areas that have previously been used for agriculture and intensively drained as they are exposed to climate change and flooding. But there is a huge potential in rewetting these areas and converting them into natural areas as GHG emissions could be reduced and buffer zones for the increasing precipitation could be created. However, there is very limited knowledge about how much emissions are reduced through this initiative and how it affects land subsidence. This will be investigated in the pilot area of Åstrup kær which has been chosen as it is one of the project areas of the national initiative and project results from DK2 can thus be directly shared with NNA and the initiative.

Kick-off Bachelor project for VIA's Climate and Supply engineering education (May 8th, 2024)

In DK2 Aarhus University (AU) is responsible for geological modelling of the area to obtain knowledge about the underground. VIA University College (VIA UC) measures and models how CO_2 concentrations in the area vary according to different climatic parameters. Together this can be used to model how rewetting of peat soils can affect GHG emissions. Furthermore, Central Denmark Region (CDR) examines how legal barriers related to nature protection challenges rewetting projects and how this can be handled, as most peat lands in Denmark are protected by different legislation e.g. §3 that prohibits changes in the natural conditions.

All project activities are coordinated with Hedensted municipality (HM) that is the local authority in the area and NNA.

OUR PILOTS



Overview of geophysical data collected in the pilot area.

Our strategy to foster a Blue Transition

Through the DK2 pilot new knowledge will be developed which can be used for future rewetting projects and assist project coordinators from e.g. local and national authorities in the planning process and will benefit the national initiative of reducing GHG emissions from peat soils and contribute to improved water management in Åstrup kær. Results from DK2 will include indications about how much emission of GHG can be reduced and information about how climatic factors such as temperature, humidity, water content and soil types influence on this. Furthermore, knowledge about how nature protection legislation such as §3 protection affects rewetting projects and how this can be handled will also be provided.

The project is conducted in collaboration with the local authority, HM and the NNA who is the lead on the national rewetting project to align project results to the existing projects and authority needs.

OUR PILOTS

What we achieved so far

- Geophysical methods have been applied in the study site in order to map the hydrogeological setting. Special interest is buried valleys and the thickness of the peat layer
  - tTEM (3.730 measurements),
  - sTEM Profiler (4169 measurements),
  - 4 ERT lines of 400 to 1.200 m length has been conducted by AU.
- Collected combinations of various geophysical mapping techniques have been used and correlated to derive existence of a buried valley, and currently we are looking into developing peat thicknesses maps (AU).
- A summer school was conducted from 8-12th of April where 11 students participated in the course on geophysical methods and the students gained insight in the aim and issues of the Aastrup Kær pilot area (AU).
- VIA UC has successfully selected, tested, and installed all IoT loggers at Åstrup Kær, marking the commencement of data collection.
- VIA UC have conducted three field trips for site inspection, equipment maintenance, and plant investigation.
- In collaboration with VIA's climate and supply engineering, BT has initiated a bachelor project that will delve into the soil and water chemistry at the site, aiming to enhance our understanding of the potential for CO_2 reduction at Åstrup Kær.

What is to be done

In the upcoming period VIA UC will focus on identifying the most suitable AI model for this study. We will also be collecting field samples of soil, water, and plants, and streamlining our data sources to optimize our modelling practices.

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tTEM data collection in the study site.

Logger installation in the lab, at VIA test site and extrem weather testing (October-December 2023)

GE3 HUMUS

Focus on

- Changes in Urban Areas
- Changes in Agricultural Areas
- Changes in Natural Areas

Dealing with

- Water balance
- Water quality
- Land-Use

Humus oriented organic farm management to foster climate change adapted soil management in North-western Germany

Humus in soil is crucial for soil fertility, to fix nutrients in the root zone and for storing carbon dioxide. Climate change with rising temperatures threatens current C stocks. The aim of this pilot is to investigate climate change adapted soil management options to foster humus-build up in arable soils currently poor in humus in Northwestern Germany, comparing conventional and organic farming.

This pilot focusses on improving climate change adapted soil management, i.e. fostering water storage capacity and improving water quality. We analyze processes in the humus/organic carbon content in soil to better understand impacts of crop rotation and humus on soil productivity and nutrient fixation, and to provide climate change mitigation options. We communicate results to the agricultural community to activate the potential of transferring best soil management practices.

Location of study area in Lower saxony, Germany.

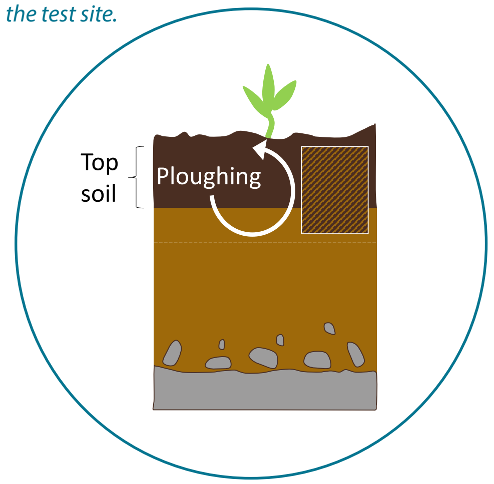
The results of conducted strip experiments on trials in the pilot as well as numerically simulated scenarios will lead to a strengthening of management capacities of land owners and farmers to improve soil and water quality.

Our strategy to foster a Blue Transition

OOWV has a long history of cooperation with farmers in drinking water protection areas. This helped to identify farmers that implement the testing measures on their fields. Contact with farmers is mainly established via a water protection consultancy, which supports the project as an external expert. The field trials were started in fall 2024. These activities are complemented by SVAT (Soil-Vegetation-Atmosphere-Transfer)-modeling by BGR, allowing for obtaining process knowledge on carbon and nitrogen dynamics, as well as on soil water budget and crop yield developments in reaction to choices in management practices and changes in climate. With this, scenario-based simulations are used to assess agricultural management options for farmers of building up permanent humus in soils whilst controlling mineralization to limit nitrate leaching. Options include a one-time increase of ploughing depth and adaptation of crop rotations/management practices, and the investigation of C and N development for future climate scenarios.

In November 2023 OOWV invited all GE3 partners to a first meeting. A public event on soil management was organised in February 2024.

Ploughing measures on the test site.



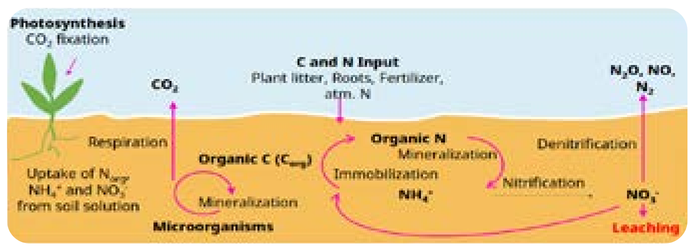
Ploughing measures on the test site – picture: INGUS

What we achieved so far

- A different ploughing approach was tested in fall 2023 – a one-time increase of ploughing depth (from ~30 to 35 cm) in order to obtain a greater soil volume for C-storage
- Further changes in farming practice (e.g. crop rotation and catch cropping) are being tested by farmers
- Codes were selected and data is gathered and processed for scenario-based simulations (some based on strip experiments) regarding humus build-up under climate-induced rising temperatures and leaching from humus decomposition in arable soils in Lower Saxony

What is to be done

- Effects of deeper ploughing on the humus content will be investigated
- Effects of the adapted management practices will be observed over the course of the project. Long-term effects will be evaluated by SVAT-Modelling.
- SVAT-models need to be validated on the collected data
- Sensitivity studies will be carried out to determine prediction uncertainties, sensitivity to site-specific conditions and sensitive management measures
- Investigation of C and N development for future climate scenarios



Carbon (C) und Nitrogen (N) cycling in arable soils.

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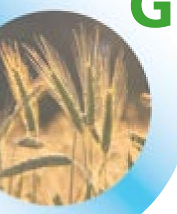


GE4 WaterFarmers

Focus on
- Changes in Urban Areas
- **Changes in Agricultural Areas**
- Changes in Natural Areas

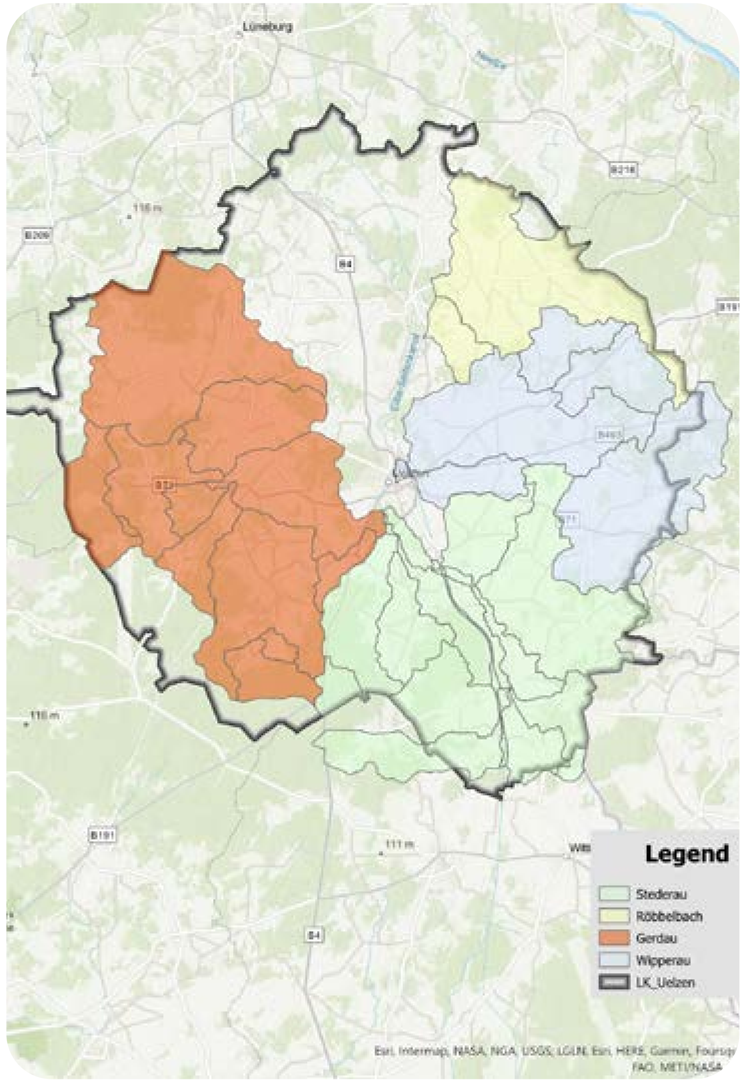
Dealing with
- **Water balance**
- **Water quality**
- Land-Use

Securing groundwater supply for field irrigatio in the country of Uelzen

The WaterFarmers project is taking place in Uelzen, a district in Lower Saxony. The district Uelzen is part of Lüneburgs Heathlands and located in the north german Geest-Landscape. This landscape is characterized by the climatic transition zone between sub-maritime and subcontinental climatic influences, marked by a climatic water balance surplus in the winter months and a negative climatic water balance in the main growing season. Figure 1 shows the project area and the relevant water bodies. This circumstance explains why the majority of the landscape is a field irrigation area and why this has been organized in associations with communal facilities for roughly six decades. Figure 2 shows a section of the full-surface irrigation option and how it is developed using irrigation wells. Climate change is intensifying the climatic characteristics mentioned above on average over the years. In order to be able to counteract the climatic water balance deficit in the growing season, which is increasing on average over the years, agriculture in Uelzen is dependent on an expansion of groundwater extraction for field irrigation. A widespread increase in groundwater extraction as a climate change adaptation measure in field irrigation agriculture is already leading to local conflicts with regard to the objective of the EU Water-Framework-Directive and the protection of groundwater-dependent terrestrial ecosystems. This particular climate change driven conflict situation forces all local actors in particular the DFU, to solve practical problems and concerns that arise from the use of groundwater for field irrigation by its members (farmers) through applied research outside of universities. The aim is to develop practical measures and to evaluate and test their technical feasibility so that a sustainable balance between nature conservation and groundwater extraction can be found for the coming decades. The measures developed must be legally assessed and agreed with the local authorities.

The aim is to ensure that the region's agronomic advantages remain usable in the future, to give irrigated agriculture a future perspective in the face of climate change and at the same time to keep the landscape water balance and the associated ecosystems climate-resilient.

Project area and relevant waterbody areas



Our strategy to foster a Blue Transition

The problem-solving strategy in the project WaterFarmers provides for three processing levels with regard to the temporal and technical organizational sequence.

1. Adapt the already established groundwater monitoring system and groundwater flow model of the association area at the DFU with regard to the following questions:

In which sub-areas can an expansion of groundwater extraction for irrigation purposes lead to a negative impact on groundwater-dependent terrestrial ecosystems? And in which sub-areas will an increase in groundwater extraction in view of climate change scenarios very likely lead to specific problems for the landscape water balance? Finally, the irrigation wells that are classified as critical for the landscape water balance will be identified.

2. If the geohydrological model of the association area provides reliable data on problematic areas and irrigation wells, a participation process should be initiated. This provides for the formation of a steering group to establish general rules for problem solving at the level of the overall project. At the local level, working groups of those affected should create awareness of the problem and work together to develop solutions locally. This participatory approach is about staying true to the guiding principle of the association system in field irrigation, developing ideas, tips and aspects together with the farmers and supporting them jointly.

3. The proposed solutions and measures developed in relation to problematic irrigation wells for the landscape water balance are analyzed/evaluated in terms of their impact and checked for feasibility. Possible measures

could be for example the closing of problematic irrigation wells, the replacement construction of these elsewhere a redistribution of the flow rate to the remaining wells. Finally, the approval authorities have to check the proposed measures for legal feasibility (including the EU Water-Framework-Directive, nature conservation law, Natura-2000-Directive...)

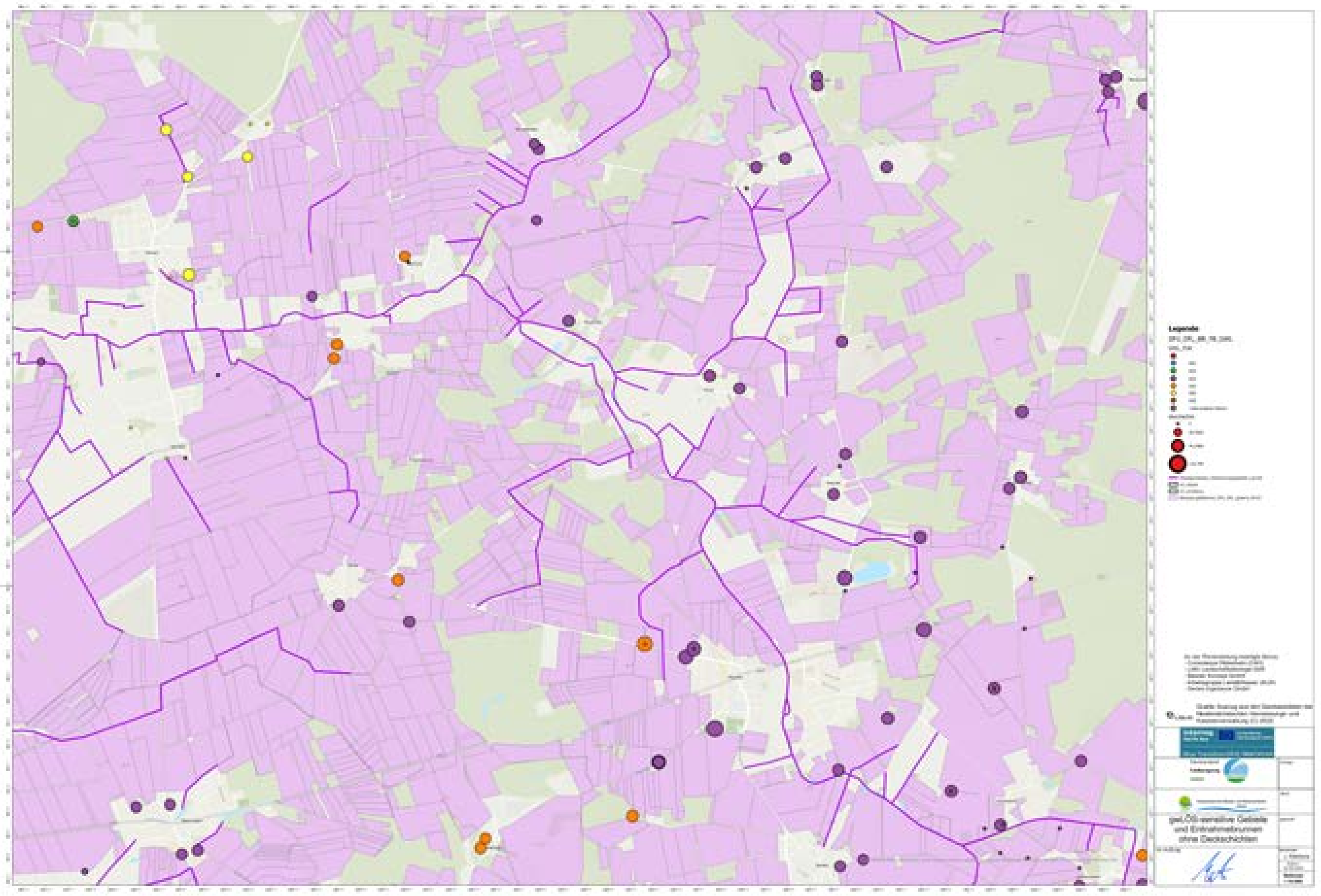
Legally and technically feasible measures should be communicated regionally and nationally as feasibility examples. Implementation should be clarified at local level with the involvement of all relevant stakeholders.

What we achieved so far

In recent months, WaterFarmers have been working on adapting the geohydraulic model of the project area (Figure p. 51) in relation to the questions explained above.

Now we have a largely viable model for the project area, which allows causal conclusions to be drawn between groundwater extraction and the landscape water balance. We can identify the groundwater-dependent landscape areas mentioned above, which are at risk of ecological damage due to falling water levels if groundwater extraction is expanded in the warm season for irrigation purposes. We then identified the irrigation wells that are critical for groundwater-dependent terrestrial ecosystems. Figure 3 visualizes the cover layers above the main aquifer, shows the groundwater-dependent terrestrial ecosystems and irrigation wells without a cover layer.

We now know which irrigation wells in the project area will lead to ecological damage and conflicts under nature conservation and water law aspects in the future if groundwater extraction for irrigation purposes is expanded.



Section of irrigation fields in the project area with irrigation wells

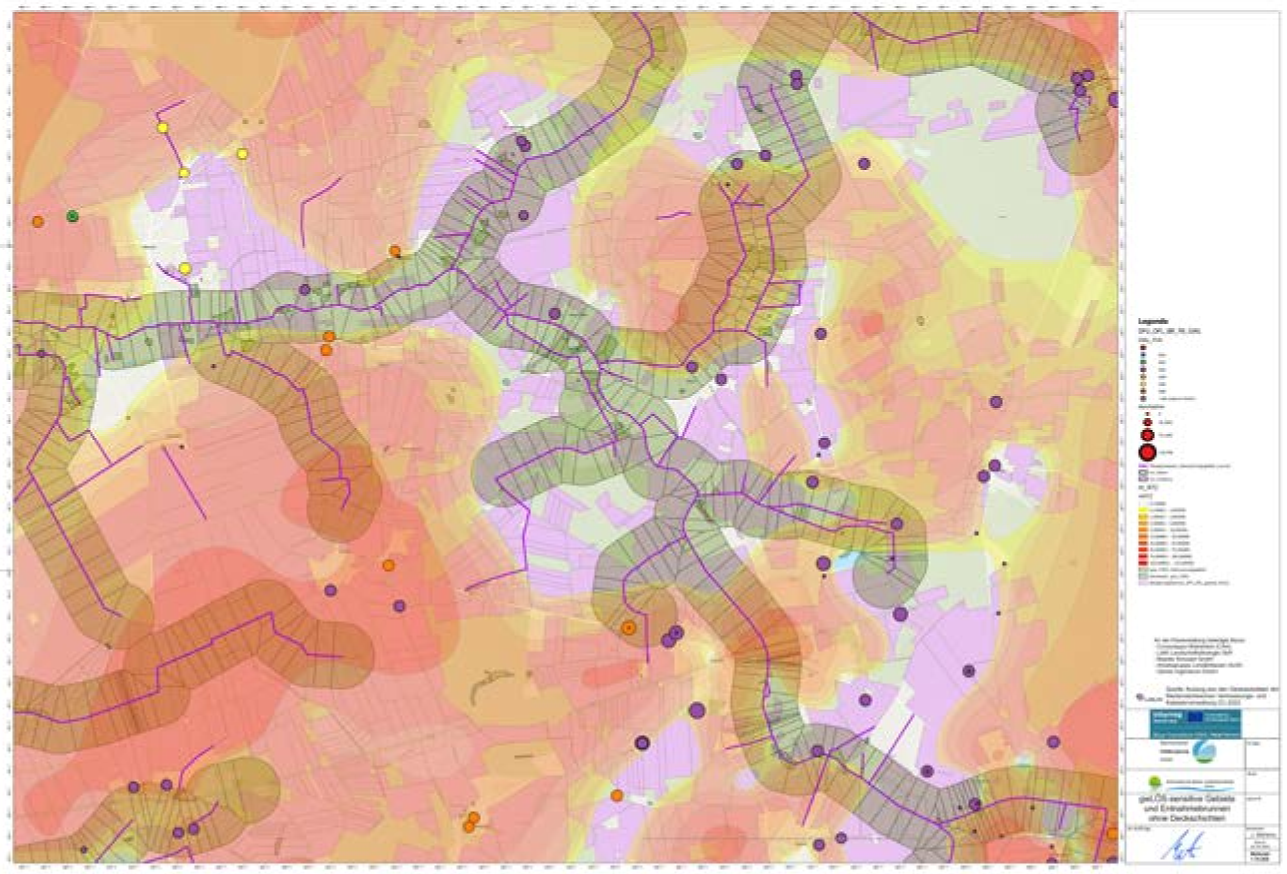
OUR PILOTS

What is to be done

The next step is to set up the steering group and local working groups described above.

The first meeting of the finance steering group took place on June 1st in this year. The steering group for professional and technical aspects will probably be constituted on August 22nd, 2024. The steering group consists of NLWKN, LBEG, local environmental/water authorities, the LWK, the DFU and the CAH office.

The start with local working groups consisting of local irrigation farmers, the BVNON, the LWK, the DFU and the CAH office is scheduled for September 2024.



Cover layers above main aquifer with groundwater-dependent terrestrial ecosystems and irrigation wells without cover layer

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NL1 Drentsche Aa

Focus on

- Changes in Urban Areas
- **Changes in Agricultural Areas**
- **Changes in Natural Areas**

Dealing with

- **Water balance**
- **Water quality**
- **Land-Use**

Climate proof Governance in the catchment of the Drentsche Aa

The Drentsche Aa is a small brook in the northern part of the Netherlands, in the province of Drenthe. In the catchment of the brook nature (including N2000 area) and agriculture area is almost the same surface (50% each). The brook is fed by rainwater and seepage. Since no water can be transported to the catchment from outside ,nature as well as agricultural possibilities are extremely dependant on the climate The climate impact in this catchment area is big, dry periods causes loss/ or less yields of crops and grass; heavy rainfall causes run off and leaching of nutrients and pesticides. The area needs to be prepared for such changes, for example by using the water efficiently and working on a sustainable soil. Good and sustainable soil maintenance can be the key to adapt to extreme weather situations. Feeding the soil instead of feeding the crops by using measures as adding extra organic matter, no tillage system and measures that store water on the field are needed. These measures can also help to diminish the need of water and even recharge the groundwater. Using weirs in local ditches will also be tested. Currently agricultural and natural land uses are mainly separated. However both land owners, governmental and nature organisations are more often trying to find ways to intertwine these land uses.

Infiltration trench

The aim of the pilot is therefore to develop strategies to cope with these periods of droughts and extreme rainfall, by the government, but also by the water users. The assumption is that intertwining the different land uses will make both more resilient and robust under climate change. This is however also a paradox as both land uses compete for the same resource: fresh water in times of drought.

Our strategy to foster a Blue Transition

We are testing measures concerning soil management and efficient water use. When measures work in this area for some farmers, other farmers may consider doing these as well. The measures are good for water quality as well as water quantity.

As regulations on ground water use, as well as restrictions on water use by irrigation from ground water nearby N2000 areas, are major limitations and barriers, the hydrological model of the pilot area can give information on where water can be stored best and how the interaction between groundwater and surface water takes place and where nature and agricultural areas benefit from different types of land use.

Together with our partners and stakeholders (individual farmers, governmental organisations; nature conservation organisation (SBB), agricultural advisory organisations, university of Wageningen, hydrological advisory organisation) we started pilots at several farms and involve the Proefboerderij Marwijksoord. We provide the stakeholders with information gathered through newsletters and field trips and demonstrations.

We expect that our waterboard, the provincial board and the national agricultural organisations implement the strategy developed in Blue Transition.

What we achieved so far

- We made a hydrological model of the pilot area, which is going to be discussed with the local farmers
- We decided which measures farmers are going test, and also made a big field trial
- We are testing a new method of measuring the discharge of a field to measure the impact of a small infiltration ditch on the total run off of the field. Besides the quantity, also the quality of the run off water will be determined.
- We will test a new field machine, the so called wafer roll (see Photo) in order to store water on the field when rainfall is not too heavy
- We are testing new mixtures of crops (pumpkin, field bean and maize)

Flow meter

What is to be done

- Outputs of the measures taken by farmers on their fields and the field trial have to be reported
- Output of the trial with the run off measuring instrument
- Analysing output and impact of the hydrological modelling measures that will be taken for storing water in local ditches and ground recharge
- Depending on outcome of these measures and modelling results the strategy and implementation is to be developed

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OUR PILOTS

NL2 Flushing Polders

Focus on
- Changes in Urban Areas
- **Changes in Agricultural Areas**
- Changes in Natural Areas

Dealing with
- **Water balance**
- **Water quality**
- **Land-Use**

Increasing freshwater availability along a saline Dutch coastline: Case study Northern Groningen

In large parts of the coastal area of The Netherlands shallow brackish and saline groundwater occurs, sometimes alternating with fresh groundwater. Because salt water from the subsoil causes salinization of the surface water, the water board flushes the waterways with freshwater in order to have sufficient water of sufficient quality available for irrigation. Waterways, weirs and small pumping stations were built for this in the 1990s. However, climate change induced sea level rise is assumed to enhance the salinization process. In addition droughts are expected to become more frequent and for an extended period of time, increasing the risks of freshwater shortages. Consequently, the system of weirs and pumping stations is not optimal, and alternating measures might be effective in mitigating the effects of saline groundwater on open water.

The pilot is situated in a highly productive agricultural area with valuable agricultural soils. Currently agricultural and natural land uses are mainly separated. However both land owners, governmental and nature organisations are more often trying to find ways to intertwine these land uses. The assumption is that intertwining the different land uses will make both more resilient and robust under climate change. This is however also a paradox as both land uses compete for the same resource: fresh water in times of drought.

At the regional scale, a water balance has been constructed without problems. The challenge is to develop a reliable EC/chloride balance, as measurements are spare. In addition, knowledge about the transport and processes of salt in the clay soils are only now gaining more understanding.

This pilot project aims to identify both bottlenecks in the systems and solutions to these bottlenecks that are both effective and proven feasible for local landowners.

Our strategy to foster a Blue Transition

Our strategy is to bridge the gap between theorized solutions and their practical applicability and effectiveness for sustainable and climate-resilient land use and water management. For instance, using freshwater to flush away salt water is sometimes perceived as unsustainable and expensive. We are currently aiming at providing more understanding of how much water the flushing requires to address this misconception.

In our day to day operations there is a close contact with the landowners about our daily water management and we expect our water board and the provincial boards to implement the strategy developed in BlueTransition. This will idealy have a positive effect on the water balance: more freshwater retention, and less freshwater supply in dry seasons.

What we achieved so far

- We constructed a regional water balance for the pilot area.

What is to be done

- Water balance at more local scale if feasible
- EC/Chloride balance and determine flushing requirements
- Model alternatives to reduce flushing requirements
- Finance and implement measures
  - political decision whether or not to invest in measures

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DK3 Endelave

Focus on

- Changes in Urban Areas
- **Changes in Agricultural Areas**
- Changes in Natural Areas

Dealing with

- **Water balance**
- **Water quality**
- **Land-Use**

Future scarcity of fresh and clean groundwater

Endelave is transitioning from farming to eco-tourism, straining its limited groundwater resources. Climate change, with rising sea levels, storm floods, and seasonal droughts, further threatens these resources by increasing the risk of saltwater intrusion. This pilot project examines the socio-economic impacts on groundwater, including effects on the island's economy, population, and water consumption. It leverages comprehensive hydrogeological data to develop a groundwater model, simulating future climate scenarios and informing local authorities and utilities. The model aids decision-making for land use transition and ecosystem service management.

Partner meeting visiting Endelave Pilot September 2023.

Our strategy to foster a Blue Transition

Based on novel combinations of fast geophysical mapping and IoT monitoring, the project partners will establish an island groundwater model to be used for scenario predictions evaluating climate change impacts and possible adaptations. Socio-economic analysis will support the catalogue of possible solutions. These results will be used in workshops and stakeholder engagement in decision making and implementation of adaptation and mitigation solutions, that benefits from synergies held by a societal transition moving away from traditional arable island community the land use transition and the best ecosystem service management with respect to vulnerable groundwater for drinking water situation.

What we achieved so far

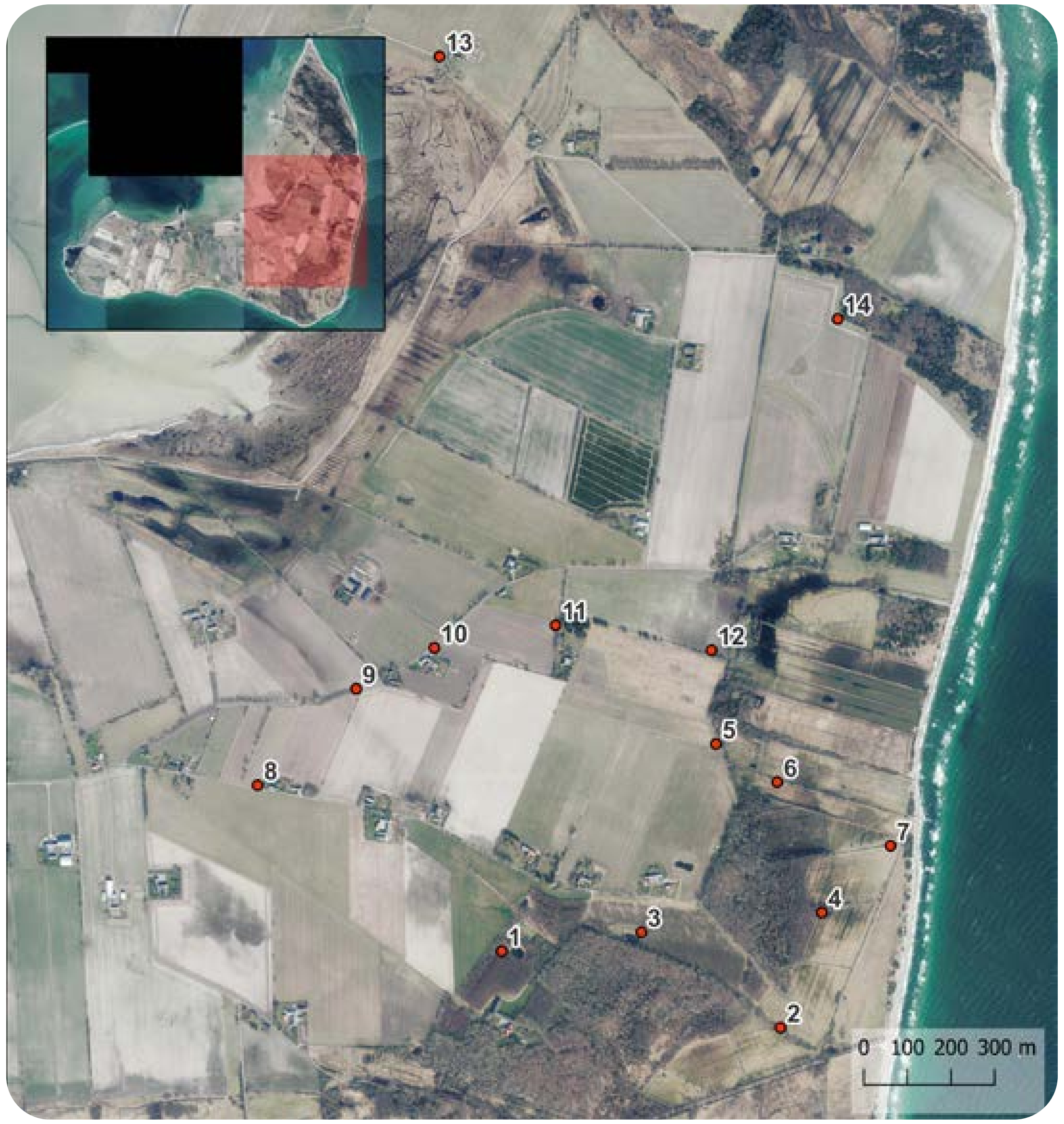
- An open and well-established stakeholder communication line has been developed between the project partners and the landowners involved in the physical interventions (drillings) of the pilot project (VIA, CDR).
- Pilot visit / fieldtrip during September 2023 partner meeting in Dk (CDR)
- A total of 14 drillings have been established on Endelave, Lithological description performed to gain knowledge about the local geology (VIA),
- Well monitoring equipment is set up to inform seasonal variation, logging is continuously ongoing (VIA).

Borehole NMR performed in front of local stakeholders.

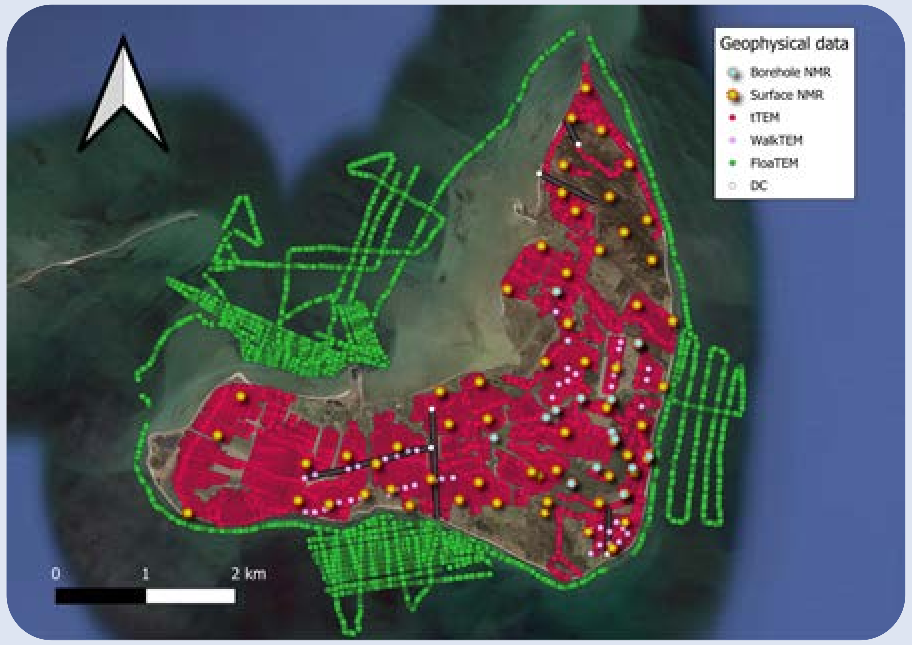
- Several geophysical methods have been utilized, solid and coherent dataset is collected.
  - tTEM (24.230 measurements), WalkTEM (49 measurements) and 5 ERT lines of 400 to 1.500 m length has been conducted and given new very important insights for Island geology with respect to groundwater aquifers and protections of current abstraction aquifer (AU).
  - Surface NMR (57measurements) and borehole NMR (14 measurements) has been conducted to inform about the soil effective porosity and transmissivity (AU).
  - FloaTEM (13.355 measurements) has been conducted on the sea around the island, this completely new dataset enables data analyses to inform about saltwater-freshwater dynamics of the island aqui fers (AU).
- Collected combinations of various geophysical mapping techniques have been used and correlated to derive existence of two new buried valleys on the island (AU, CDR).
- Communication with SAMN utility has ben initiated and data collection on water consumption on Endelave has been started (CDR).
- Project coordination between the EU financed project, RESIST and BioScape to coordinate activities and create synergies between the projects but also to coordinate dialogue with the landowners on the island (CDR).

What is to be done

- All collected geophysical mapping data and litho-logical descriptions are now being used for the hydro-geological modelling of the subsurface of the island (CDR).
- Continuous logging from well monitoring will be analyzed and used together with the hydro-geolo-gical model in setting up a new groundwater model for the island (VIA).
- The new groundwater model will be used as basis for establishing a series of scenario predictions evaluating the impact of future climate changes on ecosystem service management with respect to future groundwater consumption, quantity, and quality (VIA).
- XR solution will be developed as a visual decision support tool (VIA).
- Socio-economic analysis will be performed based on interviews with various stakeholders (CDR).
- The work on good stakeholder engagement con-tinues through dialogue, workshops, and ongoing information about the project for the island's residents and the project's other stakeholders (the municipality and the utility company) (CDR).
- Strategy development will be performed in colla-boration with authorities and utility (CDR, VIA).
- Socioeconomic analysis will be initiated as inputs for a new extraction plan (CDR).



Position of 14 established drillings at Endelave Pilot.



Overview of collected geophysical data.

tTEM system mapping on the island of Endelave.

Blue Transition partnership gathered for meeting at Endelave in September 2023 (Source: CDR)

Contact: *Majbritt Lund, VIA, majl@via.dk*
Emil Egerod Hubbard, CDR, emihub@rm.dk

Changes in natural area

Protecting natural areas to preserve biodiversity, their ecological state and ecosystem performance is a central target from many perspectives.

The demands of natural areas concerning sufficient and non-saline groundwater and healthy soil must be considered. Consequently, land-use and use of groundwater resources should be adapted to protect natural areas and support their resilience – not at least against droughts.

In five pilots we deal with the rewetting of peatlands, finding a compromise between groundwater use for municipalities or agricultural purpose and natural areas and understanding the impact of land-use change for lake water.

Foto: Pixabay, Herbert Aust

GE2 Geest Adaptation

Focus on

- Changes in Urban Areas
- **Changes in Agricultural Areas**
- Changes in Natural Areas

Dealing with

- **Water balance**
- Water quality
- **Land-Use**

Effects of peatland renaturation on groundwater system

Our pilot area is located in the northern part of Lower Saxony (Germany), near the cities of Bremerhaven and Bremen.

Via groundwater modelling we will simulate how different MAR (Managed Aquifer Recharge) measures effect the fresh-saline groundwater interface and test if it is possible to push the interface back to greater depth. A huge benefit would be the preservation of fresh water resources today and in the future, especially with regard to climate change, for the public drinking water supply. Besides groundwater salinization, we focus on the Gnarrenburger Moor. The peatland is mainly drained due to former peat mining and is therefore no longer in its natural state. Due to Germany´s national peatland protection strategy it is determined to rewet the peatlands to reduce CO2 emissions. Different strategies will be simulated in a groundwater flow model to get ideas on how the peatland water table and the groundwater table will react and how it effects the Gnarrenburg Moor region.

GPR device for mapping and monitoring peat thickness.

Our strategy to foster a Blue Transition

Due to climate change, the todays and future drinking water consumption will increase, especially in the summer months. In low lying coastal regions this possibly causes an updoming of the fresh-saline groundwater interface and so worsening in quality and quantity of fresh groundwater. Infiltration of freshwater can push the SFI back to greater depth or helps to stagnate it. The Wasserverband Bremervörde as the owner of Minstedt waterworks could implement infiltration wells in areas we figured during the project.

For the municipality of Gnarrenburg, as well as for the farmers and residents of the Gnarrenburger Moor our results will be helpful in deciding where and how much the water table can be raised. In view of the fact that the peatland is used for agricultural and residential purposes, it should be a compromise between this and a 'total' rewetting of the area.

Our stakeholders are the Wasserverband Bremervörde, the municipality of Gnarrenburg and Bremervörde and farmers of the Gnarrenburger Moor. We are in contact and exchange with the municipalities and the Wasserverband Bremervörde. Hopefully this year, we bring together some farmers in a stakeholder meeting to talk about implementation options.

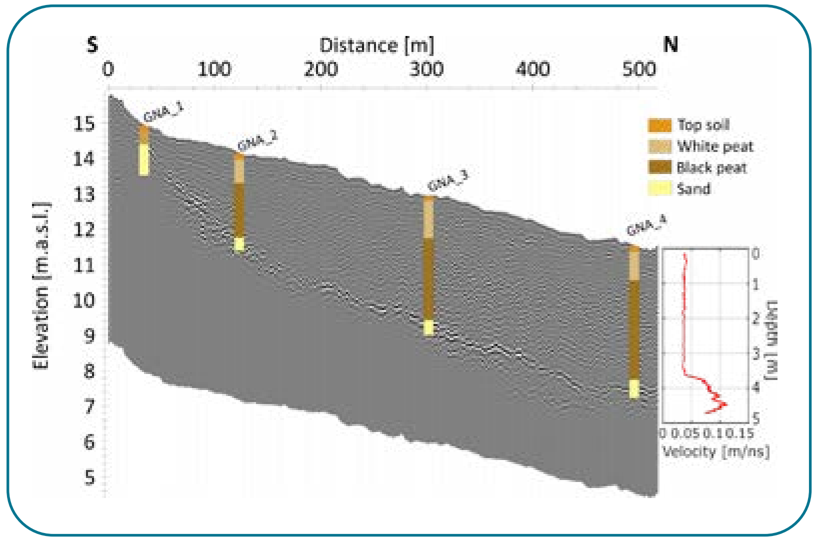
What we achieved so far

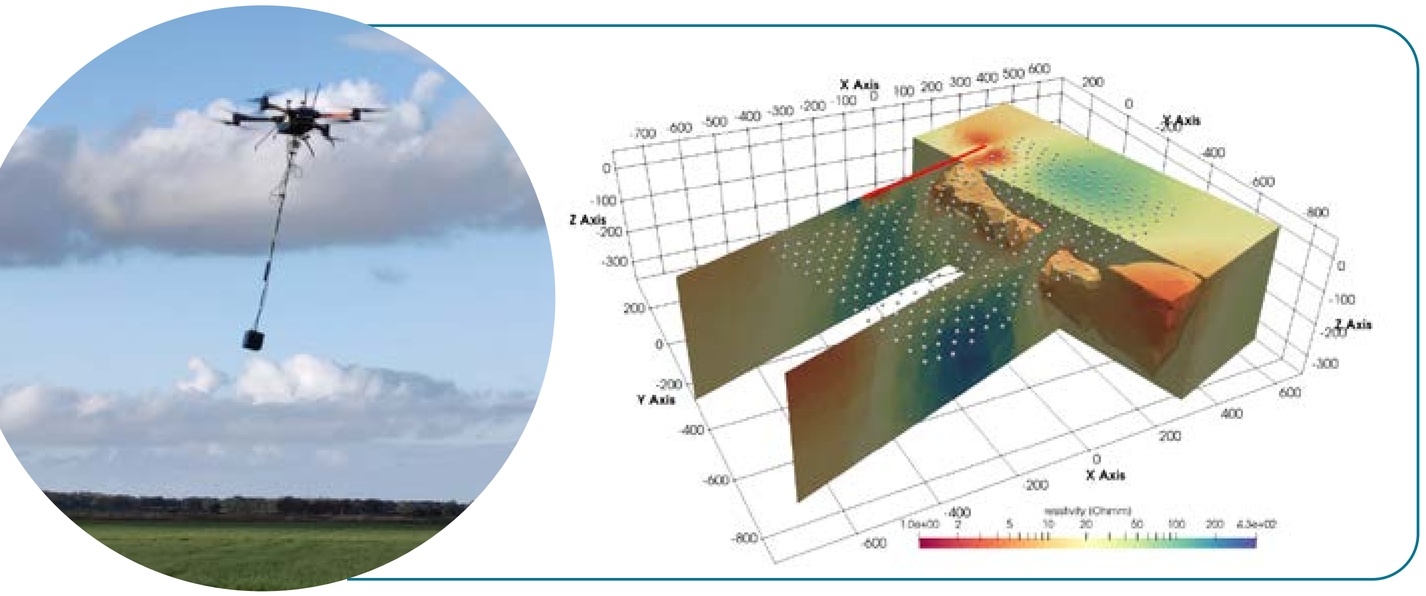
- Geophysical investigations like GPR & NMR in the Gnarrenburger Moor, Drone-EM at the Minstedt waterworks and a SkyTEM survey covering a larger area in the pilot
    - Gives us information about current state of the fresh-saline groundwater interface and the geological setting
- Geological modelling of the base surface layer of the peat
- Data acquisition for groundwater flow modelling

What is to be done

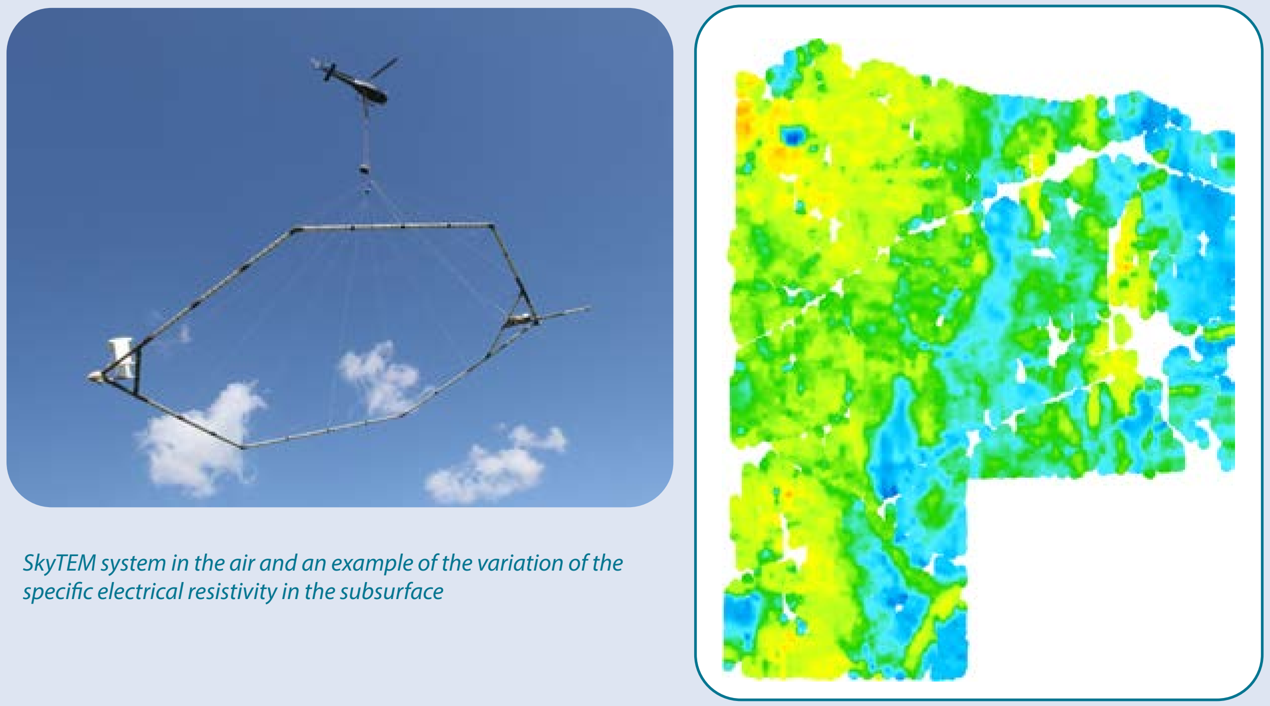
- Geological modelling of the other hydrostratigraphic units
- Including all geophysical data in geological and SFI-model
- Development of a groundwater flow model that reflects groundwater balance in the pilot

GPR profile in south-north direction with borehole information





Drone and instruments in the air and an example of a 3D inversion.



SkyTEM system in the air and an example of the variation of the specific electrical resistivity in the subsurface

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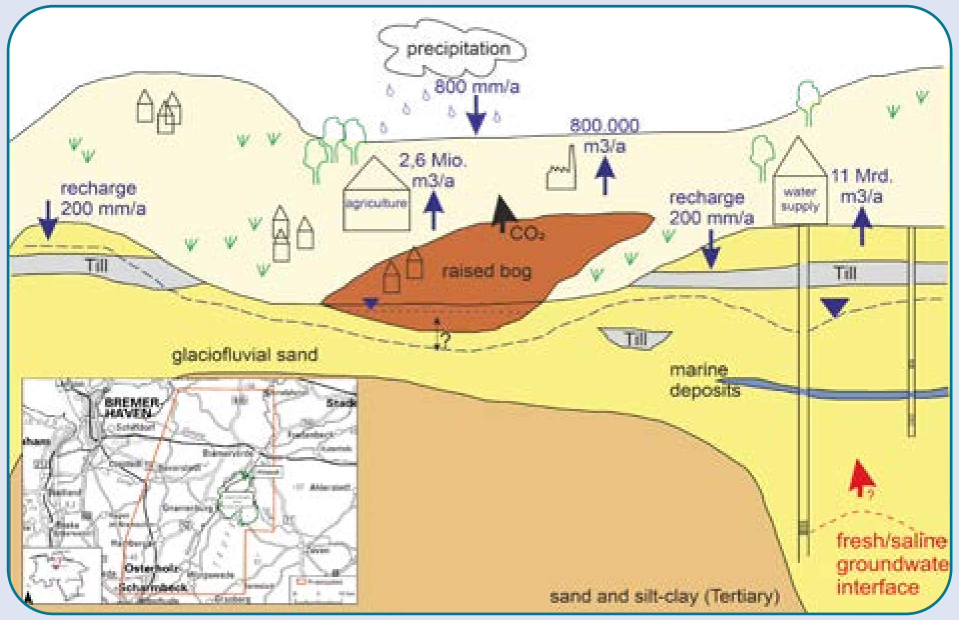


Water balance sketch and location of the GE2 pilot.

FR1 Guidel compromise

Focus on
- Changes in Urban Areas
- **Changes in Agricultural Areas**
- Changes in Natural Areas

Dealing with
- **Water balance**
- **Water quality**
- **Land-Use**

The compromise between human and ecosystem protection water needs

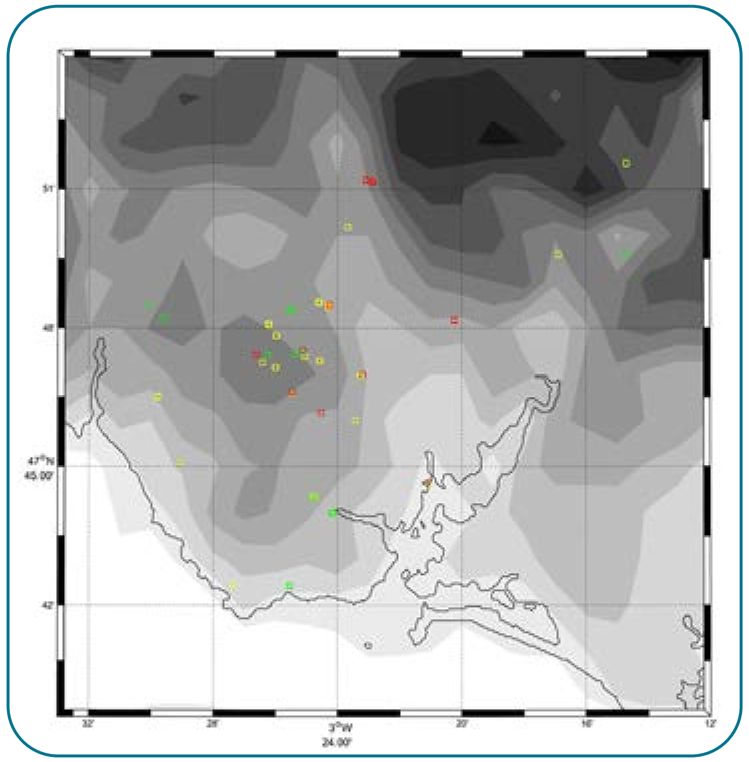
This pilot will improve water and ecosystem management in the context of large population growth and diminishing summer rainfall linked to climate change. A group of municipalities in the region of Lorient is planning a new groundwater pumping station to meet human water demand, which is located 2 km far from the sea. The expected impacted area encompasses a Natura2000 classified ecosystem, which is mostly fed by deep groundwater upflow. While the formal process in solving user conflicts is on hold for more than a decade, this pilot will use additional hydrogeological modelling in combination with stakeholders' workshop and participatory science to identify the role of groundwater to shape surface ecosystem, and communicate different impact scenarios. Our modelling approach needs to represent complex interactions between groundwater and surface water in a highly heterogeneous geological context, which can be driven by different types of scenarios (climate, human needs). Based on these simulation results, a joint water and ecosystem management plan will be discussed between managers, citizens and political representatives.

Photo of the coastal Natura2000 classified ecosystem, which is fed by upstream groundwater upflow. On the top right, focus on a wetland upstream the classified ecosystem: artesian well highlighting significant upwelling from deep aquifers, confluence between river (surface water, light brown color) and groundwater-fed river (dark orange color).

Our strategy to foster a Blue Transition

As our climate evolves into conditions which have never been experienced, current management tools, based on compromised hypotheses[1] , need to integrate a more systemic approach to water. Effective water resource management necessitates consensus-building among a wide range of stakeholders on vital concerns like water requirements, ecosystem preservation, economic activities, and the envisioned future of a given territory. In essence, it requires a forward-looking perspective on the territory's future (i.e. planning), which can be based on various tools such as prospective exercises. Though, sharing knowledge remains a one major difficulty to built constructive debate on such complex issues, in the context of heterogeneous understanding. When the sensitive, inductive experience of the actors is the main way of understanding the environment, scientific models often remain difficult to understand and require a step to translate this knowledge into the experience of actors. Our translation strategy is twofold: (1) use citizen metrology (smartphone-based nitrate concentration measurement) as a tool to meet actors on the field, and use nitrate as a tracer to explain how groundwater flow shapes surface ecosystems and (2) draw news maps, based on new cartographic conventions to make subsurface processes visible. In this way, each actor can position himself on a map and define new relationships with his neighbours.

[1] *Milly et al., Science, 2008*
https://www.law.berkeley.edu/files/CLEE/Milly_2008_Science_StationarytyIsDead.pdf



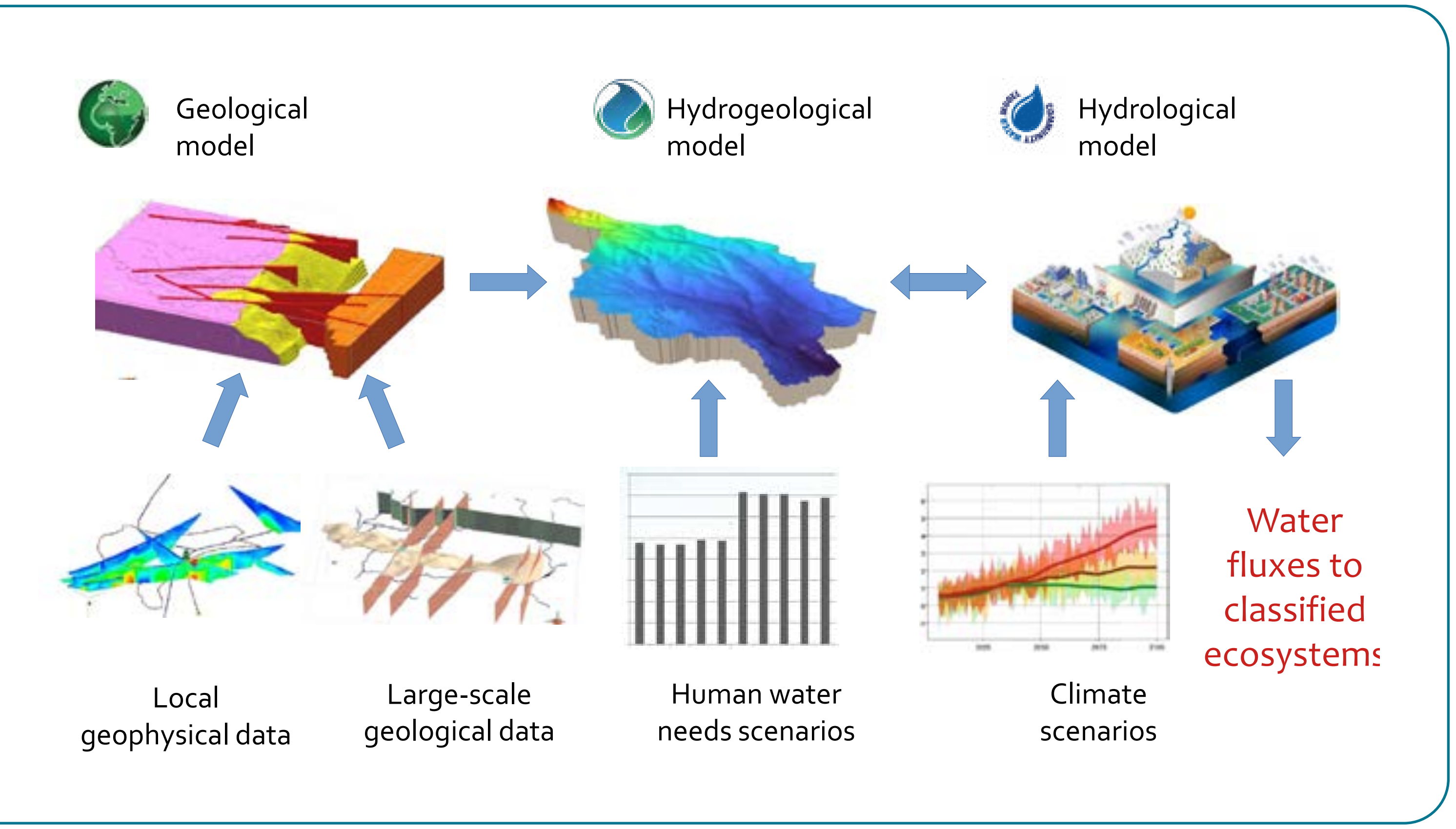
Citizen-based nitrate concentration observations in rivers, lakes and groundwater in the Lorient region. The color represents nitrate concentration. Green : between [2-10 mg/l] – good state, Yellow : between [10-25 mg/l] – medium state, Red: between [25-50 gm/l] – mediocre state

What we achieved so far

- Data acquisition and synthesis : new and previous geophysical and geological data have been synthesized into a geological model, highlighting main subsurface domains, including major permeable fractures. We selected a set of tracers to represent fast and slow flow lines in Guidel hydrological system, and set up the monitoring system. We also implement new monitoring tools based on geophysical tools to understand how surface and subsurface water are mixing.
- Prospective modeling: We coupled CWAT-M hydrological model to Modflow to define water availability in future conditions at a larger scale, with various land use scenarios. This exercise will be the starting point to better represent how anthropogenic pressures and climate change interfere, and define the most appropriate scenarios ensuring limited impact on the Natura2000 ecosystem.
- Knowledge sharing: we organized several citizen metrology meetings, from demonstration to interpretation of citizen data. First, we focus audience to a set of selected persons in environmental and fishing associations and field technicians. Students and farmers will be added to the group. We also presented Blue Transition and our approach to a public meeting organized by the "High Council for Climate in Brittany". We created maps of the pilot, with updated conventions to better represent the role of the subsurface in shaping surface ecosystems.
- Governance: the Agglomeration of Lorient is in charge of local public services and manages local development projects (territorial planning). Several politicians and services of the agglomeration, together with researchers defined a water resilience plan, i.e. an administrative roadmap required by law, which was fed by scientific knowledge and initial prospective elements.

What is to be done

- Data acquisition and synthesis : we continue the acquisition of multiple tracers, to sample the evolution of the Guidel hydrological systems in response to diverse climatic conditions (wet summer in 2024, following water scarcity in summer 2022 and 2023).
- Prospective modelling: we need to define new tools to evaluate model predictive skills and consistency, i.e. its relevance for public action. Groundwater pumping, by disconnecting groundwater to surface, remains a major tipping point in ecosystem functioning.
- Knowledge sharing: we will continue to animate workshops on citizen metrology and try to recruit new members, with an objective to disseminate the initiative to a wider audience. We will also organize meetings with services of Lorient and citizens to discuss the new cartographic representations of the pilot. A set of socio-economic scenarios will be shaped following this event.
- Governance: the socio-economic scenarios will be implemented in the modeling platform, to define how different land management and human water needs interfere with climate change and impact water fluxes towards the classified wetland. Such fluxes should be interpreted as risks and become a central point in defining a robust management plan integrating the compromise between the water needs of humans and ecosystems.



Model structure – and information – required to model the cumulative impact of human water needs and climate change on water fluxes feeding an ecosystem, in the context of large groundwater flow driven by fractures.

Demonstration of the nitrate measurement protocol to a group of citizen.

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Camille Bouchez, University of Rennes, camille.bouchez@univ-rennes1.fr
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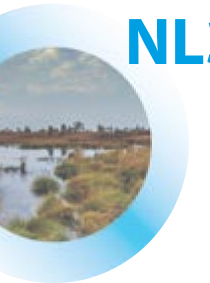
OUR PILOTS



NL3 Veenkolonien

Focus on

- Changes in Urban Areas
- **Changes in Agricultural Areas**
- **Changes in Natural Areas**

Dealing with

- **Water balance**
- Water quality
- Land-Use

Sustainable land use in the Veenkoloniën, adapting to climate change

The Veenkolonien is located in the northern part of the Netherlands, in the province of Drenthe and includes highly productive agricultural land with valuable agricultural soils as well as urban and nature protected areas. This area suffers from dry periods in the summer.

The use of water in this area continuously increased since 2018 and leads to a misbalance between the water supply and demand of water. The area is very dependant on the water supply from the biggest freshwater lake in the Netherlands, the Lake Ijssel. Through a very dense network of waterways, the water is distributed so the farmers can use it for irrigating their crops. Due to climate change, shortage of water can occur due to the decrease of water supply via the Rhine and Ijssel. The area needs to be prepared for such changes, for example by using the water efficiently and working on sustainable soil. Further, the possibilities of groundwater use considered by working on a water balance for this area that includes both groundwater and surface water.

Currently agricultural and natural land uses are mainly separated. However both land owners, governmental and nature organisations are more often trying to find ways to intertwine these land uses. The assumption is that intertwining the different land uses will make both more resilient and robust under climate change. This is however also a paradox as both land uses compete for the same resource: fresh water in times of drought. The aim of the pilot is to develop strategies to cope with these periods of drought, by the government, but also by the water users.

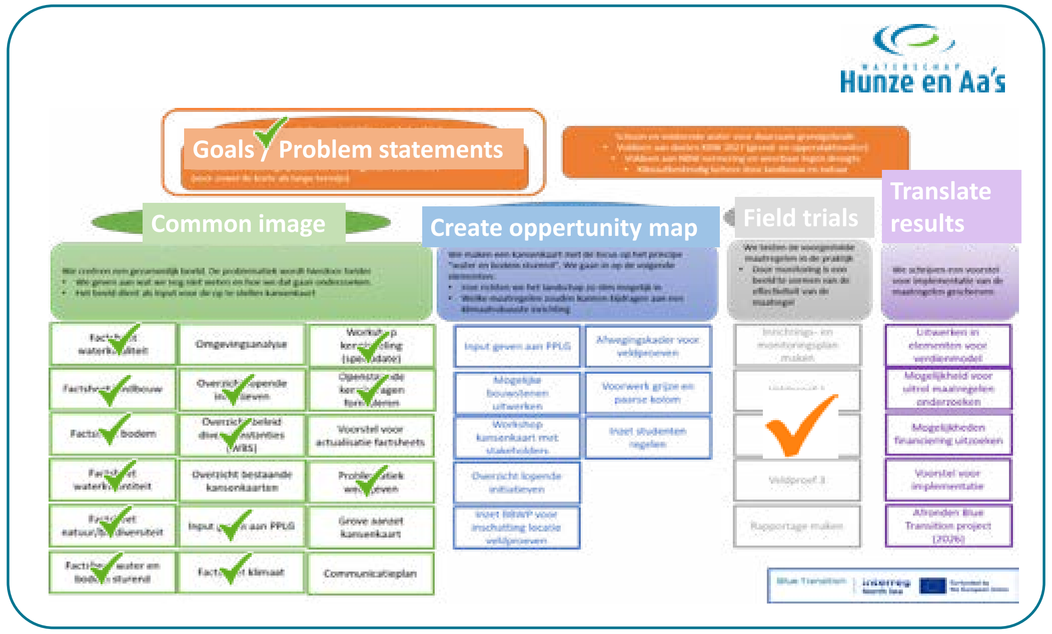
Our strategy to foster a Blue Transition

We are testing measures concerning soil management and efficient water use. When measures work in this area for some farmers, other farmers may consider doing these as well. The measures are good for water quality as well as water quantity.

We are studying the use of groundwater instead of surface water for irrigation. This only works if a water balance in the area is achieved and there are no consequences for other functions.

Together with our partners and stakeholders (individual farmers, Innovatie Veenkolonien, agricultural coorperations and governmental organizations), we started pilots at five farms and involve the test farm proefboerderij Valthermond. We provide the stakeholders with the information gathered.

We expect our water board and the provincial board to implement the strategy developed in Blue Transition.

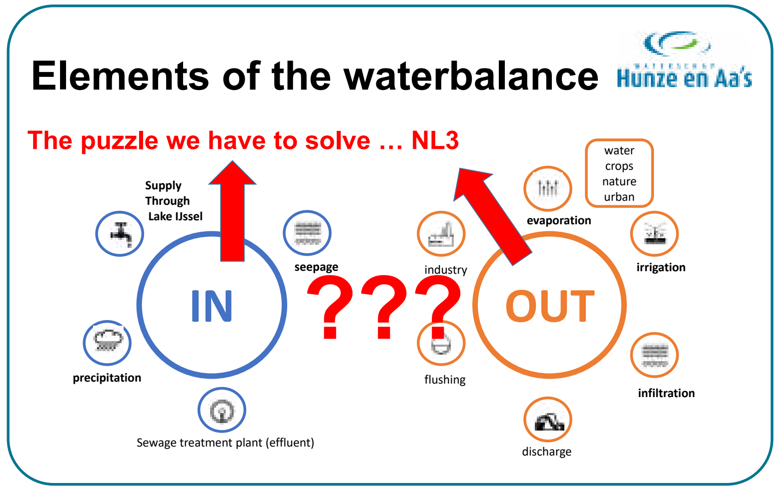


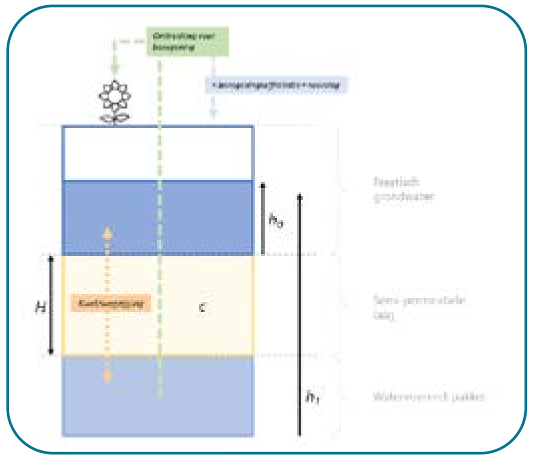
What we achieved so far

- We made a joint fact finding to create a common view
- We did an analysis on the possibilities of using groundwater for irrigation

What is to be done

- *A practical irrigation test*
- *Analyzing output and impact of model results concerning the use groundwater for irrigation (innovative method of modelling)*
- *Testing of measurements on six different farms in the Veenkoloniën*
- *Depending on the outcome of the modelling and the measurements, a strategy for this area, concerning water use and soil management, will be developed*
- *We will share the results of Blue Transition with the waterboard and the province, and expect they will implement the strategy*





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NL4 Fresh water conservation

Focus on

- Changes in Urban Areas
- **Changes in Agricultural Areas**
- Changes in Natural Areas

Dealing with

- **Water balance**
- Water quality
- **Land-Use**

Determining the effectiveness of water conservation in open waterways on higher sandy soils

The climate is changing. We are experiencing more extreme weather. It is becoming drier for longer periods, but we also see more intense rainfall, and the rainy periods are extending. These weather extremes significantly impact agriculture. In this pilot project, we aim to retain more water within the fields. The challenge in the pilot area lies in the presence of clay layers in the soil, which reduce permeability. The agricultural parcels are lying nearby a village. Retaining water in waterways for agricultural purposes may also affect the surrounding, for example the buildings. We collaborate with the province and farmers in this pilot to explore solutions for better water retention in the fields and improve freshwater availability.

Our strategy to foster a Blue Transition

To retain more water within the capillaries of the water system, we are collaborating with the province and farmers to explore parcel-level solutions. For instance, we consider installing water level-controlled drainage, placing farmer-controlled weirs, adding valves to culverts, or adjusting water levels. These modifications aim to ensure that rainwater falling on the pilot location remains available for the fields as long as possible. Working alongside farmers, we implement these solutions on their parcels. We create a user agreement for the pilot and obtain the necessary permits. This pilot project involves discussions and joint problem-solving with the province and local farmers to find the most suitable solutions for each location.

What we achieved so far

Together with the farmers, we have assessed where they currently experience the greatest problems with freshwater availability. From these locations, we analyzed the water system, soil, and subsurface, and conducted field visits. Based on this data, we determined the solutions in the field. The solutions include controlled drainage, installing farmer controlled weirs, and closing culverts. We have also placed monitoring wells to assess the impact of these solutions.

We have initiated a model study to determine the potential impact of water retention solutions, such as farmer-controlled weirs, throughout the valley of the Eelder and Peizerdiep system. With this study and the pilot program involving farmers, we aim to define a detailed strategy and implementation plan for increasing water retention in this area.

What is to be done

We are monitoring the impact of the solutions in the pilot and gaining insights about te possibilities of the soil and water system to retain water. Based on this knowledge, we will formulate a strategy to enhance water retention in high sandy soils and stream valleys, and we will draft an implementation program for these measures.

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SE1 BROWNIFICATION OF LAKE WATER

Focus on

- Changes in Urban Areas
- **Changes in Agricultural Areas**
- **Changes in Natural Areas**

Dealing with

- Water balance
- **Water quality**
- **Land-Use**

Preventing brownification of groundwater in the Bolmen lake area by improved forest management and riparian zones

Brownification of lake water poses a significant threat to drinking water supplies and lake biodiversity. This phenomenon has multiple causes, including forest management practices and connected effects that lead to increased organic matter runoff. Notably, after extreme weather events such as storms linked to climate change, the amount of organic matter entering lake water tends to rise.

To combat this issue, it is crucial to implement measures such as creating functioning riparian zones, preventing direct runoff into lakes, and improving forest water management practices. These steps can significantly reduce the influx of dissolved organic materials into lakes. Among others water treatment plants would benefit as they could use less chemicals to produce potable water, which would also decrease the waste production. Moreover, a decrease in organic matter input to the lake would benefit the fish biodiversity, as brownification disproportionally affects certain fish species and the entire ecosystem may benefit as it has shown that too high organic matter levels can lead to increased methane gas exchange into the atmosphere from lakes.

Our strategy to foster a Blue Transition

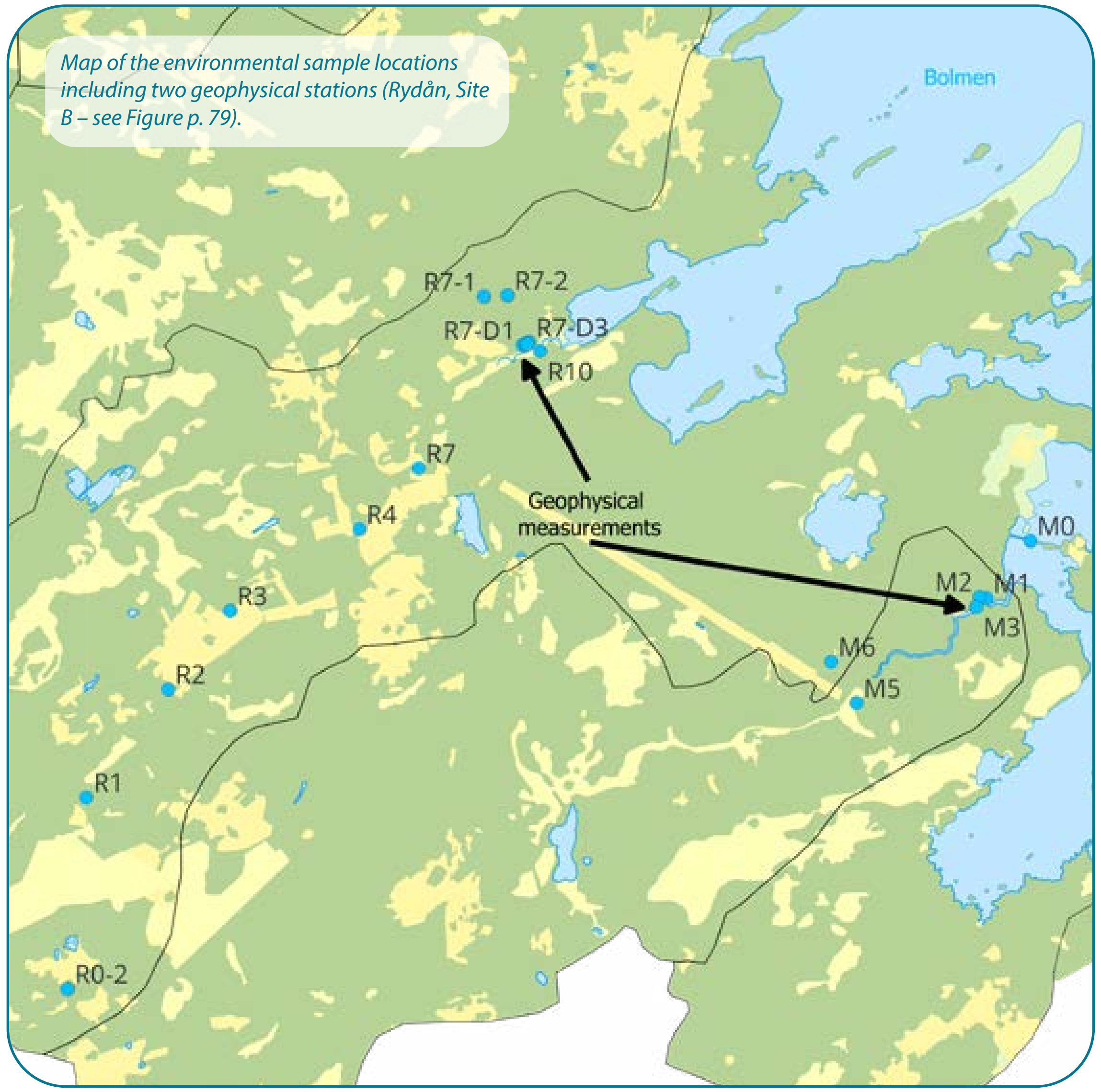
Several effective measures can reduce organic matter transport to receiving lakes. For instance, creating larger riparian zones could significantly reduce organic matter transported to receiving waters. Diversifying land use beyond monoculture conifer plantations not only improves water quality but also enhances biodiversity. Altering forest drainage ditches and strategically reconstructing wetlands can further diminish organic matter transport. These strategies benefit the lake ecosystem in various ways, including drinking water, recreation, and fishing.

However, current practices often lack thorough follow-up to assess their effectiveness and identify potential downsides. Our research aims to bridge this knowledge gap by investigating how and why these measures work, along with any unintended consequences. This will ensure the right measures are implemented at the optimal location and time. Continuous communication is crucial for successful implementation. Our project fosters collaboration with landowners, forestry professionals, municipalities, and other stakeholders through workshops, reference group meetings, and social events like open days at the Bolmen research station.

What we achieved so far

Over the past few years, we have been monitoring various environmental parameters such as total organic matter content, temperature, salinity, turbidity, and conductivity at multiple sample locations around the lake. Additionally, we collected geophysical data (GPR and DCIP) at six different test sites. Several master's theses over the last two years have focused on monitoring variations in organic matter in connection with a nearby peat bog and finding links between geophysical data and organic matter.

Our regular contact with stakeholders has fostered a trustful relationship and provided valuable insights for joint efforts to counteract brownification. Most stakeholders are very willing to contribute and implement potential measures.

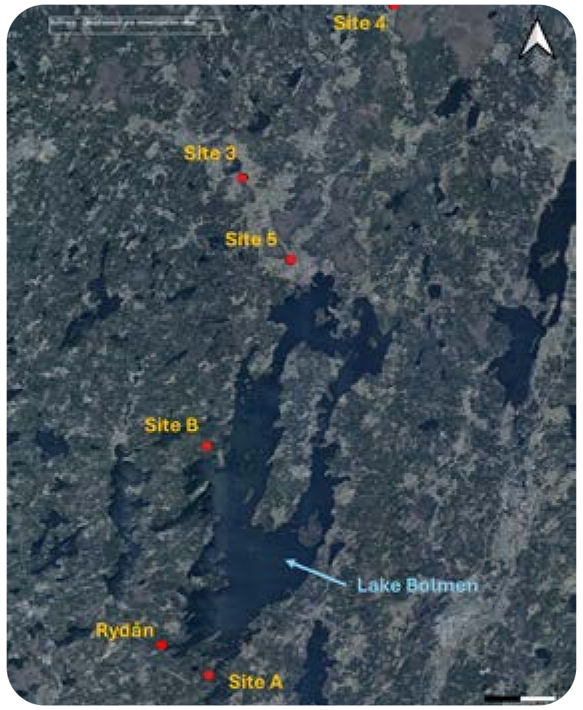


Map of the environmental sample locations including two geophysical stations (Rydån, Site B – see Figure p. 79).

What is to be done

We have several plans for the next steps. Increased monitoring is essential, particularly with the setup of a geophysical monitoring system in an area where forest regions will be rewetted. This should provide a better understanding of the influence of forest management and wetlands on brownification. In addition, it will help to further understand which circumstances are important so that an implemented measure works efficiently.

We will also continue with our communication strategy, aiming to reach as many people, societies, and stakeholders as possible. Our goal is to bring them together to discuss and raise awareness of the issues at hand. This should foster cooperative thinking leading to cooperative implementation of mitigation measures at a great scale.



Overview test sites for geophysical measurements.

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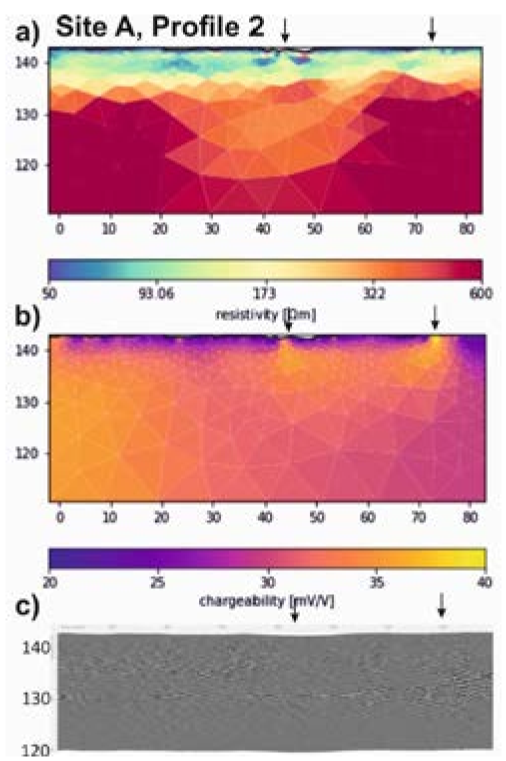
Tina Martin, Lund University, tina.martin@tg.lth.se



DCIP and GPR results for site A.

Sampling of ditch water with a high amount of organic matter.

List of Partners

List of Partners

List of Partners

Foto: Pixabay, Tomislav Jakupec

Belgium

Flanders Environment Agency
Natuurpunt

Denmark

Region Syddanmark
Region Midtjylland
Geological Survey of Denmark and Greenland
Åbenrå Kommune
Hydrogeophysics Group Aarhus University

France

University of Rennes
Centre national de la recherche scientifique
Lorient Agglomération

Germany

Bundesanstalt für Geowissenschaften und Rohstoffe
Dachverband Feldberegnung Uelzen
LIAG-Institut für Angewandte Geophysik
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