



DELIVERABLE 5.9

CLUSTER ACTIVITIES WITH SISTER PROJECTS

Work Package 5

Synthesis, Overall Communication & Outreach

30-09-2025

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Abstract	This deliverable outlines joint actions among three projects (New-Harmonica, NAPSEA, NORDBALT-ECOSAFE) funded under HORIZON-CL6-2021-ZEROPOLLUTION-01-01. They cover common topics across EU regions, including the UK and Norway, aiming to share methods, findings, and maximize impact through collaboration.
Keywords	Sister projects; NAPSEA; NORDBALT-ECOSAFE; NEW-Harmonica; joint actions

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List of abbreviations

BMP	Best Management Practices
DG RTD	Directorate-General for Research and Innovation
HELCOM	Helsinki Commission
LUWQ	Land-Use Water Quality
OSPAR	Oslo Paris conventions
REA	Executive agency for research

Executive summary

This deliverable will provide an overview of the joint actions for the three projects funded under the topic HORIZON-CL6-2021-ZEROPOLLUTION-01-01 (New-Harmonica, NAPSEA, NORDBALT-ECOSAFE). The three projects have many topics in common and covers different regions of EU and outside (UK and Norway). These projects will share methodologies and findings, identify synergies, as well as come up with joint actions that could maximize the overall impact of the projects.

1. Introduction

The three projects funded under the topic HORIZON-CL6-2021-ZEROPOLLUTION-01-01 are:

- New-Harmonica – coordinated by Wageningen University, The Netherlands
- NAPSEA – coordinated by Deltares, The Netherlands
- NORDBALT-ECOSAFE – coordinated by Aarhus University, Denmark.

The three projects have many topics in common and covers different regions of EU and outside (UK and Norway). These projects will share methodologies and findings, identify synergies, as well as come up with joint actions that could maximize the overall impact of the projects. In this report the actions are described in more detail.

2. Joint actions

Kick-off meeting

- Monday 24 October from 9h30 to 12h00

The event will gather Coordinators and Work Package leaders of the three new funded projects, as well as the Policy Officer of DG RTD and will be facilitated by REA.

The aim was to start exchanges and identify synergies, as well as joint actions among Consortia bearing the potential to maximize the overall impacts and outreach of projects. Agenda and more information in Appendix I.

Outcomes of the first meeting were that:

- the EU Commission proposed to form a cluster between the projects and define a joint roadmap for collaboration during the 3 years of the projects.
- The coordinators for each of the projects gave a brief presentation of the content of each of the projects with overview of aims, work packages and institutes involved.
- A follow-up meeting to tackle the first three topics between the three projects to take place before the 30th November 2022.

This formed the basis for questions and discussion of possible collaborations and thematic areas where possible synergies, joint communication efforts, etc., were foreseen.

First suggestions where for collaboration in the following topic areas:

- Project disseminations – like joint webinars, policy notes, final workshop.
- Project home page – create an overarching home page for the cluster of projects
- Working together on governance methods and policy across our regions.
- Working together on nature Based Solutions and Mitigation Methods – derive a joint Classification Framework for those included in our projects.
- Develop a harmonized framework for our modelling approaches – to ensure that the outcomes can be compared.
- Develop a common methodology and way of making climate change scenarios.
- Databases for our models and outputs.

Follow up meetings

On the 30th of November a follow up meeting was held between the three sister projects. More information about this meeting in Appendix II.

Mid-term meeting NORDBALT-ECOSAFE

NAPSEA and NEW-HARMONICA projects were represented with a presentation of their projects at the mid-term meeting of NORDBALT-ECOSAFE on the 19-21st February, 2024, in Aarhus, Denmark. More information about this meeting in Appendix III.

Conference LUWQ 2025

The three projects organized a joint special session at LUWQ2025 in Aarhus, Denmark 2-5th June 2025. More information about this joint session in the Appendix IV as well as in deliverable 5.8 (joint policy brief).

Joint policy brief

See deliverable 5.8 for more information on this.

Appendix I

Agenda and more information on joint kick-off meeting.



Joint Kick-off meeting of the new funded projects on “Regional nitrogen and phosphorus load reduction approach within safe ecological boundaries”¹

Webex

Description and objectives

The event will gather Coordinators and Work Package leaders of the three new funded projects, as well as the Policy Officer of DG RTD and will be facilitated by REA.

The aim is to start exchanges and identify synergies, as well as joint actions among Consortia bearing the potential to maximize the overall impacts and outreach of projects.

Expected outcomes:

- Introduce new projects, including objectives and activities towards clustering with other projects;
- Improved awareness of synergies and collaboration potential among projects;
- Discuss ways on how the projects can contribute to future policy developments and decision making;
- Shared commitments and joint actions on dissemination activities and stakeholder engagement.

¹ Topic HORIZON-CL6-2021-ZEROPOLLUTION-01-01

<i>09:15 – 09:30</i>	<i>Connecting to the meeting & participation guidelines</i>
09:30 – 09:40	Opening and introduction of the session's activities Blanca Saez Lacave & Sofia Pachini Project Adviser (REA) (10 min)
09:40 – 10:00	➤ Presentation on policy aspects ➤ Silvia Maltagliati, Policy Officer in Circular Economy & Biobased Systems, European Commission, Directorate General for Research and Innovation (15 min) ➤ Q&A (5 min)
10:00 – 10:20	➤ Project presentation: NAPSEA ➤ – Project Coordinator (15 min max) ➤ Q&A (5 min)
10:20– 10:40	➤ Project presentation: NORDBALT-ECOSAFE ➤ – Project Coordinator (15 min max) ➤ Q&A (5 min)
10:40 – 11:00	➤ Project presentation: NEW-HARMONICA ➤ – Project Coordinator (15 min max) ➤ Q&A (5 min)
11:00-11:15	➤ Break
11:15 – 11:50	➤ Discussion on synergies, common deliverables and events ➤
11:50– 12:00	Closing of the session Blanca Saez Lacave & Sofia Pachini, Project Adviser (REA)

Minutes of meeting held with EU Commission between three sister projects under funded under HORIZON-CL6-2021-ZEROPOLLUTION-01-01

The three projects funded under this thematic call is:

New-Harmonica – coordinated by Wageningen University, The Netherlands

NAPSEA – lead by Deltares, The Netherlands

NORDBALT-ECOSAFE – coordinated by Aarhus University, Denmark

The three projects have many topics in common and covers different regions of EU and outside (UK and Norway).

The aim of the meeting from the EU Commission is to provide a basis for collaboration and exploitation of synergies between these three funded projects.

Therefore, the EU Commission proposed to form a cluster between the projects and define a joint roadmap for collaboration during the 3 years of the projects.

The coordinators for each of the projects gave a brief presentation of the content of each of the projects with overview of aims, work packages and institutes involved.

This formed the basis for questions and discussion of possible collaborations and thematic areas where we can foresee possible synergies, joint communication efforts, etc.

First suggestions where for collaboration in the following topic areas:

1. Project disseminations – like joint webinars, policy notes, final workshop.
2. Project home page – create an overarching home page for the cluster of projects
3. Working together on governance methods and policy across our regions.
4. Working together on nature Based Solutions and Mitigation Methods – derive a joint Classification Framework for those included in our projects.
5. Develop a harmonized framework for our modeling approaches – to ensure that the outcomes can be compared.
6. Develop a common methodology and way of making climate change scenarios.
7. Databases for our models and outputs.

We decided to have a first meeting on the first three topics between the three projects to take place before the 30th November 2022.

Brian Kronvang, Aarhus University will take the lead for arranging this first online meeting and send around a Doodle for planning of a suitable date and time for this meeting.

Each of the three projects will send to Brian the names and e-mails of those participants that they believe should take part in this first meeting - that again only covers the first three topics on the list above.

At the meeting sub-groups are foreseen to be established around different topics.

Appendix II

Agenda and more information on joint follow-up meeting.



Funded by the
European Union

This project has received funding from the European Union's Horizon Europe research and innovation programme under Grant Agreement No. 101060020



Meeting between EU projects NAPSEA, NEW-Harmonica and NordBalt-Ecosafe

Discussion of future collaboration needs on different topics and planning for a road-map

<https://projects.au.dk/nordbalt-ecosafe>



Draft agenda for the meeting

- › **1. Introduction to meeting and participants**
- › **2. Discussion of joint work on topic about policy and governance**
- › **3. Discussion of joint work on topic about mitigation measures**
- › **4, Discussion of Road Map including joint disseminations**
- › **5. Next meetings in sub-groups and between projects**

Topic 4: Road map

- › Suggestion to hold joint webinars (1-2 per year) on selected topics with invited presenters from the three projects and one invited from outside – maybe plan for launching a first joint webinar in late spring 2023?
- › Topics could be:
 1. Safe ecological boundaries in water bodies in the regions
 2. Establishing reference nutrient concentrations
 3. NBS and Mitigation Measures
 4. Modelling nutrient hot spots for management
 5. ?
 6. ?

Road Map continued

- › **Suggestion to have a joint meeting with WP-leads+ in autumn 2023 or spring 2024 to present first outcomes from projects and how to integrate results in joint policy briefs/papers/etc. – meeting venue could be Sandbjerg Estate in Sourthern Jutland, Denmark owned by AU.**

- › **Suggestion to host special sessions at LUWQ2024 - jointly on different topics or project based?**

Main conclusions from the meeting

- › To establish a joint Teams folder for our sharing of documents, logo's, etc. – Brian Kronvang, AU
- › To send around an excel sheet to fill in by coordinators for people interested in the four different topics we have identified as common ground – Brian Kronvang
- › Coordinators of the three projects to meet regularly (every 4 month: Brian Kronvang will invite)
- › We agreed to have a joint meeting between the WP-leads from the three projects in spring 2024 – at Sandbjerg Estate, Denmark
- › We agreed to seek for hosting special sessions at LUWQ2024 in The Netherlands in 2024.
- › We will also investigate the possibility of hosting joint webinars.

Topics identified for collaboration between the three projects with first leads to take actions are:

- › Policy and Governance: Oscar Schoumans, Wageningen
- › Mitigation Measures/BMP's: Katrin Bieger AU
- › Models: xxx Deltares
- › Ecological safe boundaries: Brian Kronvang, AU

Summary of decisions taken during a status meeting between coordinators for the three Horizon Zero Pollution projects: NAPSEA, NEW-HAMONICA and NORDBALT-ECOSAFE hold on 15th January 2024.

Participants:

Gerard Velthof, Wageningen University and Research for NEW-HARMONICA

Anouk Blauw and Luuk van der Heijden, DELTARES for NAPSEA

Brian Kronvang, Aarhus University for NORDBALT-ECOSAFE

A teams meeting was held with the following agenda:

1. Short briefing about deliverables and progress within projects – 10 minutes for each project.

The three projects presented the status of their projects in brief with a focus on the deliverables produced and upcoming ones.

2. Discussion about planning for joint policy briefs – themes, planning and deadline.

We decided to at least plan for a joint policy brief about how to bridge the gap between present day nutrient levels and the boundaries set for achieving good ecological conditions for nitrogen and phosphorus in our total of 13 river basins covered in the three project (NEW-HARMONICA: 4 river basins; NAPSEA: 3 river basins; NORDBALT-ECOSAFE: 6 river basins). We plan to have a physical meeting about this back to back with the Land Use and Water Quality Conference in Aarhus, Denmark in 2025. Other joint policy briefs or other papers might appear from the work in our project WP's.

Possible main focus points for joint Policy Brief between the three projects:

- Nitrogen and phosphorus safe ecological boundaries in surface waters.
- Identified nutrient gaps from different sectors in our river basins.
- Available BMP's within our participating countries, regions and river basins.
- Models and Governance methods applied

Our project river basins are all either draining to the Balic Sea (HELCOM) or North Sea (OSPAR).

3. Discussion about joint meetings – Conferences – e.g. special session at LUWQ2025 in Aarhus, Denmark.

We agreed to apply for having a joint special session at LUWQ2025 in Aarhus, Denmark 2-5th June 2025. We will make a joint letter between the three projects applying for a special session and submit to the LUWQ2025 organizers as soon as possible.

4. Other business

We have now established the following three project home pages:

NEW-HARMONICA: <https://newharmonica.eu/>

NAPSEA: <https://napsea.eu/>

NORDBALT-ECOSAFE: <https://projects.au.dk/nordbalt-ecosafe>

We have also a shared teams folder for the three projects that will be updated with information about deliverables from the three projects before 1st February 2024 and onwards to share information between our projects.

Moreover, NAPSEA and NEW-HARMONICA projects are represented with a presentation of their projects at the upcoming mid-term meeting in NORDBAL-ECOSAFE 19-21st February 2024 in Aarhus, Denmark.

Appendix III

Agenda and more information on mid-term meeting of NORDBALT-ECOSAFE.



NORDBALT-ECOSAFE all-partner meeting 19-21st February 2024
Location: Hejmdal Conference House, Peter Sabroes Gade 1, 8000
Aarhus C – on Aarhus University Campus



HEJMDAL

MØDE- OG KONFERENCEHUS

Monday 19th February

Morning: Individual meetings if arrival on Sunday

12.00-13.00	Arrival and Lunch
13.00-13.30	Welcome and practical arrangements etc.
13.30-14.00	Information about requirements for our project periodic report to EU
14.00-15.00	Status of project work - one hour per WP – important results, upcoming deliverables, etc. – WP1.
15.00-15.30	Coffee/Tea
15.30-18.30	Status of project work - one hour per WP – important results, upcoming deliverables, etc. – WP2, WP3 & WP4.
18.30-19.30	Check-in at hotel for those arriving on Monday.
19.30-	Dinner at Hejmdal House,

Tuesday 20th February

09.00-11.00	Status of project work - one hour per WP – important results, upcoming deliverables, etc. - WP5 & WP6
11.00-12.00	Short news from PO, sister EU projects – NEW-Harmonica, NAPSEA
12.00-13.00	Lunch
13.00-15.30	Free time for WP or cross-WP discussions (will be finally planned for) 13.00-14.00: 1. round WP1 & WP2 & WP6. 14.00-15.00: 2. round: WP3 & WP4 & WP5 15.00-15.30: Time for other meetings
15.30-16.00	Coffee/Tea
16.00-18.00	Modelling Workshop – presentations from OPTAIN and own SWAT+ model setup from WP4
18.30-	Dinner at Hejmdal House
20.30	Free for smaller meetings in WPs or across WPs

Wednesday 21st February

09.00-10.30	Planning for next round of stakeholder meetings in autumn 2024 (September/October) – what should be the main themes for the meetings (G/M boundaries, modelling, mitigation measures)? Do we need feedbacks like last time via Mentimeter?
10.30-11.45	Planning for dissemination strategies, conferences and proposal for webinars
11.45-12.00	Wrapping up
12.00-13.00	Lunch and departure for those not taking part in back to back WP workshops
13.00-18.00	Parallel WP workshops at Hejmdal House
18.00	Departure from Hejmdal House

Appendix IV

Agenda and more information on special session at LUWQ conference 2025 in Aarhus, Denmark.

- Highlighting the website of LUWQ
- The program of the LUWQ conference
- The volume of abstracts of the LUWQ conference



Special Sessions

In addition to Themes A to J (see webpage Themes and Topics) it is also possible to submit abstracts to two Special sessions: S1 and S2. A Special session gives a possibility to prominently discuss/present an issue that strictly speaking would not fit (fully) in either of the Themes A to J.

Session S1. 'Finding solutions for a good ecological and chemical quality in freshwater and marine water bodies in the Baltic Sea, North Sea and Irish Sea regions'.

The three Horizon Zero pollution EU sister projects: 1) NEW-HAMONICA: <https://newharmonica.eu/>; coordinated by Gerard Velthof, Wageningen University and Research, NL; 2) NAPSEA: <https://napsea.eu/>; Coordinated by Luuk van der Heijden and Anouk Blauw, Deltares, NL; 3) NORDBALT-ECOSAFE: <https://projects.au.dk/nordbalt-ecosafe>; Coordinated by Brian Kronvang, Aarhus University, DK will host a special session that involves urgent questions to be solved for the Water Framework Directive, Nitrates Directive and the Marine Strategy Framework Directive. The three projects aim to develop new standards for setting safe ecological boundaries in water bodies and developing novel nutrient regulations using models, mitigation and policy tools and governance schemes.

The special session will cover the following aspects of the three sister projects:

- What are the nutrient boundaries between good and moderate ecological conditions in different types of surface water bodies?
- Can we correctly model nutrient concentrations, loadings, and sources in river basins?
- How can we meet the nutrient boundaries choosing the regional Best Management Practices, Mitigation Measures and Nature based Solutions (NbS)?
- How to choose among governance methods for implementing mitigation measures and NBSs with inclusion of examples from the NORDIC-BALTIC region?

This special session will share the main results from the three projects through short presentations focusing on main project outcomes. Moreover, we will invite for a longer plenary discussion in the special session about the shared outcomes of the three projects (policy brief) with gathering of feedbacks from the audience through a virtual discussion.

International Interdisciplinary Conference on Land Use and Water Quality Agriculture and the Environment Aarhus, Denmark, 3–6 June 2025



Conference Programme

Main organiser



AARHUS
UNIVERSITY

DCE – DANISH CENTRE FOR ENVIRONMENT AND ENERGY

DCE - Danish Centre for Environment and Energy,
Aarhus University, Denmark



AARHUS
UNIVERSITY

DEPARTMENT OF BIOSCIENCE

Department of Bioscience,
Aarhus University, Denmark



G E U S

Geological Survey of Denmark
and Greenland (GEUS)

Co-organisers



National Institute for Public Health
and the Environment
Ministry of Health, Welfare and Sport

RIVM National Institute for Public Health
and the Environment, the Netherlands



Forschungszentrum Jülich (FZJ),
Agrosphere Institute (IBG-3),
Jülich, Germany,

LuWQ2025

International Interdisciplinary Conference

on

Land Use and Water Quality

Agriculture and the Environment

Aarhus, Denmark,

3 - 6 June 2025

Conference Programme

Version 06-06-2025



International Interdisciplinary Conference on
Land Use and Water Quality
Agriculture and the Environment
Aarhus, Denmark, 3–6 June 2025

Welcome

Welcome to LuWQ2025 in Aarhus! We are delighted that you have decided to join us here. Based on a large number of high-quality abstracts, we have been able to develop a programme that covers a wide range of topics related to the scope of the conference:

Land use and Water Quality.

We hope that this will be a conference filled with interesting new knowledge, meeting new people and fruitful discussions.

Contact Organising Committee

For all questions related to the technical/scientific content of the conference, the conference publications and the conference programme, please contact one of the members of the Organising Committee (by email info@luwq2025.nl or via the registration desk during the conference).

Lærke Thorling – Geological Survey of Denmark and Greenland (GEUS), Denmark

Gitte Blicher-Mathiesen – Department of Ecoscience - Aarhus University, Denmark

Susanne Wuijts – RIVM National Institute for Public Health and the Environment/Utrecht University, the Netherlands

Richard van Duijnen – RIVM National Institute for Public Health and the Environment, the Netherlands

Björn Tetzlaff – Forschungszentrum Jülich (FZJ), Agrosphere Institute (IBG-3), Germany

Frank Wendland – Forschungszentrum Jülich (FZJ), Agrosphere Institute (IBG-3), Germany

Jointly convened by

Geological Survey of Denmark and Greenland (GEUS), Copenhagen, Denmark

Department of Ecoscience, Aarhus University, Denmark

DCE – Danish Centre for Environment and Energy, Aarhus University, Denmark

Forschungszentrum Jülich (FZJ), Agrosphere Institute (IBG-3), Jülich, Germany

RIVM National Institute for Public Health and the Environment, Centre for Environmental Quality, Bilthoven, the Netherlands

Main organiser



DCE - Danish Centre for Environment and Energy,
Aarhus University, Denmark



Department of Bioscience,
Aarhus University, Denmark



Geological Survey of Denmark
and Greenland (GEUS)

Co-organisers



RIVM National Institute for Public Health
and the Environment, the Netherlands



Forschungszentrum Jülich (FZJ),
Agrosphere Institute (IBG-3),
Jülich, Germany,

Important congress information, addresses and activities

Conference venue	- Aarhus University, Lake Lecture Theaters, building 1250, Bartholins Allé 3, 8000 Aarhus, Denmark
Icebreaker and Conference Pre-registration	- Aarhus University, Vandrehallen, building 1410, Nordre Ringgade 4, 8000 Aarhus, Denmark
Conference Dinner	- Restaurant Varna Palæet, Ørneredevej 3, 8000 Aarhus, Denmark
Aarhus Central Station	- Banegårdspladsen 1, 8000 Aarhus, Denmark
Airport busses	- Busses to Aarhus Airport and Billund Airport Banegårdspladsen (in front of Aarhus Central Station)

Parking at Aarhus University

Please note that parking at Aarhus University is limited. We therefore kindly recommend participants to use public transportation whenever possible.

Both Letbanen (train) and bus are available near [Søauditoriet](#).

Vehicle registration

If you plan to park at Aarhus University, you **MUST** register your vehicle to avoid a fine.

Click the link below to register for a parking permit valid from **2 June 2025 at 7:00 AM to 6 June 2025 at 11:00 PM**:

<https://parkcare.parkzone.dk/Link/?2f594937505844764e593766536174713268776635654f2f456b335065436f6e>

The parking permit is valid only during the above period and exclusively for staff parking areas in the University Park (Universitetsparken) designated as Aarhus University staff parking. These parking spaces are marked with black ParkZone signs labelled “**AU medarbejderparkering / AU Staff Parking**”.

Please note that the permit is not valid for:

- Parking areas near the Natural History Museum and the Steno Museum.
- Public streets in and around University Park, where municipal parking regulations apply as indicated by signage.

If you enter an incorrect license plate number during registration, please return to the link and enter the correct number.

For any questions regarding parking, please contact us at tek@au.dk.

Conference dinner busses

To get to the conference dinner location, participants can take a nice scenic walk along the coast from the Tangkrogen/Strandvejen busstation (around 1.7 km to the restaurant) or go straight with public transport to the Oddervej/Strandvejen busstation (500 meters from the restaurant). Busses will be arranged for the return journey to the city centre at the end of the dinner.

Reception – Icebreaker

The Icebreaker event will take place Monday evening June 2nd at 18:00 to 20:00 at the Aarhus University Campus, next to the main assembly hall in the “Vandrehallen” (“the walking hall”). Use this opportunity to get acquainted with the campus and meet new and old colleagues!

The address is Building 1410, [Nordre Ringgade 4, 8000 Aarhus, Denmark](#)

Walking Tour with a guide

On Wednesday afternoon, guided walking tours will be offered. Participants can choose between two routes: one exploring the historic Old Town and the other showcasing the new part of the city, known for its modern architecture. Along the way, guides will also share insights about Aarhus university and its significance to the city. All tours will start at the conference venue. The tour of each group will end at a restaurant where a reservation has been made for dinner (medium priced restaurants). If you want to join the walking tour you can register at the registration desk. Participants have to pay for their own dinner costs. The guides are already paid for.

Vouchers for ARoS Art Museum or Old Town

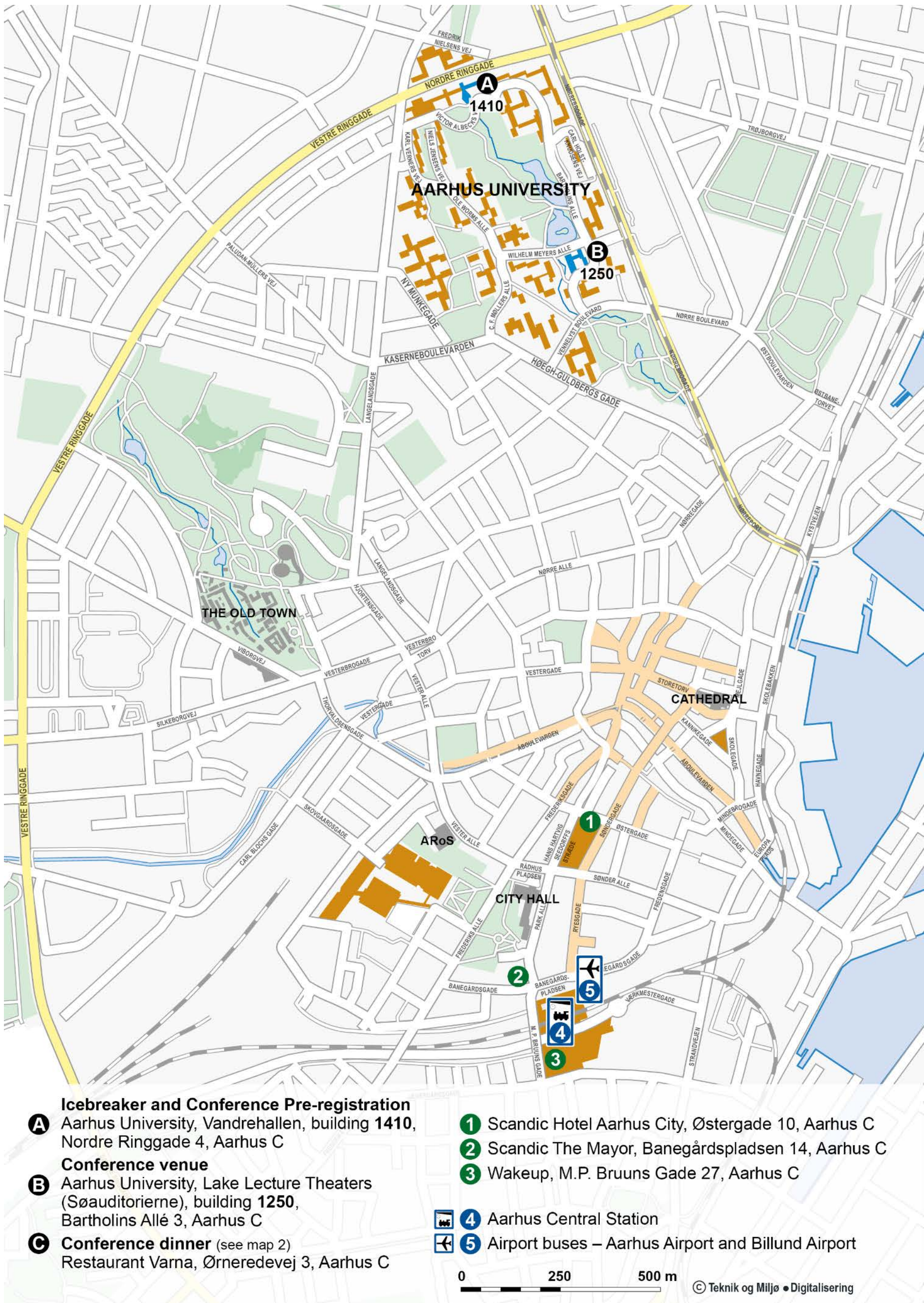
At the registration desk you can request a free voucher for visiting either the ARoS Art Museum, featuring Olafur Eliason's “Your rainbow panorama” and Ron Mueck’s “Boy” collection (<https://aros.dk/en/>), or the Open Air Old Town Museum, which offers a fascinating time journey through 400 years of Danish history (<https://www.dengamleby.dk/en/>).

Irish Pub

Meet your colleagues and relax together after the conference fuss. LuWQ2025 has reserved part of the Irish pub Tir Na Nog, in the centre of Aarhus, on Wednesday and Thursday evenings in the FLUX room. The pub is situated close to most hotels and restaurants. If you don't join the walking tour, eat your dinner here or join us after a visit to one the many different other restaurants or cafés in central Aarhus.

Situated at [Frederiksgade 38-42, 8000 Århus C.](#)

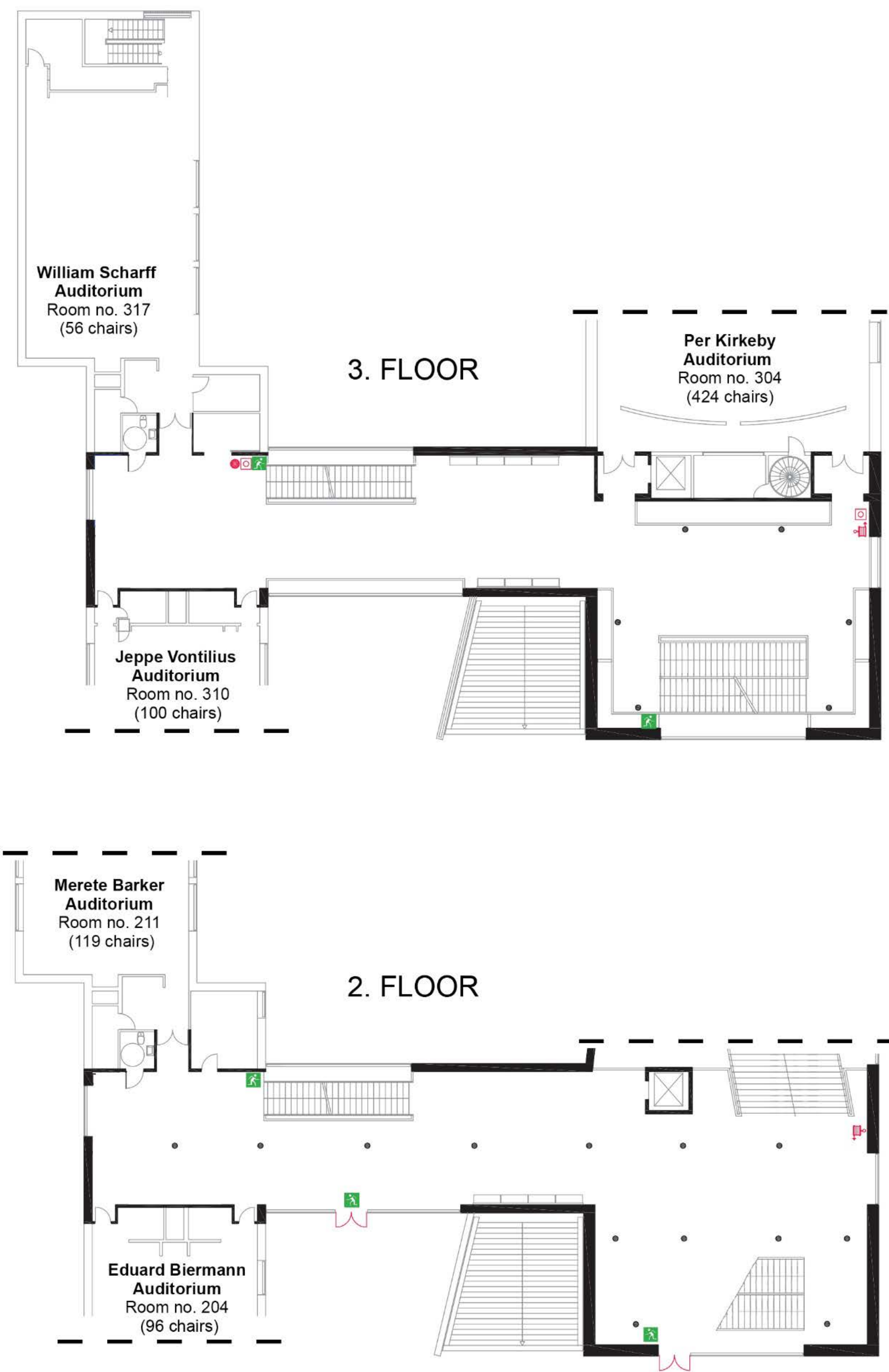
Map 1 – Overview Map of Aarhus and important conference locations



Map 2 – Overview Map of Aarhus and important conference locations



Map 3 – Overview Map LuWQ2025 conference rooms at Aarhus University



LuWQ2025 Conference Themes and Topics

Contributions are solicited according to the following themes, themes A to J.

Themes

A. Driving forces for trends in agriculture and water quality:

UN sustainable development goals (SDGs), food-energy-water nexus, Green Deal, climate change and strategies, trade-offs from other developments (e.g. urbanization, water reuse., climate migration, population growth).

B. Increasing our understanding of ‘systems functioning’:

research, tools and methodologies to increase understanding and improving modelling of the hydro(geo)logical, geochemical and biochemical processes.

C. Water quality monitoring:

improving the effectiveness and increasing the added value of monitoring – use of new sensor techniques, remote sensing, dating of groundwater, improved (meta)data management, analysis and interpretation, modelling and generalisation of observations, and assessment of status and trends.

D. Impact of weather variability and climate change on water quality:

assessment of impact on land use, groundwater and surface water quality.

E. Assessment of national or regional policy:

effectiveness of programs of measures on water quality on a regional and national scale.

F. Managing protected areas for water supply and nature conservation:

risk assessment techniques, monitoring and modelling of water quality and quantity for the protection of (a) water resources for drinking water supply, and (b) groundwater dependent terrestrial ecosystems.

G. Improving water quality by farm management practices:

research (monitoring and modelling) at plot, field and catchment scales to quantify the effects of farming practices and changes in land use.

H. Improving water quality by establishing eco-technological mitigation measures:

development, testing, implementation and operation at plot, field and catchment scales to quantify the effects of structural measures.

I. Development and Decision-making on Programs of Measures:

the role of stakeholder input and science in policy decision-making.

J. Implementation, Evaluation and Adaptation of Programs of Measures:

social and economic incentives and regulatory mandates that drive implementation (carrots and sticks), catchment officers, etc.

Special Sessions

In addition to the Conference Themes A to J it was also possible to submit abstracts to two Special sessions, namely:

Session S1. Special Session on finding solutions for a good ecological and chemical quality in the North Sea and Baltic Sea.

- Presentation of the main results from NAPSEA: Current challenges to reduce nutrient pollution, eutrophication and its negative impacts on inland and coastal waters are addressed by an integrated approach focusing on nutrient pollution from source to sea.
- Presentation of the main results from NEW-HARMONICA: Combining science and policy to maximize the uptake and effectiveness of best management practices to improve water quality in NW European river basins.
- Presentation of the main results from NORDBALT-ECOSAFE: Nitrogen and phosphorus load reduction approach within safe ecological boundaries for the Nordic-Baltic region.

Session S2. Special Session on the Water Framework Directive: challenges and pathways towards 2027.

- Towards a Good Ecological Status? The Prospects for the Third Implementation Cycle of the EU Water Framework Directive in The Netherlands.
- Policy entrepreneurs' strategies leading to effective hydro morphological measures, Lessons learned from good practices in the Netherlands.
- Can a sewage treatment plant expand even if it increases the phosphorus load to a recipient where it needs to decrease? A case study from Uppsala, Sweden.
- Deficiencies and action perspectives for WFD objective achievement in the Netherlands.
- Closing the Gap: Are the Measures Achieving Water Quality Objectives in Ireland?
- The necessity for and implementation of the right measures in the right places to combat eutrophication from agriculture.

For details on Special Sessions refer to webpage [Special Sessions & Side Events](#).

Side events

During the LuWQ2025 conference, two side-events are organised. Interested LuWQ-participants are welcome to an open discussion about the following subjects:

Drinking water and agriculture. Discussing strategies to enable 'groundwater-friendly agriculture'

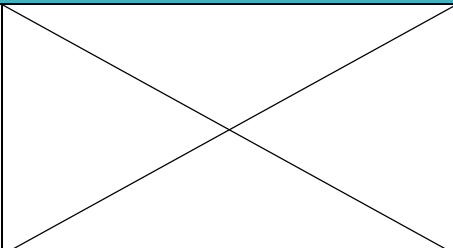
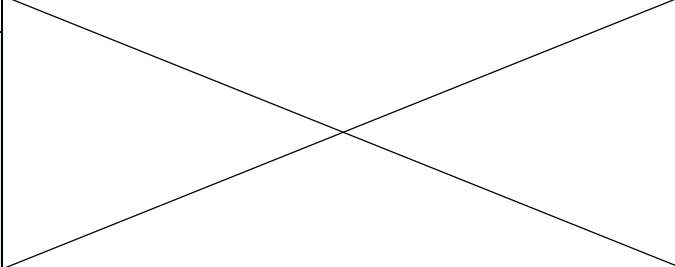
Scheduled for Wednesday 4 June 2025 10:30-12 AM.

New Harmonica. Improving institutional arrangements for nutrient governance

Scheduled for Thursday 5 June 2025 10:30-12 AM.

For details on the Side events refer to webpage [Special Sessions & Side Events](#).

Overview Preliminary Programme LuWQ-2025 conference

Monday 2/6/'25 "Vandrehallen" (Walking Hall) , Aarhus University Campus								17:00 - 20:00	18:00 – 20:00
								Pre-registration.	Welcome, Icebreaker
Tuesday 3/6/'25 Søauditorierne (Lakeside Lecture Theatres), Aarhus University Campus									
7:30 - 8:30	8:30 - 10:00	10:00 - 10:30	10:30 - 12:00	12:00 - 13:00	13:00 - 14:30	14:30 - 15:00	15:00 - 16:15	18:30 - ?	
Registration. Posters to be installed. <i>Open all day</i>	Plenary session P.1 Welcome & Introduction A new green deal for the Danish water management	Coffee break 	Parallel sessions B.1 / E.1 / G.1	Lunch break 	Parallel sessions D.1 / J.1 / C.1	Coffee break 	Parallel sessions F.1 / H.1 / Poster pitches	Conference Dinner 	
	Posters on display								
Wednesday 4/6/'25 Søauditorierne (Lakeside Lecture Theatres), Aarhus University Campus									
7:30 - 8:30	8:30 - 10:00	10:00 - 10:30	10:30 - 12:00	12:00 - 13:00	13:00 - 14:30	14:30 - 15:00	15:00 - 16:15	16:30 - ?	
Registration. Posters to be installed. <i>Open all day</i>	Plenary session P.2 EU water ambitions: Implementation challenges	Coffee break 	Parallel sessions B.2 / E.2 / I.1 / Side event	Lunch break 	Parallel sessions S1.1 / S.2.1 / C.2	Coffee break 	Parallel sessions S1.2 / S2.2	Guided walks through Aarhus	
	Posters on display								
Thursday 5/6/'25 Søauditorierne (Lakeside Lecture Theatres), Aarhus University Campus									
7:30 - 8:30	8:30 - 10:00	10:00 - 10:30	10:30 - 12:00	12:00 - 13:00	13:00 - 14:30	14:30 - 15:00	15:00 - 16:15	16:15 – 18:15	
Registration. Posters to be installed. <i>Open all day</i>	Plenary session P.3 From policy to strategies leading to water quality improvement	Coffee break 	Parallel sessions B.3 / E.3 / G.2 / Side event	Lunch break 	Parallel sessions D.2 / C.3 / H.2	Coffee break 	Parallel sessions B.4 / J.2	Poster session with drinks and snacks	
	Posters on display								
Friday 6/6/'25 Søauditorierne (Lakeside Lecture Theatres), Aarhus University Campus									
7:30 - 8:30	8:30 - 10:00	10:00 - 10:30	10:30 - 12:00	12:00 - 13:00	13:00 - 14:00				
Registration. <i>Open all day</i>	Plenary session P.4 Land use and water quality management from continents other than Europe	Coffee break 	Parallel sessions B.5 / D.3 / G.3	Lunch break, posters to be removed 	Plenary session P.5 Wrap up, key messages and Closure				
	Posters on display								

Tuesday 03-06-2025

7:30 - 8:30				Registration. Posters to be installed. Ppt. sent by email to info@luwq2025.nl by 2 June 10 AM. Registration desk open all day. Organising Committee Contact: <i>Richard van Duijnen</i>					
				Per Kirkeby Auditorium (3. Floor – Room no. 304)					
8:30 - 10:00				Welcome & Introduction (Plenary session P.1) (<i>Chairs: Gitte Blicher-Mathiesen/Lærke Thorling</i>)					
8:30 - 10:00				Welcome from Århus University. <i>Maria Sommer Holtze</i> Welcome from GEUS. <i>Claus Kjøller</i> Welcome from the Danish Minister of Green Transition. <i>Jeppe Bruus</i> A new green deal for the Danish water management. <i>Peter Kaarup</i> #1 Multidisciplinary capacity development to improve water quality affected by agricultural pollution: An introduction to the LuWQ2025 conference. <i>Lærke Thorling and Gitte Blicher-Mathiesen</i> Practical issues during the conference. <i>Lærke Thorling</i>					
				Main Hall 2. Floor					
10:00 - 10:30				Coffee break					
				Eduard Biermann Auditorium (2. Floor – room no. 204)		Merete Baker Auditorium (2. Floor – Room no. 211)		Jeppe Vontilius Auditorium (3. Floor - Room no. 310)	
10:30 - 12:00				Understanding of ‘systems functioning’ (B.1) (<i>Chairs: Katri Rankinen/Job Spijker</i>)		Assessment of national or regional policy (E.1) (<i>Chairs: Wibke Christel/Dominika Krzeminska</i>)		Improving water quality by farm management practices (G.1) (<i>Chairs: Gerard Velthof/Morten Graversgaard</i>)	
10:30 - 10:45				#7 Impact of transfer time on trends in nitrate concentrations in mainland France. <i>Nicolas Surdyk</i>		#11 Effects of the tightened German Fertiliser Ordinance in practice - findings from model regions. <i>Burkhard Stever-Schoo</i>		#3 Effect of catch crops after maize and potato on nitrate concentrations in groundwater: 3-4 years of measurements using various catch crops. <i>Rene Rietra</i>	
10:45 - 11:00				#33 How dynamic are flow contributions and mean water ages in a diverse group of regional rivers? <i>Roland Stenger</i>		#21 Predicting the effects of fertilizer policy on the nutrient leaching and runoff in the Netherlands. <i>Piet Groenendijk</i>		#68 The impact of crop rotations on fertiliser application rates in arable land-dominated agricultural area: a case study from Latvia. <i>Arturs Veinbergs</i>	
11:00 - 11:15				#52 National nitrogen model for national regulation of nitrogen. <i>Anker Lajer Højberg</i>		#117 Options to achieve the good ecological state of the Wadden Sea: Scenario analyses for the river basins of Elbe and Rhine. <i>Andreas Gericke</i>		#142 Assessment of the relationship between farm structure, farm management, and environmental quality on Dutch dairy and arable farms, and their impact on the nitrogen soil surplus. <i>Jamal Roskam</i>	
11:15 - 11:30				#53 Literature review and meta-analysis of denitrification rates for unconsolidated sedimentary aquifers. <i>Denitza Voutchkova</i>		#160 Assessing nutrient hotspots in Denmark’s agricultural fields: A focus on the livestock sector. <i>Raffaele Grieco</i>		#153 Satellite imaging insights on autumn cover, catch crop establishment, and nitrogen load in Danish catchments. <i>Anastasia Kratschmer</i>	
11:30 - 11:45				#90 Exploring Trends and Travel Times: 30 years of Groundwater Quality Monitoring in the Netherlands. <i>Hans Peter Broers</i>		#209 From 20 years of water quality and quantity monitoring at a river scale towards modelling in the future. <i>Ainis Lagzdins</i>		#162 Effects of different drainage systems on subsurface runoff and nitrogen leaching. <i>Franziska Katharina Fischer</i>	
11:45 - 12:00				#136 Assessing groundwater nitrate reduction on a national scale in Denmark. <i>Birgitte Hansen</i>		#232 Modelling nitrate transport at watershed outlets and identifying nitrate-vulnerable zones in agricultural areas using redoxcline and nitrate leaching data. <i>Abdul Hadi Al Nafi Khan</i>		Discussion	
				Main Hall 2. Floor					
12:00 - 13:00				Lunch break					
				Eduard Biermann Auditorium (2. Floor – room no. 204)		Merete Baker Auditorium (2. Floor – Room no. 211)		Jeppe Vontilius Auditorium (3. Floor - Room no. 310)	
13:00 - 14:30				Impact weather variability and climate change (D.1) (<i>Chairs: Thomas Harter/Tim Wolters</i>)		Implementation, Evaluation and Adaptation of Programmes of Measures (J.1) (<i>Chairs: Berit Hasler/Denitza Voutchkova</i>)		Water quality monitoring (impact, effectiveness) (C.1) (<i>Chairs: Job Spijker/Arno Hooijboer</i>)	
13:00 - 13:15				#85 From Rain to Runoff: Understanding Nutrient Dynamics in Dutch Agricultural Waters. <i>Kevin Ouwerkerk</i>		#16 Mainstreaming Natural/Small Water Retention Measures in Europe – evaluation of drivers and hindrances with a dedicated SWOT framework. <i>Federica Monaco</i>		#8 Untangling the relative importance of policy, soil moisture and land use variables on stream water quality. <i>Maelle Fresne</i>	
13:15 - 13:30				#124 Agricultural land lacks resistance to water erosion during the wettest winters of the past decade. <i>Yusheng Zhang</i>		#54 Building value in environmental monitoring for more informed decision-making about trade-offs between ecosystem services and disservices from nature-based solutions. <i>Martyn Futter</i>		#22 The use of high-frequency in-situ sensor measurements of nitrate concentrations for exploring the uncertainty of monthly and annual load calculations in two headwater Danish streams. <i>Sofie Gyritia Madsen van't Veen</i>	
13:30 - 13:45				#157 Flexible timing of agricultural practices depending on weather conditions. <i>Sophie Nawara</i>		#69 Aligning policies and practice: Addressing governance and capacity gaps in the implementation of ponds and wetlands in Swedish municipalities. <i>Nairomi Eriksson</i>		#25 A decision workflow for best practice in high-frequency water quality monitoring. <i>Joachim Rozemeijer</i>	
13:45 - 14:00				#180 Impacts of Climate Change on Nitrogen Use Efficiency in Germany. <i>Faranak Omid Saravani</i>		#129 Enhancing Water Quality in the Great Barrier Reef Catchments through Sustainable Agricultural Practices and Technological Innovation. <i>Mika Rowston</i>		#64 Understanding and improving water quality on local catchment scale: an example of cooperative monitoring and research by farmers and a regional water authority. <i>Frank van Herpen</i>	
14:00 - 14:15				#188 Strategies for climate adaptation in water quality and quantity management across Nordic countries: The Danish Cases. <i>Lone Juul</i>		#174 Agro-environmental measures – a catalogue framework for communication about efficiency and functionality. <i>Katarina Kyllmar</i>		#93 Using turbidity sensors to assess uncertainty in mean suspended sediment and phosphorus concentrations from infrequent water sampling. <i>Eva Skarbovik</i>	
14:15 - 14:30				#219 Climate change effect jeopardizes the effectiveness of the natural small water retention measures in mitigating nitrate losses in an agricultural catchment in Poland. <i>Mikolaj Piniewski</i>		#212 Effects of regulations and other drivers on nitrogen use in Germany. <i>Philipp Löw</i>		#121 Experiences with high resolution UV/Vis-spectrometric sensors to detect peaks and hot spots in river nutrient inputs in the catchment of Füsinger Au (Schlei Fjord, Baltic Sea). <i>Kirsten Rücker</i>	

Main Hall 2. Floor			
14:30 - 15:00 Coffee break			
	Eduard Biermann Auditorium (2. Floor – room no. 204)	Merete Baker Auditorium (2. Floor – Room no. 211)	Jeppe Vontilius Auditorium (3. Floor - Room no. 310)
15:00 - 16:15	Managing protected areas (F.1) (Chairs: Cors van den Brink/Wibke Christel)	Improving water quality by eco-technological measures (H.1) (Chairs: Katarina Kyllmar/ Ryan Turner)	Poster pitches (Chairs: Simon Buijs/Tessa Rotscheid/ Charlotte Offringa)
15:00 - 15:15	#63 Large scale implementation of groundwater protection in Aarhus Municipality. <i>Ulla Lyngs Ladekarl</i>	#24 Perspectives on available support motivating or demotivating adoption of agro-environmental measures. <i>Ingrid Nesheim</i>	#140 Novel high resolution monitoring program iFOODis of surface waters in relation agricultural activities and environmental factors in Northern Germany (Baltic Sea). <i>Loky Stein</i> #152 Farmers measuring their own on-farm water quality: experiences and outcomes. <i>Arno Hooijboer</i> #175 Installation of a woodchip bioreactor as an area specific approach to reduce nitrate loads from agriculture. <i>Joachim Rozemeijer</i> #235 Implementation of a climate-adapted water management in grasslands in North-West Germany – first effects on nutrient discharge and water availability. <i>Mareike Schloo</i> #236 Impact of drought on nitrate concentrations in leaching water from agricultural areas in the Netherlands. <i>Harm Wismans</i> #237 Anthropogenic Groundwater Contamination: A Case Study from the Nitra Region, Slovakia. <i>Katarína Tarabová</i> #239 Irish stakeholder collaboration in developing Ireland’s Nitrates Action Programme and beyond. <i>Noeleen McDonald</i> #155 Model simulations for climate-robust manure spreading and sowing of catch crops, <i>Mia Tits</i> #210 Water levels and dissolved organic carbon in deep-drained peatlands treated with subsurface irrigation. <i>Lydia Roesel</i>
15:15 - 15:30	#82 Nitrate Mitigation in Drinking Water Supply Management Areas. <i>Reid Christianson</i>	#38 Hydrological ecosystem services from constructed agricultural wetlands – now and in the future. <i>Alina Kuehn</i>	
15:30 - 15:45	#150 Setting safe ecological boundaries for nutrients for rivers and lakes in the Nordic and Central-Baltic regions. <i>Jan-Erik Thrane</i>	#206 Monitoring and Evaluating Targeted Mitigation Approaches to Improve Water Quality: Measures for Water. <i>Russell Adams</i>	
15:45 - 16:00	#184 Integrated Water and Nature Parks: A Nature-based Solutions Strategy in Aarhus Municipality for Improving Water Quality and Climate Adaptation. <i>Morten Revsbæk</i>	Discussion	
16:00 - 16:15	#159 Pesticides in Dutch sources for drinking water supply. <i>Arnaut van Loon</i>		
Restaurant Varna Palæet (Ørneredevej 3, 8000 Aarhus, Denmark)			
Start 18:30 Conference Dinner			

7:30 - 8:30		Registration desk open all day. Organising Committee Contact: <i>Björn Tetzlaff</i>	
	Per Kirkeby Auditorium (3. Floor – Room no. 304)		
8:30 - 10:00	EU water ambitions: Implementation challenges (Plenary session P.2) (<i>Chairs: Björn Tetzlaff/Gitte Blicher-Mathiesen</i>)		
8:30 - 9:00	#207 Large-scale land use changes ahead: Reducing nitrogen loss to the aquatic environment, greenhouse gas emissions from the agricultural sector and restoring nature in “a green Denmark”. <i>Wibke Christel</i>		
9:00 - 9:30	#17 Germany’s new impact monitoring on the effectiveness of the Nitrates Directive Action Program. <i>Maximilian Zinnbauer</i>		
9:30 - 10:00	#241 The rocky road towards water quality ambitions: experiences from the Netherlands. <i>Susanne Wuijts and Richard van Duijnen</i>		
Main Hall 2. Floor			
10:00 - 10:30		Coffee break	
	Eduard Biermann Auditorium (2. Floor – room no. 204)	Merete Baker Auditorium (2. Floor – Room no. 211)	Jeppe Vontilius Auditorium (3. Floor - Room no. 310)
10:30 - 12:00	Understanding of ‘systems functioning’ (B.2) (<i>Chairs: Roland Stenger/Nicolas Surdyk</i>)	Assessment of national or regional policy (E.2) (<i>Chairs: Birgitte Hansen/Piet Groenendijk</i>)	Development and Decision-making on Programmes of Measures (I.1) (<i>Chairs: Dominika Krzeminska/ Joachim Rozemeijer</i>)
10:30 - 10:45	#14 Decreasing TN and TP concentrations and increasing TOC concentrations in Finnish rivers. <i>Katri Rankinen</i>	#2 Understanding and Improving Institutional Arrangements for Nutrient Governance: Insights from the New Harmonica Project. <i>Nigel Watson</i>	#41 OPTAIN - Optimal strategies to retain and reuse water and nutrients in small agricultural catchments. <i>Martin Volk</i>
10:45 - 11:00	#55 Nitrous oxide emissions in agricultural streams: The critical influence of pH. <i>Mette Carstensen</i>	#100 Change to more sustainable dairy and arable farming: an integrated approach with attention for water quality. <i>Co Daatselaar</i>	#42 Locally Based River Basin Management Plan: An Integrated Modelling Framework for Ringkøbing Fjord. <i>Flemming Gertz</i>
11:00 - 11:15	#87 Nitrogen and phosphorus food system flows in five European livestock intensive catchments. <i>Shane Rothwell</i>	#49 Using Land Use to Predict the Risk Posed by Mixtures of Pesticide Active Ingredients in Waterways Entering the Great Barrier Reef Lagoon, Australia. <i>Cath Neelamraju</i>	#60 Pesticide metabolites – a regulatory perspective on an emerging group of contaminants for groundwater and drinking water. <i>Helena Banning</i>
11:15 - 11:30	#103 Sediment color as a predictor for subsurface redox conditions at large scale. <i>Hyojin Kim</i>	#203 Addressing Phosphorus Pollution in Interconnected Danish Lakes: A Spatial Environmental-Economic Analysis. <i>Raphael Filippelli</i>	#72 Eating the metaphorical elephant: Meeting nitrogen reduction goals in Upper Mississippi River Basin states. <i>Christopher Hay</i>
11:30 - 11:45	#134 Identifying the source of anthropic pressures on in-stream benthic algae communities. <i>Maria Snell</i>	#205 Impact of derogation from the Nitrates Directive on water quality: comparison of five European countries. <i>Simon Buijs</i>	#167 The establishment and use of local coastal water boards is tested in Denmark to find bottom-up solutions for RBMP 2027. <i>Kristoffer Piil</i>
11:45 - 12:00	#204 Spatially Differentiated Assessment of Denitrification Conditions in Groundwater across Germany. <i>Tim Wolters</i>	#233 Leaching of unexpected cyazofamid degradation products into groundwater demonstrates gaps in current pesticide risk assessment. <i>Nora Badawi</i>	#183 Identifying site-specific opportunities for implementing nutrient reduction measures in catchments. <i>Katrin Bieger</i>
10:30 - 12:00		William Scharff (3. Floor – Room no. 317) Side Event 'Strategies for groundwater-friendly agriculture' (<i>Chairs: Inez de Leau-Kolkman and Martin de Jonge</i>) Discussing strategies to enable 'groundwater-friendly agriculture'	
Main Hall 2. Floor			
12:00 - 13:00		Lunch break	
	Eduard Biermann Auditorium (2. Floor – room no. 204)	Merete Baker Auditorium (2. Floor – Room no. 211)	Jeppe Vontilius Auditorium (3. Floor - Room no. 310)
13:00 - 14:30	Finding solutions for a good ecological and chemical quality in freshwater and marine water bodies in the Baltic Sea, North Sea and Irish Sea regions (S1.1) (#244) (<i>Chairs: Brian Kronvang/Gerard Velthof</i>)	Special Session on the Water Framework Directive: challenges and pathways towards 2027 (S2.1) (#245) (<i>Chairs: Susanne Wuijts/Marleen van Rijswick</i>)	Water quality monitoring (impact, effectiveness) (C.2) (<i>Chairs: Gunnar Lischeid/Hyojin Kim</i>)
13:00 - 13:15	Presentation of the main results from NAPSEA: Current challenges to reduce nutrient pollution, eutrophication and its negative impacts on inland and coastal waters are addressed by an integrated approach focusing on nutrient pollution from source to sea. <i>Luuk van der Heijden and Anouk Blauw</i>	#18 Towards a Good Ecological Status? The Prospects for the Third Implementation Cycle of the EU Water Framework Directive in The Netherlands. <i>Carel Dieperink</i>	#29 Identifying waterlogging on arable fields - combining high-resolution distributed modelling and satellite images. <i>Faruk Djodjic</i>
13:15 - 13:30		#78 Policy entrepreneurs’ strategies leading to effective hydro morphological measures, Lessons learned from good practices in the Netherlands. <i>Charlotte Offringa</i>	#59 Monitoring vegetated buffer strips by using remote sensing data: Chances and Challenges in Germany. <i>Patrick Merita</i>
13:30 - 13:45	Presentation of the main results from NEW-HARMONICA: Combining science and policy to maximize the uptake and effectiveness of best management practices to improve water quality in NW European river basins. <i>Gerard Velthof</i>	#113 Can a sewage treatment plant expand even if it increases the phosphorus load to a recipient where it needs to decrease? A case study from Uppsala, Sweden. <i>Martin Erlandsson Lampa</i>	#107 Application of cell-based bioassays to assess toxicity in agriculture catchments contaminated with mixtures of pesticides. <i>Reinier Mann</i>
	Presentation of the main results from NORDBALT-ECOSAFE: Nitrogen and phosphorus load reduction approach within safe ecological boundaries for the Nordic-Baltic region. <i>Brian Kronvang</i>		
	Interactive discussion on cross-cutting observations and key-messages (see questions in volume of abstracts (#244))		

13:45 - 14:00		Discussion	#118 Long-term monitoring indicates that land use and soil drainage interactions drive macroinvertebrates and diatoms composition but not diversity in Irish agricultural catchments. <i>Jean Carlo Gonçalves Ortega</i>
14:00 - 14:15			#128 Hydrological and physico-chemical drivers of benthic diatom community dynamics in agricultural stream ecosystems. <i>Maria Snell</i>
14:15 - 14:30			#226 Assessing Pesticide Trends in Groundwater: A Comparative Study of the Netherlands and Denmark. <i>Mariëlle van Vliet</i>
Main Hall 2. Floor			
14:30 - 15:00 Coffee break			
	Eduard Biermann Auditorium (2. Floor – room no. 204)	Merete Baker Auditorium (2. Floor – Room no. 211)	
15:00 - 16:15	Finding solutions for a good ecological and chemical quality in freshwater and marine water bodies in the Baltic Sea, North Sea and Irish Sea regions (S1.2) (#244) (Chairs: Brian Kronvang/Gerard Velthof)	Special Session on the Water Framework Directive: challenges and pathways towards 2027 (S2.2) (#245) (Chairs: Susanne Wuijts/Marleen van Rijswick)	
15:00 - 15:15	A final discussion and debate on the shared outcomes of the three projects and key messages. The discussion questions can be found in the volume of abstracts (#244)	#148 Deficiencies and action perspectives for WFD objective achievement in the Netherlands. <i>Tessa Rotscheid</i>	
15:15 - 15:30		#181 Closing the Gap: Are the Measures Achieving Water Quality Objectives in Ireland? <i>Eva Mockler</i>	
15:30 - 15:45		#88 The necessity for and implementation of the right measures in the right places to combat eutrophication from agriculture. <i>Matilda Valman</i>	
15:45 - 16:00		Discussion	
16:00 - 16:15			
Start 16:30 Guided walks through Aarhus			

7:30 - 8:30Registration desk open all day. Organising Committee Contact: <i>Lærke Thorling</i>			
	Per Kirkeby Auditorium (3. Floor – Room no. 304)		
8:30 - 10:00	From policy to strategies leading to water quality improvement (Plenary session P.3) (Chairs: <i>Susanne Wuijts/Richard van Duijnen</i>)		
8:30 - 9:00	#222 Phosphorus pollution in Germany: actual state and developments. <i>Björn Tetzlaff</i>		
9:00 - 9:30	#168 Nutrients state and trend for the Danish water bodies from 35 years with national monitoring. <i>Mette Thorsen</i>		
9:30 - 10:00	#97 Implementation of a National Scale Water-AGRI European Innovation Partnership in Ireland. <i>Mairead Shore</i>		
Main Hall 2. Floor			
10:00 - 10:30Coffee break			
	Eduard Biermann Auditorium (2. Floor – room no. 204)	Merete Baker Auditorium (2. Floor – Room no. 211)	Jeppe Vontilius Auditorium (3. Floor - Room no. 310)
10:30 - 12:00	Understanding of ‘systems functioning’ (B.3) (Chairs: <i>Hans Peter Broers/ António Guerreiro de Brito</i>)	Assessment of national or regional policy (E.3) (Chairs: <i>Berit Hasler/Joachim Rozemeijer</i>)	Improving water quality by farm management practices (G.2) (Chairs: <i>Piet Groenendijk/Cors van den Brink</i>)
10:30 - 10:45	#225 Leaching of mineralized soil nitrogen is highly influenced by vegetation type. <i>Peter Sørensen</i>	#91 A hydrologically informed agricultural land use intensity index to assess the agricultural impacts on streams and rivers. <i>Michael Kyei Agyekum</i>	#45 The Effect of Nature-inspired Farming Systems on Soil Hydrological Functioning and Nutrient Leaching. <i>Cécile Alsbach</i>
10:45 - 11:00	#161 A new approach for identifying catchment phosphorus impact risks and quantifying the underlying processes. <i>Per-Erik Mellander</i>	#105 Nitrogen Use Efficiency in Nitrate Polluted Areas in Germany: How effective are regulatory measures? <i>Philipp Löw</i>	#71 Optimising the spatial allocation of water and nutrient retention measures in small agricultural catchments. <i>Michael Strauch</i>
11:00 - 11:15	#194 Mapping Nitrogen and Phosphorus Hotspots in Irish Agricultural Lands Using Raster Data and Geostatistical Techniques: Implications for Water Quality. <i>Fabiola Iasi de Barros Costa</i>	#171 Watershed scenarios for implementation of the EU Water Framework Directive and the Danish Tripartite Agreement targets for green transition in agricultural landscapes. <i>Tommy Dalgaard</i>	#77 Modelling the effectiveness of Natural/Small Water Retention Measures in Hungary and Lithuania: Similarities and differences. <i>Péter Braun</i>
11:15 - 11:30	#102 Methods to quantify nutrient load reduction targets for surface water bodies to meet Nitrogen and Phosphorus targets for good ecological status. <i>Peter Schipper</i>	#189 Towards an integrated view on Safe Ecological Limits from the Wadden Sea catchments to the Wadden Sea. <i>Justus van Beusekom</i>	#216 Comparing of agricultural systems: sustainability vs. intensification in mountain farming using the ARMOSA Model. <i>Marco Acutis</i>
11:30 - 11:45	Discussion	#202 Nitrogen-input into groundwater and surface waters in Germany. <i>Tim Wolters</i>	#104 Effect of mitigation measures on nitrate in the agricultural lands of groundwater protection areas in the Netherlands: A modelling study. <i>Kevin Duan</i>
11:45 - 12:00		Discussion	Discussion
10:30 - 12:00	William Scharff (3. Floor – Room no. 317) Side Event New Harmonica project (Chair: <i>Nigel Watson</i>) Facilitated discussion on: <i>Improving institutional arrangements for nutrient governance</i>		
Main Hall 2. Floor			
12:00 - 13:00Lunch break			
	Eduard Biermann Auditorium (2. Floor – room no. 204)	Merete Baker Auditorium (2. Floor – Room no. 211)	Jeppe Vontilius Auditorium (3. Floor - Room no. 310)
13:00 - 14:30	Impact weather variability and climate change (D.2) (Chairs: <i>Tim Wolters/Hyojin Kim</i>)	Water quality monitoring (impact, effectiveness) (C.3) (Chairs: <i>Gunnar Lischeid/Arno Hooijboer</i>)	Improving water quality by eco-technological measures (H.2) (Chairs: <i>Ryan Turner/Simon Buijs</i>)
13:00 - 13:15	#75 Investigating seasonal Nitrate and Orthophosphate Losses in Surface vs. Subsurface Drainage in Northwest Minnesota. <i>Murad Ellafi</i>	#37 How to proceed with impact monitoring for groundwater quality protection in agricultural landscapes? <i>Gunnar Lischeid</i>	#12 Denitrifying bioreactor monitoring network in Illinois, USA: Field-scale effectiveness assessment. <i>Laura Christianson</i>
13:15 - 13:30	#130 Extreme weather effects on wetland nutrient retention and maintenance needs. <i>Pia Geranmayeh</i>	#39 Unlocking the secrets of soil: Harnessing machine learning to predict autumn mineral nitrogen levels in Germany’s agricultural fields. <i>Mona Dieser</i>	#31 Decreased aqueous exports of nitrogen, phosphorus and carbon after rewetting of pump-drained fen. <i>Rasmus Jes Petersen</i>
13:30 - 13:45	#132 Long-term evidence of nitrogen removal from four decades of wetland restoration in Denmark. <i>Joachim Audet</i>	#131 Loss of organic nitrogen from agricultural fields and catchments. <i>Brian Kronvang</i>	#43 Stream restoration reduces nitrate loads in agricultural landscapes. <i>Michael Rode</i>
13:45 - 14:00	#135 Examination of flow, sediment and phosphorus relationships using monitored storm event data from a multiscale research platform. <i>Yusheng Zhang</i>	#176 Assessing PFAS Contamination in Dutch Groundwater: Insights from Age-Dated Depth Profiles. <i>Tano Kivits</i>	#47 Evaluating nitrogen removal efficiency in a constructed wetland dominated by diffuse agricultural groundwater inflows using an integrated catchment–wetland model. <i>Chris Tanner</i>
14:00 - 14:15	#154 Field-level nitrogen leaching and crop yield under extreme climate events. <i>Emilie Lissner</i>	#198 The Network for Monitoring Agricultural Loads and the Effects of Mitigation Measures in Finland. <i>Pasi Valkama</i>	#145 Are woodchip denitrifying bioreactors a viable edge-of-field N-mitigation strategy for New Zealand farming?: Insights from field-trials and comparisons with constructed wetlands. <i>Lee Burbery</i>
14:15 - 14:30	Discussion	Discussion	Discussion

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14:30 - 15:00 Coffee break			
	Eduard Biermann Auditorium (2. Floor – room no. 204)	Merete Baker Auditorium (2. Floor – Room no. 211)	
15:00 - 16:15	Understanding of ‘systems functioning’ (B.4) (Chairs: António Guerreiro de Brito/ Marco Acutis)	Implementation, Evaluation and Adaptation of Programmes of Measures (J.2) (Chairs: Katarina Kyllmar/Birgitte Hansen)	
15:00 - 15:15	#57 Managing the trade-off between agricultural productivity and groundwater protection in Switzerland – a model-based approach. <i>Annelie Holzkämper</i>	#15 Nitrate challenge in vulnerable groundwater protection areas. <i>Cors van den Brink</i>	
15:15 - 15:30	#70 Linking pesticide use data and water quality. <i>Alexandra Müller</i>	#144 Water quality improvements for the Great Barrier Reef catchments: Can we achieve change through Carrots and Sticks, or do we also need Golden Nuggets? <i>Ryan Turner</i>	
15:30 - 15:45	#156 The challenges with reconciling field-based measurements into balanced sediment budgets on a national scale. <i>Simon Pulley</i>	#214 Approaches in climate adaptation for water quality and quantity management: A Nordic comparison of farm level action towards water resilience. <i>Jennie Barron</i>	
15:45 - 16:00	#173 A Source: Pathway Prioritisation Index for diffuse P mitigation in agricultural catchments. <i>Rachel Cassidy</i>	Discussion	
16:00 - 16:15	Discussion		
Main Hall 2. Floor			
16:15 - 18:15 Poster session with drinks and snacks			

Friday 06-06-2025

7:30 - 8:30		Registration. Registration desk open all day. Organising Committee Contact: <i>Susanne Wuijts</i>	
	Per Kirkeby Auditorium (3. Floor – Room no. 304)		
8:30 - 10:00	Land use and water quality management from continents other than Europe (Plenary session P.4) (Chairs: <i>Lærke Thorling/Björn Tetzlaff</i>)		
8:30 - 9:00	#114/#115 Constructed wetlands intercepting mixed agricultural runoff across diverse landscapes. <i>Brandon Goeller and Chris Tanner</i>		
9:00 - 9:30	#211 Long-term Salinization of Production Aquifers in Irrigated Agricultural Landscapes. <i>Thomas Harter</i>		
9:30 - 10:00	#166 Navigating Human Dimensions in Agricultural Practice Adoption: From Individual Perceptions to Collective Water Quality Improvements in the Great Barrier Reef catchment, Australia. <i>Katerina Kanakis</i>		
Main Hall 2. Floor			
10:00 - 10:30		Coffee break	
	Eduard Biermann Auditorium (2. Floor – room no. 204)	Merete Baker Auditorium (2. Floor – Room no. 211)	Jeppe Vontilius Auditorium (3. Floor - Room no. 310)
10:30 - 12:00	Understanding of ‘systems functioning’ (B.5) (Chairs: <i>Hans Peter Broers/Denitza Voutchkova</i>)	Impact weather variability and climate change (D.3) (Chairs: <i>Katri Rankinen/Chris Tanner</i>)	Improving water quality by farm management practices (G.3) (Chairs: <i>Marco Acutis/Susanne Wuijts</i>)
10:30 - 10:45	#81 Effect of uncertainties in manure and fertilizer application on modelled N losses to surface and groundwater. <i>Hans Kros</i>	#28 Tracing the factors controlling the climate-induced migration and role of floating farming as adaptive measure in Southwest coastal region of Bangladesh. <i>Pankaj Kumar</i>	#111 Mitigation measures for phosphorus and nitrogen under changing climate: conflicts and synergies. <i>Jian Liu</i>
10:45 - 11:00	#98 Modelling Annual Total Organic Nitrogen Concentrations in Streams using Machine Learning at National Scale. <i>Rasmus Rumph Frederiksen</i>	#65 Impacts of annual weather conditions and available soil data on modelling nitrate leaching from farmland at regional and national scale. <i>Christen Duus Børgesen</i>	#182 Prioritising investment in nutrient management reform for farms in the catchments of the Great Barrier Reef. <i>Melanie Shaw</i>
11:00 - 11:15	#99 Evaluating Nature-Based Solutions for Nitrogen and Phosphorus Reduction: A comprehensive modelling approach in agricultural catchment. <i>Joy Bhattacharjee</i>	#76 Towards climate-resilient intensive farming with minimal environmental impact; preventing unnecessary losses of fresh water and nutrients at an arable farm in Anna Paulowna, The Netherlands. <i>Kim Gommans</i>	#185 Impact of various management measures on soil water regime in three European biogeographical regions. <i>Csilla Farkas</i>
11:15 - 11:30	#158 A Machine Learning approach for modeling Nitrate Leaching from Agricultural Land in Denmark. <i>Jian Wienke</i>	#79 National flow-dependent and local through-time source apportionment to help manage diffuse / point source pollution using the CSF-HYPE model for England. <i>Barry Hankin</i>	#192 Best management practices to deliver load reduction targets in NW Europe under a changing climate – findings from the New-Harmonica project. <i>Hywel Lloyd</i>
11:30 - 11:45	#186 Nitrogen retention in Danish surface waters – a new model. <i>Hans Thodsen</i>	#96 Impact of climate-change on nutrient dynamics in agricultural catchments: An empirical modelling approach. <i>Golnaz Ezzati</i>	Discussion
11:45 - 12:00	#187 Predicting nitrate leaching using Nmin soil measurements on farm parcels. <i>Job Spijker</i>	#165 Extreme Weather Impacts on Nitrate Leaching to Groundwater: A Field Scale Assessment in the Central Valley. <i>Isaya Kisekka</i>	
Main Hall 2. Floor			
12:00 - 13:00		Lunch break. Poster to be removed	
	Per Kirkeby Auditorium (3. Floor – Room no. 304)		
13:00 - 14:00	Wrap up, key messages and Closure (Plenary session P.5) (Chairs: <i>Gitte Blicher-Mathiesen/Susanne Wuijts</i>) A summary, key messages and outlook to next edition LuWQ. <i>Lærke Thorling and Richard van Duijnen</i>		

Posters

A. Driving forces for trends in agriculture and water quality: UN sustainable development goals (SDGs), food-energy-water nexus, Green Deal, climate change and strategies, trade-offs from other developments (e.g. urbanization, water reuse..., climate migration, population growth).

-

B. Increasing our understanding of ‘systems functioning’: research, tools and methodologies to increase understanding and improving modelling of the hydro(geo)logical, geochemical and biochemical processes.

#10 Mapping alkalinity in Danish streams, *Albert Rosenkrantz Conradsen*

#19 Introduction of a river basin nutrient source apportionment modeling tool, ECHO, and an example of its application, *Yan Gegotek*

#34 How will rapidly rising atmospheric CO₂ concentrations affect freshwater systems?, *Roland Stenger*

#56 From Literature to Lab: Transformation and Sorption Behaviors of Nitrification and Urease Inhibitors, *Eva Weidemann*

#84 Hydrochemical Processes and Groundwater Quality in the Basement-Sediment Aquifer of Lapai, Central Nigeria, *Kolawole Aweda*

#110 Can local data strengthen assessments of groundwater extraction permits for field irrigation?, *Rikke Krogshave Laursen*

#116 Spatial Data Preparation for SWAT+ Model: A Case Study of the Berze River in Latvia, *Ainis Lagzdins*

#164 Monitoring and Assessment of Nitrogen Leaching in an Irrigated Orchard Farm under Semi-Arid Climate, *Thomas Harter*

#177 Interaction of steady state flow and geochemical processes controlling the phosphorus release in anaerobic soil columns, *Nimisha Krishnankutty*

#234 Dissolved Organic Nitrogen Leaching from Cropland: Factors and transformations in soil, *Shristi Khanal*

C. Water quality monitoring: improving the effectiveness and increasing the added value of monitoring – use of new sensor techniques, remote sensing, dating of groundwater, improved (meta)data management, analysis and interpretation, modelling and generalisation of observations, and assessment of status and trends.

#23 Soil water dynamics in the vadose (soil) zone under real environmental conditions, *Anja Koroša*

#40 Current phosphorus status of agricultural fields in Germany, *Steffen Zieseniß*

#66 Comparing soil hydraulic properties of an agricultural field to non-invasive remote sensing and GPR data, *Marjana Zajc*

#109 Storage ponds as a multifunctional tool for irrigation and nutrient removal., *Lone Juul*

#112 Using turbidity sensors to assess retention of particles and phosphorus in a small Norwegian constructed wetland, *Anastasija Isidorova*

#140 Novel high resolution monitoring program iFOODis of surface waters in relation agricultural activities and environmental factors in Northern Germany (Baltic Sea), *Loky Stein*

#149 Monitoring nitrate leaching under vegetable crops in the Netherlands, *Richard van Duijnen*

#152 Farmers measuring their own on-farm water quality: experiences and outcomes, *Hooijboer Arno*

#172 Dynamic Water Quality Monitoring in the Kielstau Catchment: Optimization of High-Frequency UV Sensor Performance and Nutrient Hysteresis Analysis, *Kirsten Rücker*

#199 Detection of nutrient input pathways along the shores of a shallow lake with optical sensors, *Kirsten Rücker*

#221 Effect of microalgal biostimulants used in agriculture: An ecotoxicological assessment, *Mishal Antony*

#237 Anthropogenic Groundwater Contamination: A Case Study from the Nitra Region, Slovakia, *Katarína Tarabová*

#240 High-frequency water quality monitoring to support a spatial targeting approach for nutrients in two agricultural catchments, *Joachim Rozemeijer*

D. Impact of weather variability and climate change on water quality: [assessment of impact on land use, groundwater and surface water quality.](#)

#236 Impact of drought on nitrate concentrations in leaching water from agricultural areas in the Netherlands, *Harm Wismans*

E. Assessment of national or regional policy: [effectiveness of programs of measures on water quality on a regional and national scale.](#)

#74 Does the exception prove the rule? How well are small surface waters in Germany actually protected from agricultural pesticide inputs caused by erosion?, *Alexandra Müller*

#101 Nitrogen use in the Netherlands in relation to nitrogen use standards, *Co Daatselaar*

#122 The evolution of the nitrate nitrogen residues measured in autumn in Flemish grassland soils since 2004, *Karoline D'Haene*

#197 Harmonized approaches for transboundary groundwater vulnerability assessment in the Estonian-Latvian region, *Magdaleena Männik*

#208 Historical and Future Nitrogen Sources, Retention, and Exports in the Hunze and Rhine River Basins, *Xiaochen Liu*

F. Managing protected areas for water supply and nature conservation: [risk assessment techniques, monitoring and modelling of water quality and quantity for the protection of \(a\) water resources for drinking water supply, and \(b\) groundwater dependent terrestrial ecosystems.](#)

#50 Impact of Pesticide Mixtures on Aquatic Ecosystems: A Risk-Based Approach, *Cath Neelamraju*

#51 The Temporal Response Surface: Assessing the delayed and cumulative impacts of imidacloprid on aquatic ecosystems, *Cath Neelamraju*

#125 Protection of drinking water resources from agricultural pressures: embracing interdisciplinary cooperation to enhance governance approaches, *Susanne Wuijts*

#137 Nitrate in drinking water and health studies in Denmark, *Birgitte Hansen*

#243 PROTECT – Groundwater Protection in a Changing Landscape, *Birgitte Hansen*

G. Improving water quality by farm management practices: [research \(monitoring and modelling\) at plot, field and catchment scales to quantify the effects of farming practices and changes in land use.](#)

#6 Minimal tillage as a farming practice to improve soil water retention and reduce soil erosion, an example from Slovenia, *Matjaž Glavan*

#61 Modelling of soil mineral nitrogen in leachate using APSIM, *Michel Willgerodt*

#80 Evaluating Agricultural Strategies for Groundwater Protection: Impact of Crop Rotations on Nitrate Leaching on Field Scale in Denmark, *Maryam Dastranj*

#92 Nutrient input changes in grassland-dominated agricultural lands: effects of crop rotations and land transformations in Latvia, *Arturs Veinbergs*

#95 Assessing the effects of conservation tillage practices on water, nutrient, and sediment retention in six European case studies using SWAT+, *Piroska Kassai*

#123 Testing gypsum amendment for reducing the agricultural phosphorus load to the Baltic Sea, *Petri Ekholm*

#155 Model simulations for climate-robust manure spreading and sowing of catch crops, *Mia Tits*

#190 Effectiveness of Natural/Small Water Retention Measures in the Boreal biogeographical region, *Csilla Farkas*

#191 Linking Crop Rotations and Nitrate Leaching Potential: A Multiyear Study of Agricultural Land Use Effects on Groundwater Nitrate Levels, *Max Eysholdt*

#210 Water levels and dissolved organic carbon in deep-drained peatlands treated with subsurface irrigation, *Lydia Roesel*

#218 Optimising Agronomic Practices for Nitrogen and Carbon Management in Intensive Livestock Farming: A modelling analysis on the Lombardy Plain., *Marco Acutis*

H. Improving water quality by establishing eco-technological mitigation measures: [development, testing, implementation and operation at plot, field and catchment scales to quantify the effects of structural measures.](#)

#35 First-year performance of a pumped, cold-climate woodchip bioreactor, *Lindsay Pease*

#46 Amending Water Quality through Nature-inspired Principles – an Overview, *Cécile Alsbach*

#58 Exploring intensified catalytic role of biochar in facilitating advanced oxidation of tebuconazole in agriculture drainage, *Shubiao Wu*

#67 Soil rehabilitation and protection by fungi from polyaromatic hydrocarbons contamination, *Teresa Tavares*

#106 Assessment of Rare Earth Element Accumulation by Willow (*Salix* spp.) in Floating Treatment Wetlands., *Muhammad Ramzan*

#120 Willow Growth Potential and Nitrogen and Phosphorus Accumulation Under Processed Municipal Wastewater, *Muhammad Mohsin*

#139 In-stream sand traps as a measure to reduce transport of phosphorus, *Hans Estrup Andersen*

#141 Leaky dams as a mitigation option for nutrient losses via agricultural drainage ditches, *Demi Ryan*

#169 Looking into buffer zones with different vegetation cover – monitoring subsurface runoff - results from TOTBUFFER project, *Dominika Krzeminska*

#170 Looking into buffer zones with different vegetation cover – monitoring of the surface runoff - results from TOTBUFFER project, *Anne-Grete Buseth Blankenberg*

#175 Installation of a woodchip bioreactor as an area specific approach to reduce nitrate loads from agriculture, *Joachim Rozemeijer*

#201 Particulate and dissolved phosphorus removal in agricultural drainage waters with a compact filter system, *Lorenzo Pugliese*

#217 Catchments as the first stage of treatment, *Andre Frota*

#235 Implementation of a climate-adapted water management in grasslands in North-West Germany – first effects on nutrient discharge and water availability, *Mareike Schloo*

#242 Can we save our waterbodies from excessive dissolved phosphorus?, *Karolina Andrioti*

I. Development and Decision-making on Programs of Measures: [the role of stakeholder input and science in policy decision-making.](#)

#9 Locally Based River Basin Management Plans: Advancing Co-Governance to Accelerate Nitrogen Reductions in Denmark, *Flemming Gertz*

#239 Irish stakeholder collaboration in developing Ireland’s Nitrates Action Programme and beyond, *Noeleen McDonald*

J. Implementation, Evaluation and Adaptation of Programs of Measures: [social and economic incentives and regulatory mandates that drive implementation \(carrots and sticks\), catchment officers, etc.](#)

#62 Exploring the role of structural and financial factors to implement Natural Small Water Retention Measures in agriculture: insights from a survey to practitioners, *Federica Monaco*

#195 Cooperating in agricultural transition and emission reduction by regional deals, *Martin de Jonge*

International Interdisciplinary Conference on Land Use and Water Quality Agriculture and the Environment Aarhus, Denmark, 3–6 June 2025



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The abstracts in this volume were evaluated by members of the Scientific Advisory Committee and the Organising Committee, resulting in the selection and allocation in oral presentations and poster presentations. This volume of abstracts contains only those abstracts that are expected to be actually presented at the conference. The Organising Committee takes no responsibility for any error and omission or for the opinions of the authors.

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PREFACE

Agriculture provides food, fibre, energy, and, last but not least, it provides a living for many people around the world. The potential drawback of agricultural production is pollution of the terrestrial and aquatic environment by nutrients, pesticides, trace elements, antibiotics, and natural and synthetic hormones. Growth in agricultural production, as it has occurred in Europe and North America since 1950s, and more recently in many other parts of the world, threatens the quality of groundwater and surface waters or has already led to deterioration of the quality of these waters.

Policies to abate deterioration of water quality have been developed and programs of measures to improve water quality have been implemented over the last decades all over the world. Nevertheless, it has become clear that achieving the objectives of these policies gets more difficult, not only since the easier, low-cost measures already have been implemented, but also because there is a tendency to increase agricultural production. In addition, other policies, for example to abate climate change, may affect land use and thereby water quality. Are we aware of potential conflicting policies? Countries use different approaches to implement measures, which approach works best? What are the experiences with measures enforced by law (top down) compared to implementation on a voluntary basis (bottom up)? Experiences show that the latter depends on a long-term investment in building relationships, gaining mutual trust and raising awareness. Do we have the resources and enough time for such approaches? These are some of the issues that are addressed at LuWQ2025.

This volume contains the selected abstracts as they were received. The Abstract Numbers in the TABLE OF CONTENTS are identification numbers, that were assigned as part of the submission process. These abstract identification numbers are referred to from the Conference Programme, both for oral and poster presentations. For example, “(abstract #241)” in the Conference Programme relates to “*Abstract number–241 The rocky road towards water quality ambitions: experiences from the Netherlands*” in this Volume of Abstracts. We wish you a fruitful and enjoyable stay in Aarhus.

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Abstract number–1 Multidisciplinary capacity development to improve water quality affected by agricultural pollution: An introduction to the LuWQ2025 conference

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Agriculture provides food, fibre, energy and, last but not least, a livelihood for many people around the world. However, agricultural production also pollutes the terrestrial and aquatic environment with nutrients, pesticides and other substances applied in agriculture, depending on the type and design of the agricultural system. Since the 1950s, agricultural production growth in Europe and North America, and more recently in many other parts of the world, has threatened the quality of groundwater and surface waters, leading to chemical and ecological deterioration. Typical hotspot areas include Europe, e.g. Denmark, the Netherlands, northern Italy, Germany and France, as well as China, USA, Australia and New Zealand.

Over the last decades, policies to overcome deterioration of water quality have been developed, and programmes of measures to improve water quality have been implemented worldwide. For example, the European Union has adopted an extensive legal framework aiming to achieve and preserve good water quality by 2027 (Nitrates Directive in 1991, Water Framework Directive in 2000). Experiences from the last 15 to 25 years indicate that achieving these objectives within the set timeframe will be a great challenge. Nevertheless, the European Commission monitors compliance with these directives, and several Member States have been forced through the European Court of Justice to amend their national legislation, such as the Netherlands in 2003, France in 2013/2014 and, more recently, Germany in 2018.

In other parts of the world, such as New Zealand, the government has initiated a national science challenge to improve land and water quality. Recently, California and other US states have also implemented laws to control water pollution, including pollution from agriculture. However, achieving the objectives of these policies is becoming more difficult, as the easier, low-cost measures have already been implemented, and measures based on voluntary participation are often preferred. Additionally, there is a tendency to increase agricultural production. Trends like population growth, economic development and climate change may furthermore add to the challenges of abating water pollution, while technological development and capacity building may support the development of effective strategies.

Although decades of research have improved our understanding of the soil-water system and the sources and effects of pollution, there is still a knowledge gap regarding the

effectiveness of mitigation measures and the information needed to adequately support policy-making. Recent advancements in data collection, sensor measurements and machine learning methods seem promising in overcoming this knowledge gap. Still, long-term monitoring programmes are essential to assess the effectiveness and proper implementation of programmes of measures leading to improved water quality, as water quality changes may have long time lags and unclear impacts. Monitoring and the acceptance of its results by various stakeholders can also play an important role in agenda setting and fostering local debates on the need for (further) measures. In this context, 'citizen science' projects should also be mentioned, as they can increase support or acceptance of measures by farmers and other practitioners.

The implementation of measures is a multifaceted challenge that will be addressed specifically at the conference. Countries use different approaches to implement measures, but which approach works best? What are the experiences with measures enforced by law (top down) compared to implementation on a voluntary basis (bottom up)? Experiences show that the latter depends on long-term investment in building relationships, gaining mutual trust and raising awareness. Do we have the resources and enough time for such approaches? It is also important to reflect on the polluter pays principle in agriculture. Although this is a central principle in European law, the livelihoods of farmers play an important role in the debate on agriculture and pollution. How do we handle the issue that the measures may cost the farmers income possibilities, while society seems to accept paying for environmental pollution by agriculture?

As an alternative to cost-intensive technical solutions, nature-based solutions (NbS) are gaining increasing importance. This will be demonstrated by several contributions regarding rural and urban case studies from different European countries.

In recent years, the effects of climate change have become more prominent and will continue to develop and affect agricultural practices and their environmental impacts due to changes in temperature, longer periods of excess water and droughts and weather extremes. Research has shown that clean water scarcity increases significantly when the impacts of climate and poor water quality are assessed jointly. Other policies, for example regarding energy transition to mitigate climate change, may affect land use and thereby water quality. Are we sufficiently aware of trade-offs or co-benefits of other related policies? The impact of climate change and possible adaptation strategies will be addressed in several contributions during thematic sessions.

The Land Use and Water Quality Conferences aim to address these issues through both presentations of the latest research findings and science-policy debates, focusing on the central theme of the conference – land use and water quality. Scientists from various fields of expertise (soil/water, agriculture, hydrology, social sciences, ecology and economy) and experts from policy and practice from 32 countries worldwide have provided numerous valuable abstracts on a wide variety of relevant themes.

Denmark, as the hosting country of this LuWQ-conference, is set to implement a new approach in the coming years through a joint plan developed between the State and two NGOs: the largest farmer organisation in Denmark and The Danish society for Nature Conservation. The plan is called Green Transition and aims to address challenges with both nutrients and climate change (CO₂-reductions) in the agricultural sector. Several presentations at the conference will discuss this example of cooperation between partners

with conflicting interest, seeking to find synergies and commonly accepted solutions. LuWQ2025 is the sixth follow-up to the previous successful LuWQ conferences, LuWQ2022 (Maastricht, the Netherlands), LuWQ2019 (Aarhus, Denmark), LuWQ2017 (The Hague, the Netherlands), LuWQ2015 (Vienna, Austria) and LuWQ2013 (The Hague, the Netherlands).

Abstract number–2 Understanding and Improving Institutional Arrangements for Nutrient Governance: Insights from the New Harmonica Project

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The impact of nutrients from land use on water quality is as much an institutional problem as it is a scientific and technical problem. Appropriate institutional arrangements are required for the governance of nutrients and for policy development. Similarly, institutional arrangements are important for the management of land and water, particularly regarding the effective implementation of policies, plans and other agreed actions.

The New Harmonica project is focused on four catchment areas in North-West Europe (the Dutch Meuse, Flemish Meuse, Neagh Bann, and Wye) where there are significant water quality problems related to nutrients from a variety of sources, including agriculture and waste water treatment. An institutional analysis was undertaken for each of the four catchment areas in order to identify current arrangements for decision making and to make an assessment of the effectiveness of nutrient governance and management. The overall research objective was to identify needs and opportunities for institutional improvements, and to generate policy recommendations for balanced use and protection of land, water and related ecology.

Key research findings pertaining to six institutional dimensions are presented here: context, legitimation, functions, structures, processes and mechanisms, and organisational cultures and attitudes. While actions are being taken to reduce nutrient losses and inputs, current efforts are often impeded by bureaucratic structures and weak coordination, lack of political support and leadership, complex and overlapping planning processes, insufficient implementation capacity and fundamental differences in values and priorities among stakeholders. At the same time, the research has revealed some opportunities to enhance institutional capacities. The presentation concludes by outlining some recommendations to overcome current institutional obstacles and strengthen efforts to govern and manage the use of nutrients effectively.

Abstract number–3 Effect of catch crops after maize and potato on nitrate concentrations in groundwater: 3-4 years of measurements using various catch crops

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Nitrate concentrations in shallow groundwater with arable farming often exceed the European threshold of 50 mg/l in the south sandy part of the Netherlands. While over winter nitrogen catch crops can decrease the nitrate concentrations, the effect of different types of catch crops and sowing time are less known. We have tested the effect of three winter-hardy catch crops, sown at different times in autumn after the harvest of potato and silage maize. Two different potato varieties, with a high and low nitrogen demand, were included and three maize varieties differing for earliness of maturity. The catch crops were winter rye, winter barley and black oats. After maize, also two sowing densities of the catch crops were compared, and two others were under-sown in spring: Italian ryegrass and tall fescue (at one sowing density). They were set up as a split-plot design with four replicates and plot sizes of 4.5 x 12 meters. The trials were repeated during three years (2018-2020) for potato and four years (2018-2021) for maize in the southeast of the Netherlands on freely draining humous sandy soils. We used a new field every year, and fertilised using cattle slurry and CAN. We determined yield and N uptake by the catch crop, including roots, the soil mineral nitrogen in autumn and in spring (0-0.9 m soil layer), and the nitrate concentration in the groundwater using static PVC wells up to 2.5 meters below the soil surface. The groundwater level was monitored and varied between 2.5 m below soil surface in the summer and 0.5 m in winter. In the winter four groundwater samples were taken. The average sum of above and belowground N uptake of the catch crops varied after maize and potato, 31-69 and 32-45 kg N/ha respectively. The effect of sowing time or density, and the type of cover crop on N uptake differed per year, but over the sum of years the differences were small after potato but larger after maize. The study shows that cover crops after maize and potato are effective in decreasing nitrate concentrations at the end of winter from 86 to 39-74 mg/l, from 98 to 63-76 mg/l respectively, averaged over the trial years. Even sowing in the third week of October gave a significant decrease. Other factors affect the nitrate content as well. Nitrate concentrations also showed a strong negative correlation with dissolved organic carbon (DOC) in the groundwater.

Abstract number–5 Modelling the impact of agricultural measures to protect the underground habitat of black olm (*Proteus anguinus parkelj*) against nitrate pollution

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The black olm (*Proteus anguinus parkelj*) is an endemic species that lives only in a 2 km² area of the underground karst water system of the Dobličica River in the area of the Dinaric Karst in Bela Krajina, Slovenia. The upper limit of the concentration of nitrates, which are dangerous for humans, is 9.2 mg NO₃⁻ /l. The measured values in individual karst springs were between 3 (natural background) and 20 mg NO₃⁻ /l, which exceeds the safe limit and presents a severe risk to the health of black olm. The most effective scenario of changing agricultural rotations (R3), which includes a combination of measures (winter greening of fields, reduction of fertilization by 20% and expansion of the rotation with additional years of grass-clover mixture), would impact the reduction of nitrates leaching under the soil profile by more than 60 % compared to existing practice. The amount of biomass produced would decrease by 3-5%. Considering the various hydrological, geological and pedological characteristics, the implementation of the R3 scenario is expected to reduce the amount of nitrate nitrogen in the waters of the surface streams, which drain from the karst sub-basins and feed Dobličica River, by 2% to 32%. Measures in agriculture, as well as in the field of wastewater management from individual households, must be implemented in a coordinated and directed manner according to the hydrogeological and pedological characteristics of the area in question. The results confirm the suitability of the SWAT model for assessing the impacts of agricultural activities on karst soils, but at the same time, highlight the need for further adaptation of farming practices to protect the vulnerable habitats of the black manfish.

This research was carried out within the framework of the CRP V1-2139 HAČLORI project, which was funded by the Slovenian Research and Innovation Agency, the Ministry of Environment, Climate and Energy, and the Ministry of Agriculture, Forestry and Food.

Abstract number–6 Minimal tillage as a farming practice to improve soil water retention and reduce soil erosion, an example from Slovenia

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The objective of the research was to examine the environmental and economic sustainability of agricultural soil water management (abundance, scarcity) and soil management (erosion), using small measures to retain water and prevent soil erosion in fields under conventional and conservational minimal tillage. When analysing the impact of soil water deficit in all observed catchments, we did not observe significant differences in the monthly mean values of matric soil water potential during the growing season. During the driest period of the measurements, both conventionally and conservatively cultivated fields were in a dry state since the soil does not provide plants with access to water for a large part of the growing season. Erosion measurements on a corn field in 2021 showed the total annual amount of eroded soil in arable land (39.13 t/ha), which is 39-48 times more than direct sowing (no-till) (0.808 - 1.09 t/ha) and five times more than conservation minimum tillage (7.74 t/ha). In terms of yield, the cultivation methods are comparable, with virtually identical yields achieved by conservation minimal tillage (40.64 t/ha) and direct sowing (no-till) (39.89 t/ha). Modelling with the SWAT model showed that by choosing effective measures, we can reduce erosion and at least partially increase water retention so that farms can effectively deal with the consequences of expected climate change. The optimisation results showed that the most economically efficient measure in all cases is conservation tillage. When introducing conservation tillage, it is necessary to be aware that the purchase of the machinery represents a relatively high cost. The effects of alternative scenarios from the point of view of the economy can be considerable (up to a few 10 %) and from the environmental efficiency minimal (a few %) or vice versa. Based on the analyses carried out, the farmers' overall highest rating for the probability of implementation was given to the measure "summer and winter greening", followed by "conservation tillage". The lowest ranked measure at the overall level is "field buffer strips on steep slopes", followed by the measure "change of ploughing direction from vertical to transverse".

This research was carried out within the framework of the CRP L4-2625 CeVoTaK project, funded by the Slovenian Research And Innovation Agency and the Ministry of Agriculture, Forestry and Food, the OPTAIN project funded by the European Union's Horizon 2020 research and innovation program under grant agreement No. 862756.

Abstract number–7 Impact of transfer time on trends in nitrate concentrations in mainland France.

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The Water Framework Directive (WFD) and its daughter directive aim to reduce water pollution and improve groundwater quality, especially concerning nitrate levels. Although various measures have been put in place to address contamination, their effectiveness can differ due to complex interactions among farming practices, climate, and geological features. Nitrate in the unsaturated zone mainly come from the application of fertilizers and the breakdown of organic matter. Predicting how long it takes for nitrate to move from the surface to groundwater is challenging because of lag time.

This study examines how to estimate nitrate transfer times through the unsaturated zone, using an analysis of dominant rock types and hydrogeological models at the level of groundwater bodies. This method is particularly helpful for assessing contamination without needing detailed data on agricultural practices. By simplifying the assessment process, this approach improves our ability to manage contamination risks.

The study compares nitrate transfer times with trends in groundwater concentrations, as these trends show changes over several years. The results indicate that shorter transfer times are associated with a higher percentage of monitoring points showing downward nitrate trends. In contrast, longer transfer times are linked to an increase in points with upward nitrate trends.

In France, the findings reveal that areas with upward nitrate trends are often found in northern and eastern France, while those with downward trends are mainly in the west. This geographical difference is related to the unique properties of the various water bodies.

The results underscore that challenges in achieving Good Status for water bodies are partly due to these transfer times, highlighting the importance of delays in the movement of contaminants. Such delays make it harder to improve water quality and comply with regulatory standards. Overall, understanding these dynamics is crucial for developing effective strategies to manage water resources and reduce nitrate pollution.

Abstract number–8 Untangling the relative importance of policy, soil moisture and land use variables on stream water quality

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There is concern that agri-environmental policies to mitigate diffuse pollution pressures to receiving water bodies are being constrained by extremes in weather patterns. Untangling these relative effects is therefore important to identify when reviewing the outcomes of individual policy measures.

In terms of the closed soil fertilisation period, and impacts immediately after it ends, we investigated the relative importance of soil moisture, land use, and policy variables for stream water nutrient concentration in two intensively monitored agricultural river catchments in Northern Ireland. In each catchment, fortnightly monitoring of stream water TP, SRP, and TON concentrations in eleven to thirteen sub-catchments from 2009 to 2023 provided a

range of soil moisture conditions, land use, and policies on which we based the analysis. We performed Random Forest Regressions using Soil Moisture Deficit, 7-days mean Soil Moisture Deficit, proportion of fertilised land, minimum application distances to watercourses of chemical fertilizer and organic manure, and maximum application rate of organic manure as predictor variables of TP, SRP, and TON concentrations at the outlet of the sub-catchments.

We found that models explained 28% to 60% of the variability in P concentrations. In the more intensive catchment, soil moisture and land use were the most important predictors of P concentrations while land use was the most important predictor of P concentrations in the more extensive catchment. In the former, soil moisture was the most important predictor of TP concentrations while soil moisture and land use had a similar importance for explaining the variability in SRP concentrations. The models explained 84% to 93% of the variability in TON concentrations. For both catchments, land use was the most important predictor of TON concentrations and it was at least ~45% more important than the soil moisture and policy predictors.

The analysis shows that, over the 6 weeks following the closed period, soil moisture and land use pressures override the effects of policies regarding fertilisation. It supports the need for policy to better account for weather conditions and land use in designing future agri-environmental regulations.

Abstract number–9 Locally Based River Basin Management Plans: Advancing Co-Governance to Accelerate Nitrogen Reductions in Denmark

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Only 5 out of 109 Danish coastal water bodies are in Good Ecological Status (GES). Since the 1980s, the main focus for achieving GES has been reducing nitrogen. Since 1990, nitrogen emissions to Danish coastal waters have decreased by approximately 50%. Most of this reduction has been achieved through on-field measures, such as better utilization of livestock manure, a 50% reduction in the use of mineral fertilizers, winter cover crops, and catch crops.

Wetland restoration has also been part of the measures used since the 1990s, but it has not been the primary cause of the observed decline in nitrogen emissions. Danish water management has focused on regulating agriculture through general regulations, decrees, and predominantly top-down approaches. Individual farmers have been involved to a limited extent in finding solutions beyond compliance with existing legislation. This approach worked until around 2010, when the decrease in nitrogen levels in the aquatic environment stagnated.

Achieving GES in Danish coastal waters is not only a matter of reducing nitrogen, even though nitrogen plays a key role. In 2021, the Danish government decided to allocate funds

to test a more locally based water planning approach aimed at achieving GES in coastal waters. In 2023, as part of an experiment, local River Basin Management Plans (RBMPs) were created in four locations across the country. Local stakeholders came together in advisory councils, and with the assistance of experts, they created local RBMPs. In all four locations, wetland restoration was highlighted as a solution for improving water quality on an even larger scale than the official RBMPs made by the national authorities. The four local RBMPs also included significant additional measures besides nitrogen reduction, including phosphorus reduction, addressing point sources, and marine measures like eelgrass restoration and reestablishment of stone reefs.

The significant advantage of developing locally based RBMPs with local stakeholders is the establishment of greater ownership and trust in the plans. This is crucial, especially when wetland restoration relies primarily on voluntary participation.

Changing the Danish governance structure towards a more locally based approach is still in the decision-making process. Currently, it is suggested by the Danish parliament to expand from the four experimental local water councils to up to 18 permanent water councils to achieve greater ownership and trust in the plans for accelerating nitrogen reductions and achieving GES in Danish coastal waters.

Abstract number–10 Mapping alkalinity in Danish streams

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In the realm of mass transport, scientific and public attention predominantly centers on nitrate, phosphorus, and similar substances, often neglecting the significance of alkalinity. Yet, alkalinity - a measure of water's capacity to neutralize acids - serves as a vital buffer against acidification, thereby safeguarding aquatic life in Danish streams. Additionally, higher alkalinity levels reduce the susceptibility of water systems to pipe corrosion, leading to decreased metal leaching.

I will present detailed maps displaying the variation in alkalinity across Danish catchments, emphasizing the crucial effect of the composition of the topsoil layers. Furthermore, I will demonstrate how the amount of water flow functions as a predictor for alkalinity levels. Groundwater moving through the soil takes up alkaline substances such as bicarbonates, and the proportion of groundwater decreases as the water flow in streams increases due to a heightened contribution of surface water runoff. Lastly, I will display how lakes in chains mitigate the relationship.

Abstract number–11 Effects of the tightened German Fertiliser Ordinance in practice - findings from model regions

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With the background of regionally high nitrate concentrations in ground water bodies in Germany, model regions with practical farms were set up starting in 2016 with the aim to overcome the often missing link between nitrogen management and nitrate pollution of groundwater bodies. By means of a comprehensive system of nitrate indicators the impact of the measures to mitigate nitrate pollution should be assessed and deficits identified. Furthermore, results contribute to nitrate reporting to the European Commission. The investigations started with 48 farms and 576 test sites in five test regions in Germany and were expanded to a total of 96 farms with 1.116 test sites in 12 regions in 2021. Among other indicators, nitrogen balances as well as measurements of mineral nitrogen contents in soil (SMN) were applied to elucidate the reasons for nitrate pollution. The measures of the German Fertiliser Ordinance were tightened in the years 2017 and 2020 and have already led to a significant improvement in N efficiency in arable farms. However, decreasing N surpluses are not yet reflected in autumn SMN values. These were mainly influenced by crop rotation, post-harvest management, location and weather factors. Compared to crop rotation and post-harvest management (autumn fertilisation, tillage, catch crops), the current average level of N inputs in spring probably offers comparatively little potential for further reducing nitrate loads. Therefore, the correlation between nitrogen input and nitrate leaching potential is low, except for excessive amounts. The effectivity of political measures to date and further potential to reduce nitrate loads are discussed.

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Abstract number–12 Denitrifying bioreactor monitoring network in Illinois, USA: Field-scale effectiveness assessment

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The state-based “Nutrient Reduction Strategy” framework used in the US Mississippi River basin centers on the voluntary adoption of agricultural conservation practices to reduce the size of the Gulf of Mexico hypoxic zone. Denitrifying woodchip bioreactors are one of the

promoted practices for nitrate-laden subsurface drainage in the Upper Mississippi River basin, but there have been few comprehensive bioreactor performance assessments across sites and over years. Ten full-size denitrifying bioreactors were built between 2016 and 2021 in Illinois, USA, and were monitored for a total of 36 site-years. Annual performance was assessed in a variety of ways including: nitrate-nitrogen (N) load removal of 49 kg N/y; annual removal rate of 4.6 g N/m³-d; and 51% N removal for treated water but an efficiency of only 17% when untreated bypass flow was considered (all median values). Annual flow-weighted hydraulic retention time (HRT) was strongly negatively correlated with the annual percent of water captured by these bioreactors (Spearman correlation coefficient, ρ : -0.67) but positively correlated with the N removal efficiency from that captured water (ρ : 0.60). The annual mass of N removed (kg N/y) was correlated with the hydraulic loading and N loading both from the drainage area and captured by the bioreactors. Although the most appropriate performance metric depends upon the specific design criteria and assessment context, these ten bioreactors provided N removal across all years which reiterated this practice's dependability.

Abstract number–14 Decreasing TN and TP concentrations and increasing TOC concentrations in Finnish rivers

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The water quality of Finnish rivers needs to be improved to reach the target levels of the Water Framework Directive. Soil management is an essential factor that affects nutrient losses from agricultural and forestry areas. The main aim of the EU Horizon project Nordbalt Ecosafe (Grant Agreement No. 101060020) is to find safe ecological boundaries of river water quality for the Nordic-Baltic regions. In this study our main aim was to study 1) how the total nitrogen (TN) and total phosphorus (TP) and total organic carbon (TOC) concentrations in Finnish rivers has changes since 1985, and 2) how the stoichiometry of these rivers is changing. We used regression-based model EGRETci (Exploration and Graphics for RiVEr Trends) and long-term national monitoring data from 20 large rivers discharging to the Baltic Sea. The model is designed to describe the evolving behavior of the watershed and to estimate the actual history but also the flow-normalized history of water quality trends. It calculates how daily concentration varies as a function of time, discharge, and season. The monitored rivers showed declining total nutrient concentrations but increasing TOC concentrations. The stoichiometry is slowly changing from relationship in which TOC resources balance N and P availability to C rich relationship. Increase in TOC concentration is related to decrease in acidic deposition, increase in temperature and forestry practices. Trends in total nutrients were attributed to agri-environmental measures of the Rural programme in EU, point loads and forest management in the catchment areas. The main

agri-environmental measures, upper limits for fertilization and soil surface cover in winter, have proved to be effective. At the same time, it is also evident that the nutrient concentrations are still above the safe ecological boundaries, and special efforts beyond the present agri-environmental measures are needed.

Abstract number—15 Nitrate challenge in vulnerable groundwater protection areas

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Setting for a discussion

Since 2017, part of the 6th Action Program of the Nitrate Directive has been a governance agreement to work with farmers, water companies, and provinces in designated vulnerable groundwater protection areas (GWPA) to achieve the nitrate objectives in groundwater. Although the voluntary approach has been assessed as successful in process terms, the groundwater quality objectives have not been met. Necessary "supplementary measures" to achieve the goals negatively impact farmers' business results, making them economically unviable.

The provinces have received funding from the national government to continue the approach, facilitating a soft landing in the National Program for Rural Areas. This program had funds available to devalue land and develop agriculture into a less intensive farm management. These funds have been scrapped by the new Dutch Cabinet. The water companies—co-financers of the agreement—are increasingly pressuring the provinces to fulfill their duty of care to adequately protect groundwater but lack the instruments to enforce those measures or to compensate farmers. The farmers have voluntarily participated in the project since 2018, among other reasons, to avoid additional generic measures. However, since the derogation decision of 2022, the derogation in GWPA has been revoked, and additional generic measures are looming. This creates uncertainty, which is translated by farmers' financiers into devaluation of land and farm buildings. The necessity of "supplementary measures" to meet the goals and the lack of funding for farmers have led to a stalemate in the areas.

The years-long process still forms the basis for working together with farmers and water companies towards a perspective. The process has led to an enhancement of mutual understanding but not to additional financial resources. Political polarization does not help, especially for farmers who primarily seek perspective and clarity. Therefore, the water company and province—leveraging the knowledge and experience gathered—are returning to the areas to collaboratively develop a new approach with the farmers.

Abstract number–16 Mainstreaming Natural/Small Water Retention Measures in Europe – evaluation of drivers and hindrances with a dedicated SWOT framework

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There is strong evidence that Natural/Small Water Retention Measures can be an important solution to problems associated with managing water quality and quantity, soil erosion, and nutrient loss. Moreover, they deliver multiple co-benefits such as increased biodiversity, climate change adaptation and mitigation, alongside aesthetic and recreational functions. Although there is a growing recognition of the importance of NSWORMs and a growing body of literature dedicated to this subject, the motivations behind their systematic implementation remain quite underexplored. To answer this question, we developed a comprehensive SWOT (Strengths, Weaknesses, Opportunities, Threats) analytical framework and applied it to 14 case study locations in Europe with various soil and climatic conditions and agricultural systems. The framework consists of six Topics (Attitudes, Knowledge, Institutions, Financing schemes, Technology and Communication) with specific Factors that have been evaluated by 26 local experts. Ranking results reveal current strengths and weaknesses and future opportunities and threats for NSWORM implementation. A cluster analysis helps to better understand the relationships between the Topics and points to specific intervention areas to better utilize the strengths and opportunities and address weaknesses and threats.

Abstract number–17 Germany's new impact monitoring on the effectiveness of the Nitrates Directive Action Program

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In 2018, Germany has been convicted in front of the European Court of Justice after the European Commission has introduced infringement proceedings due to insufficient implementation of the European Nitrates Directive (91/676/EEC) Action Program. As a

result, Germany had to revise its Fertilizer Application Ordinance, one key instrument of the Program, including the novel designation of “Nitrate Polluted Areas” with additional mitigation measures. Also, Germany has to introduce a new monitoring program to evaluate the program’s effectiveness. Against this background, a group of agricultural and environmental research institutions and federal agencies has been tasked to implement the “impact monitoring”. This contribution presents the structure, novel insights and first results of the impact monitoring.

The impact monitoring is supposed to evaluate the Fertilizer Application Ordinance’s effectiveness and to act as an early warning system to facilitate policy adjustments. While it focuses primarily on developments in the recently designated Nitrate Vulnerable Zones, it is designed as an area-wide monitoring considering both water quality as well as agricultural emission data. The program operates on three pillars: i) monitoring of agricultural emissions, ii) monitoring of immissions (water quality) and iii) nutrient flux modeling and long-term field measurements in model regions. A national database is created where area-wide data on water quality, land use and fertilization intensity are assembled, including novel farm-level fertilization data in the medium to long term. However, German federalism makes data acquisition challenging and comes with path-dependencies and lock-ins.

So far, main goals have been to extend the groundwater measurement network, to create a sufficient database for site-specific evidence that is based on agricultural administration data and field measurements, and to apply the modelling framework AGRUM-DE. First results indicate a very strong decline of agricultural fertilization intensity – likely due to a combination of economic, structural and policy factors, while ground- and surface water quality has not yet improved considerably. The successful communication of time lags between developments on the soil surface and in the water bodies remains challenging. Through targeted improvement of the approach, access to additional reliable data sources, and persistent continuance, a promising methodology is being established that provides insights beyond routine reporting requirements

Abstract number–18 Towards a Good Ecological Status? The Prospects for the Third Implementation Cycle of the EU Water Framework Directive in The Netherlands

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The aim of the EU Water Framework Directive (WFD) is to achieve a “good” chemical and ecological status for all waters by 2027. Currently, the Netherlands and other EU Member States are implementing their plans for the third iteration of the WFD management cycle. In this paper, we conducted an ex nunc evaluation of these plans by assessing the perceptions of regional water authorities on goal attainment and the factors that account for it. In order to gain these insights, we first reviewed literature and developed a framework of factors that stimulate or hamper the implementation of the WFD. More detailed insights into the

relevance and characteristics of these factors were found by applying the framework in two in-depth case studies. A more generalizable pattern was found by translating the case study results into a survey among the regional water authorities. We found that the majority of the participating water authorities expect that 50% (or more) of their WFD objectives will be achieved in 2027. Recent evaluation report however show that these expectations may be too optimistic. Moreover, hampering factors such as a lack of political will or the impossibility to address key causes of the problems that were identified during earlier management cycles are still present. We therefore conclude that it will be highly unlikely that ecological ambitions will be met by 2027 and following this provide some recommendations for future policies.

Abstract number–19 Introduction of a river basin nutrient source apportionment modeling tool, ECHO, and an example of its application

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Over recent decades, the deterioration of surface water quality, particularly due to eutrophication, has become a critical global issue. To address these issues, it is crucial to accurately quantify nutrient sources and their pathways. Unlike point sources, which are localized and easier to regulate, diffuse sources from agriculture, atmospheric deposition, and groundwater seepage enter water systems through complex, variable pathways. Effective nutrient management thus requires a detailed understanding of both the sources and the transport mechanisms, which include hydrological and biogeochemical interactions. Additionally, the temporal lag between agricultural practices and observable changes in water quality, often spanning decades, complicates efforts to achieve rapid improvements.

Recognizing the need for targeted, region-specific solutions, this study introduces ECHO, a mass-balance modeling tool designed to analyze the movement of water and nutrients across catchments. ECHO integrates data from routine stream monitoring and other models, allowing for the calculation of water quality parameters at various scales and time steps. The tool's application in Dutch catchments has provided critical insights for stakeholders, facilitating the development of effective water management strategies aligned with WFD goals.

This research addresses key questions, including the distinction between anthropogenic and natural nutrient sources, the tracing of contaminants, and the analysis of nutrient transport and loss. By examining diffuse pollution, particularly from agriculture, the study aims to inform reduction targets for specific sectors. Additionally, scenario simulations offer pathways for achieving nutrient load reductions, aiding policymakers in evaluating the effectiveness of current measures and planning future interventions. The ECHO model's capacity to incorporate local data and validate outputs against field measurements makes it

a valuable tool for enhancing decision-making and ensuring sustainable water quality management.

Abstract number–21 Predicting the effects of fertilizer policy on the nutrient leaching and runoff in the Netherlands.

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As a contribution to the Evaluation of the Fertiliser Act in 2024 and the interim Evaluation of the Water Framework Directive, the effects of adopted policy measures on the runoff and discharge of fertilisers to ground and surface water have been predicted with sub-models of the Dutch National Water Quality Model. These include measures taken in the past and the measures in the 7th Action Program Nitrates Directive and the Derogation Decision of September 2022, stacked on the effects of other policy measures and trends in the size of agricultural land, livestock and the manure excretion.

In addition, the effects of uncertainties with respect to dry and wet weather conditions, a calculated excess of fertilisation rates above the fertiliser standards, and the measures implemented voluntarily by farmers were assessed.

The results indicate that with the adopted policy, all sandy areas can meet the standard of 50 mg/L on average. A value higher than 50 mg/L is still calculated for the loess region. The reduction of the nitrogen leaching as a result of the 7th Action Program and the Derogation Decision are greatest in the so-called Nutrient Polluted Areas in the sand region (8-10%). The reduction of phosphorus runoff to surface waters was estimated at a few percent.

Abstract number–22 The use of high-frequency in-situ sensor measurements of nitrate concentrations for exploring the uncertainty of monthly and annual load calculations in two headwater Danish streams

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This study explores the use of NITRATAX plus sensor measurements from HACH to monitor nitrate concentrations in two Danish headwater streams, Horndrup Stream and Lyby-Grønning Stream, over two hydrological years (June 1, 2021, to May 31, 2023). The aim was to calculate the annual and monthly nitrate(N) loads based on such high-frequency sensor and flow data and explore the uncertainty associated with normal use of grab sampling strategies in national and regional monitoring programmes.

A Monte Carlo (MC) approach was applied for simulation of five grab sampling strategies: daily, weekly, fortnightly, 18 samples annually, and monthly using one minute nitrate load data. We simulated 1000 loads for each strategy and stream based on random grab sample selection within each strategy. Main statistical assessment parameters were bias, standard deviation, and total uncertainty being calculated for each MC run for each sampling strategy and stream.

The annual nitrate load and loss for the two monitoring years was 5228 kg (9.5 kg N/ha) and 5482 kg in Horndrup Stream (10 kg N/ha), and 1171 kg (10.4 kg N/ha) and 11559 kg (10.2 kg N/ha) in Lyby-Grønning Stream. In both years and streams, the average annual percentage bias from the true nitrate load increased as the number of grab samples per year decreased meaning that the monthly sampling strategy showed the highest deviations from the true N-load amounting to -1.6% in year 1 and -7,7% in year 2 in the Horndrup Stream. In case of Lyby-Grønning Stream, the bias was below 1% for all sampling strategies each year. Generally, we found that grab sampling strategies underestimated the annual N-load in Horndrup stream and tended to overestimate the annual N-load in Lyby-Grønning stream. The MC assessment of the monthly N-load showed a much higher bias and standard deviation for monthly N-loads as compared to annual results. An underestimation of true N-load was found in December and January in both Horndrup stream (-2% to -13%) and Lyby-Grønning stream (-0.4 to -12%) except for the second monitoring year in Lyby-Grønning where an overestimation was found (0.1 and 0.3%). The highest total uncertainty was observed in Lyby-Grønning Stream amounting to 194% in August 2022 and in Horndrup Stream amounting to 28% in September 2022.

We tried to link our MC results for monthly grab sampling strategy for each stream to a calculated Richard Baker Flashiness index (RBI) and found a correlation for both years with the standard deviation in Lyby-Grønning Stream and with the bias in Horndrup Stream. In addition, we found higher correlations for the fall months. Consequently, it appears that the uncertainty may increase with the frequency of storm flow events in both streams.

Keywords: Nitrate sensor; NITRATAX plus; streams; nitrate load; uncertainty, Monte Carlo Approach

Abstract number–23 Soil water dynamics in the vadose (soil) zone under real environmental conditions

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The transport and dynamics of pollutants are among the most important processes in the aquifer, however they are often not so well known. The transport of water and pollution in aquifers depends, among other factors, on the characteristics of the unsaturated zone. The unsaturated zone of an aquifer serves as a water reservoir that discharges water and potential pollution to the saturated zone for a relatively long time. Nitrate pollution in groundwater, originating mainly from agricultural activities, remains a worldwide issue. Determining the transport characteristics of pollutants, including nitrate in a gravel unsaturated zone, is particularly difficult. Understanding the mechanisms and rates of movement of nitrate in the unsaturated zone is an important issue in the process of groundwater protection. One of the most valuable ways of investigating the characteristics, groundwater flow, and solute transport in the unsaturated zone is by conducting experimental research and tracing experiments.

Water and nitrate transport processes under different agricultural land uses have been studied. To sample the infiltrated water that flows into the agricultural land and through the unsaturated zone downward into the saturated aquifer zone, lysimeters were installed below the agricultural field. These capture the infiltrated water that feeds the aquifer and also transports pollutants from the surface to the groundwater. The $\delta 2H$, $\delta 18O$ and NO_3-N values in the unsaturated zone water were measured monthly. The knowledge of the chemical status of the infiltrated water helps us understand the impact of agricultural activity on groundwater quality under real weather conditions.

As expected, preliminary results show that the leaching of nitrates from agricultural land is much more significant in the case of agricultural use than in the case of grassland. The isotopes of pore water were in a similar range to those of precipitation in all three profiles. Variable isotope ratios in the upper 100 cm for the different sampling times indicate dynamic water fluxes in this upper part of the vadose zone. The results show also different evaporation levels in different soil types.

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Abstract number–24 Perspectives on available support motivating or demotivating adoption of agro-environmental measures

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Runoff of nutrients and sediments from agricultural areas are together with leakage of wastewater among the main causes for why European waterbodies still struggle to achieve good biological and chemical status (EEA report 07/2024). Further, soil loss and reduced fertility negatively impact crop yields and jeopardize income for farmers. It is the mandate of policy makers in agriculture to regulate on and incentivize farmers for sustainable management practices by means of mandatory, cross compliance and voluntary agro-ecological schemes. Considering the ecological status of water bodies, an increased adoption of agricultural sustainable management practices is needed, which demands efforts to better understand what promotes or demotivates them.

This presentation draws on work in the EU project OPTAIN (OPTimal strategies to retAIN and re-use water and nutrients in small agricultural catchments across different soil-climatic regions in Europe, 2021-2026). The project includes case studies in catchments dominated by agricultural land use that are experiencing challenges related to water management (floods and droughts) and quality (nutrient retention and runoff), soil health (erosion). We present results from an online survey with land managers, including farmers and farmers' associations, conducted in all the sites, namely in Belgium, Czech Republic, Germany, Hungary, Italy, Latvia, Lithuania, Norway, Poland, Slovenia, Sweden, and Switzerland. The survey focused on a site-specific set of already adopted/implemented measures: afforestation, basins and ponds, buffer strips and hedges, conservation tillage, cover crops, drainage infrastructures, floodplain restoration, grassed waterways, intercropping, wetlands and traditional terracing. The practitioners' perspectives for them about the sufficiency of currently available financing schemes, the adequacy of administrative support for funds and the assistance for reporting, as well as advice and training for technical and practical implementation of measures are presented. We show that there is a need to further tailor incentives to specific measures to address the needs of practitioners in different countries.

Abstract number–25 A decision workflow for best practice in high-frequency water quality monitoring

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The use of high-frequency water quality monitoring has increased over several decades. This has mostly been motivated by curiosity-driven research and has significantly improved our understanding of hydrochemical processes. In addition, high-frequency water quality datasets have been used to identify cases where low-frequency statutory data proved insufficient for adequate policy reviews and decision making. Despite these scientific successes and the growth in sensor technology, the large-scale uptake of high-frequency water quality monitoring is hampered by a lack of comprehensive practical guidelines. Therefore, the objective aim of this research was to provide a practical decision workflow for sensor applications based on international experiences, including considerations of monitoring data needs, equipment choice, maintenance and calibration, and structured data processing. The presented workflow aims at filling the knowledge-exchange gap between scientific research and practical water quality management and at promoting the effective uptake of high-frequency water quality monitoring. This becomes more relevant as climate change emphasizes the impact of short pollution load pulses during extreme events which are missed in conventional low-frequency monitoring.

Abstract number–28 Tracing the factors controlling the climate-induced migration and role of floating farming as adaptive measure in Southwest coastal region of Bangladesh

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The probability of environmental migration depends on a range of environmental, social, economic, political, and cultural issues. These critical factors must be accounted for meaningfully evaluating households' future mobility decisions. Considering Bangladesh as one of the most climatic vulnerable countries, and the frequent climatic extreme events in

Bangladesh's southwest coastal region significantly affected the local agricultural system and socio-economic well-being. Moreover, water plays as a focal point for these vulnerability as it is facing various challenges such as salt-water intrusion, drinking water availability, flooding etc. Many of the places in this region remained submerged around the year. With above mentioned information, this study strives to address two objectives: a) to evaluate the social, demographic, economic, environmental, and political drivers that affect the mobility decision of the households at risk in southwest coastal Bangladesh; b) to evaluate the role of floating farming as one of the climate change adaptive measures to optimize human well-being. Integrated approach of quantitative (multi-stage sampling technique, and Endogenous Switching Regression (ESR) model) and qualitative analysis was employed. Using a multi-stage sampling technique, we selected more than households in rural and urban areas, who had moved from their current locations due to climatic extremes. We applied relevant regression models to analyze the complex interplay of socioeconomic, environmental, and institutional factors shaping migration decisions. Empirical results suggest that, despite having greater access to services in cities, migrants reported lower levels of well-being than their rural counterparts, which could be attributed to reduced social cohesion and limited opportunities for participation in decision-making. Disaster preparedness, early warning access, and prolonged exposure to environmental hazards significantly influence migration decisions and well-being. Prolonged disaster suffering increases the likelihood of migration to urban slums, emphasizing the vulnerability of rural populations. Surprisingly, while slum dwellers have better service access, their well-being scores are lower than rural residents. To evaluate the effect of adopting floating farming as an adaptation strategy on farm households' profitability of floating farming, we used Endogenous Switching Regression (ESR) model. Our findings suggest that 79% of sampled farm households used floating farming to adapt to extreme climatic events like waterlogging, hazard effects, and erratic rainfall. Adopting farm households had a 60% higher farm profit than non-adopters, and cooperative membership, technical, credit, and training positively affected farm profits. This research contributes to understanding environmental migration dynamics in Bangladesh and informs policymakers about possible sustainable solutions.

Abstract number–29 Identifying waterlogging on arable fields - combining high-resolution distributed modelling and satellite images

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Waterlogging of arable soils worsen both quality and quantity of crop production. Water saturated conditions caused by extreme precipitation or snowmelt in combination with poor soil drainage lead to oxygen depletion affecting root and overall crop development. Climate change with increased occurrence and severity of extreme events will result in higher frequency of waterlogging events. Further, waterlogging may lead to increased loss of Nitrogen (N) due to higher denitrification and leaching. Similarly, waterlogging may increase

Phosphorus (P) losses due to enhanced P solubility under anoxic conditions, but also through an increased mobilization of soil particles and attached P due to weakened soil structure. Reliable identification of areas prone to waterlogging is therefore a precondition to efficient management at catchment and field scale to lessen production failure, reduce nutrient losses and avoid unnecessary management operations.

Topography controls spatial variations of hydrological conditions. Increased accessibility to high-resolution data and modelling approaches have enabled accurate identification of Critical Source Areas (CSAs) at catchment, field and sub-field scales. Here we have developed and applied a simple distributed model based on high-resolution elevation data to identify spreading of areas prone to waterlogging. In short, flow accumulation calculations based on elevation data result in focusing of flows to a single cell. Using flow accumulation cells as elevation reference cells, we modify original Digital Elevation Model (DEM) to identify flow dispersion to neighboring cells revealing in that way areas prone for waterlogging. The model was tested for a 164 square kilometers large, clay soil dominated, catchment in central Sweden. The modelling results are compared to Sentinel 2 satellite images and calculated Normalized Difference Water Index (NDWI). In total, 7.7% of catchment area was identified as vulnerable to waterlogging. The proportion of waterlogging prone arable land (45% of catchment area) was somewhat higher, amounting to 11.8%. Modelling results, satellite images and NDWI are compared to discuss pros and cons of different approaches.

Abstract number–31 Decreased aqueous exports of nitrogen, phosphorus and carbon after rewetting of pump-drained fen

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Draining organic soils over centuries has transformed them from carbon and nutrient sinks into significant sources. Naturally, wetlands act as the “kidneys” of landscapes, providing anaerobic conditions that enable redox processes like denitrification, supported by abundant electron donors in the form of organic carbon. However, prolonged drainage and agricultural use have degraded these soils, leading to phosphorus (P) accumulation, particularly in the topsoil. A substantial amount of this P is often bound to iron (Fe) oxides, which are sensitive to redox changes. Upon rewetting, these oxides can dissolve, releasing soluble reactive phosphorus (SRP) into downstream recipients. Therefore, reintroducing anaerobic conditions in rewetted soils poses a risk of substantial SRP release.

In Danish restoration projects, this risk is typically evaluated using a model that considers the soil molar ratio of P to Fe (extracted by bicarbonate-dithionite) alongside hydraulic loading rates (HLR). However, current assessments do not consider P release from drained soils prior to rewetting, which may lead to an overestimation of P release in the overall risk assessment.

This study monitored water, nitrogen (N), phosphorus (P), and carbon (C) balances in a pump-drained fen in northwestern Jutland, Denmark, comparing nutrient retention and export before and after rewetting. Preliminary findings indicate that significant amounts of N (>100 kg/ha/yr), P (>5 kg/ha/yr), and C (>1000 kg/ha/yr) were released before rewetting, with N primarily in organic forms and P roughly split between particulate P (PP) and SRP. After rewetting, which included hydrological reconnection to a nearby stream and a substantial increase in HLR, the fen shifted from a nutrient source to a significant nutrient sink, removing over 400 kg N/ha/yr and more than 15 kg P/ha/yr. Aqueous C export also decreased to about 200 kg ha/yr. Notably, SRP was the main form of retained P, while small amounts of PP were still released.

These results have important implications for the rewetting of pump-drained soils. Given the risk of SRP release, some restoration projects may be delayed to allow for P depletion through plant harvesting, or face additional costs for removal of degraded top soils. In some cases, restoration efforts may be abandoned entirely due to SRP risks. However, accounting for P release before rewetting could reduce the perceived risk and enable more projects to proceed, benefiting greenhouse gas reduction, nutrient management, and biodiversity.

Abstract number–33 How dynamic are flow contributions and mean water ages in a diverse group of regional rivers?

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Assuming that a hydrograph can be explained by temporally varying flow contributions by different hydrological pathways, the mean age of the river water (or Mean Transit Time, MTT) will also vary with flow. Three-component models differentiating between very young, episodic, near-surface water (NS), young, seasonal, shallow groundwater (SGW), and old, perennial, deep groundwater (DGW) have often been found adequate to describe contributions. This study aimed to ascertain spatiotemporal flow contribution and MTT patterns in a group of 19 rivers spread across the Waikato region of Aotearoa New Zealand. The corresponding catchments differed widely in their environmental and land use characteristics.

Bayesian chemistry-assisted hydrograph separation (BACH), which combines a recursive digital filter with a chemical mixing model for two environmental tracers (e.g. Total Nitrogen, Electrical Conductivity), was carried out to split the hydrographs into the three components potentially feeding flow. MTTs were derived by applying an exponential-piston flow model (EPM) with 70% mixing fraction to the tritium data from 4 – 9 samples analysed to capture the observed annual flow range.

The relationship between estimated MTTs and flow could in most cases be well described by a power function ($R^2 \geq 0.90$ in 12 cases). MTTs ranged most widely at low flows (5 – 58 yrs at Q90), still widely at median flows (1 - 33 yrs at Q50), but only modestly at high flows (0 - 14 yrs at Q10). Based on their MTT dynamics, the rivers could be clustered into three distinct groups. Six rivers, mostly arising in volcanic upland catchments with big aquifers, featured the highest variation (21 – 51 yrs between Q90 and Q10). MTTs in seven (predominantly lowland) rivers distributed across the region varied modestly (6 – 17 yrs), and very low MTT variation of <5 yrs was observed in six rivers, which originated from steep catchments with particularly high rainfall.

The MTTs varied widely between catchments, but they were always highest when BACH modelling suggested that the flow was dominated by DGW, and dropped when flow contributions by SGW or NS pathways increased. This occurred episodically throughout the year during storm events, and more prolonged during wet periods with high river flows in winter/spring.

While these results demonstrate a broad agreement between MTT and pathway dynamics, further analysis revealed a systematic discrepancy between the MTT distributions that can be described using an EPM and the age assumptions inherent in BACH. Binary Mixing Models (BMMs) that explicitly describe the combination of a younger and an older source of water, would be required to describe the wide age distributions indicated by BACH. As tritium time series of sufficient length and quality to fit BMMs are very rare, future work will explore whether BACH modelling to constrain the young water fraction could potentially enable alternative approaches to the fitting of binary models.

Abstract number–34 How will rapidly rising atmospheric CO₂ concentrations affect freshwater systems?

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Gases in air and water continuously exchange. Amongst these, oxygen (O₂) and carbon dioxide (CO₂), linked by ecosystem metabolism, are central to both ecosystem health and water chemistry. Our analysis of a limited amount of existing monitoring data shows that the concentration of these gases in the Waikato River has steadily changed over the last three decades. Exponentially rising atmospheric CO₂ concentrations therefore have the potential to add substantial pressure to Aotearoa-New Zealand's freshwater systems already suffering degradation.

Our new five-year research programme 'Safeguarding Te Mana o Te Awa o Waikato from emerging climatic pressures' seeks to understand the effects of rising CO₂ pressures on the iconic Waikato River, and freshwater more generally.

Our programme sets the ambitious goal of developing a mechanistic understanding of the relationship between pCO₂ (the partial pressure of carbon dioxide) and phytoplankton growth responses to dissolved inorganic carbon and nutrient bioavailability, thereby allowing prediction of future riverine water quality.

From the first-order controls (i.e. the balance between heterotrophic metabolism and CO₂ efflux), to second-order feedbacks (e.g., pH-dependant changes in nutrient bioavailability), we aim to identify and predict the precursors of harmful algal blooms (HABs) in the Waikato River under plausible climate emissions scenarios. If successful, the mechanistic understanding developed will have broader relevance for freshwater habitats across Aotearoa-New Zealand, and globally.

Our work includes fundamental research on:

- genomic studies of the tolerance (and potential adaptation) of freshwater mussels (kāhaki, *Echyridella menziesi*) to elevated pCO₂ and associated carbonate undersaturation (which dissolves shell material);
- how pCO₂ affects the processes of inorganic carbon accumulation by phytoplankton and influences algal phenology (e.g., diatoms vs cyanobacteria);
- how riverine pCO₂ influences harmful algal bloom formation via feedbacks in nutrient availability; and
- how flow and meteorological conditions on varying length scales influence CO₂ exchange across the river-atmosphere interface.

These studies will further inform the development of river ecosystem models also to be developed within this programme for forecasting freshwater quality changes under projected climate conditions (up to the year 2100). Kaupapa Māori researchers in our team will then investigate the implications of the programmes' technical findings for Te Ture Whaimana o Te Awa o Waikato, the Vision & Strategy document guiding the restoration of Waikato River.

Abstract number–35 First-year performance of a pumped, cold-climate woodchip bioreactor

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Information on bioreactor performance is limited in colder northern agricultural climates such as the Red River Basin of the North. Although the primary environmental concern in this watershed is phosphorus loss to Canada's Lake Winnipeg, nitrogen losses are a statewide resource concern for the U.S. state of Minnesota. Additional information on strategies for mitigating excess nitrogen loss is needed in northern climates. Northwest Minnesota's first bioreactor was installed in November 2023 with an innovative design: water is pumped into the bioreactor from the subsurface drainage lift station. The site location was a strong candidate for a denitrifying bioreactor to remove excess nitrates in subsurface drainage discharge based on its site characteristics. This site has a loamy-sand soil type on which irrigated corn is grown. This presentation will provide an overview of the bioreactor's design

and its initial performance metrics (hydrologically and for water quality improvement) during Summer and Fall 2024.

Abstract number–37 How to proceed with impact monitoring for groundwater quality protection in agricultural landscapes?

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Legal constraints and voluntary commitments have been established to reduce harmful effects of intensive agriculture on groundwater quality. There is general agreement on adequate measures in this regard. Providing proof of effectiveness of implemented measures in real-world settings beyond experimental fields, though, faces serious problems. Groundwater quality is affected by a variety of different effects, including, e.g., short-term meteorological extreme events, long-term climate shifts, changes of management, etc. Last but not least, there is increasing awareness about ubiquitous pronounced legacy effects after more than half a century of intensive agriculture in many regions of the world. But management without impact monitoring does not only run the risk of wasting resources but of impairing the willingness of farmers, authorities and policy makers to implement adequate measures. Thus development of impact monitoring approaches should be of high priority in science.

We report on related activities in North Germany and derive some general recommendations. We focus on the analysis of data from standard monitoring programs. We do not include comprehensive modelling approaches due to the common lack of appropriate data as well as of the required high time investment. Including as many observations as possible in the analysis has proven to be decisive to differentiate between different effects. This applies in the first place to the number of observables: Due to different sensitivities toward different effects multivariate analyses can elucidate the interplay of various synchronous effects and minimise the risk of drawing inferences from spurious bivariate correlations analyses. E.g., joint analysis of the concentration of various solutes in groundwater allows further conclusions to be drawn than, e.g., analysing nitrate concentration only. Common analysis of different metabolites of the same pesticide can reveal a lot of information about turnover and transport in the subsurface. Last but not least, persistent and soluble metabolites can be used as tracers to elucidate subsurface immobilisation, re-mobilisation and transport processes. In fact and contrary to common expectations short-term dynamics of contaminant concentration often reflect in the first place the role of subsurface processes rather than allowing direct inferences on agricultural management. In general we found overwhelming evidence for the prevalence of long-term legacy effects in the vadose zone. On the other hand, the potential of modern diagnostic

tools to address the challenges of impact monitoring is still widely underrated and deserves much more attention from scientists, consultants and authorities.

Abstract number–38 Hydrological ecosystem services from constructed agricultural wetlands – now and in the future

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How efficiently constructed wetlands (CWs) support hydrological ecosystem services in agricultural areas is still unclear due to a lack of knowledge and understanding of the underlying processes and interactions of the different wetland components. Here, we assess to what extent CWs designed for nutrient-retention and biodiversity in Mälardalen, Sweden, can contribute to mitigating hydrological extremes. We used hourly water level measurements from CWs collected between 2023 and 2024 to calibrate the PERSiST rainfall-runoff model. The calibrated models were then used to project future water levels for a 30-year period (2041-2070) under different RCP (RCP4.5, RCP8.5) and extreme precipitation scenarios. In a second step, the findings were used to investigate the water storage capacity of the CWs and hence their potential flood and drought buffering capacity. All climate scenarios projected an increase in temperature and precipitation. Furthermore, simulated water level fluctuations indicate that there will be more water in the landscape under all projected climate scenarios, especially the extreme precipitation ones. Factors that crucially influence water storage capacity of CWs included purpose (i.e. biodiversity vs. nutrient retention), management, relative area of the CW compared to the catchment, location in the landscape and interaction with the surrounding environment. Additionally, it became apparent that CWs are extremely complex and even CWs with apparently similar characteristics display very different hydrologic responses. This rules out the possibility of a “one-size-fits-all” concept but highlights the need for more in-depth and site-specific assessment of CW performance. This paper introduces an innovative and simple approach to modeling hourly water level dynamics in individual CWs. The method supports inferences about the resilience of single CWs in the landscape towards climate and especially extreme precipitation scenarios and what role they can play as nature-based solution to mitigate consequences of climate change. Nonetheless, further research should progress to a broader spatial scale and holistic watershed-based perspective on CWs for more robust decision making.

Abstract number–39 Unlocking the secrets of soil: Harnessing machine learning to predict autumn mineral nitrogen levels in Germany’s agricultural fields

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In Germany, the implementation of the European Nitrates Directive (91/676/EEC) is facilitated through the establishment of a monitoring programme as part of the broader action programme. To overcome the mostly ambiguous relationship between nitrogen management and nitrate concentrations observed in groundwater, potential nitrate loads from agriculture need to be properly estimated. For this reason, data from farms in selected model regions have recently been collected and analysed as part of a new approach to nitrate monitoring in Germany.. The installation of the first model regions started in 2016. In the ongoing project, “Monitoring nitrogen emissions in crop production (MoNi2)”, data are collected on 96 farms with 1116 test fields in 12 model regions throughout Germany. A substantial number of parameters is being gathered from these test fields. The data set includes management, field and farm balance data, soil mineral nitrogen contents (0-90 cm depth) in spring, at harvest, and in autumn, and nitrate concentrations in leachate in soil depths down to 3 m. The soil mineral nitrogen content in autumn is of particular interest to estimate the nitrate leaching potential. It serves as an indicator of the potential nitrate load that can be lost during the subsequent leaching period. In a previous study, we identified the primary factors influencing soil mineral nitrogen content in autumn through a machine learning approach. Since then, the model has been improved through the inclusion of more test areas and the availability of longer time series. The main crop grown on the field remains the most significant influencing factor on soil mineral nitrogen content in autumn. Other important factors are the soil type, the soil mineral nitrogen content in spring, and precipitation in October. In this study, we used this enhanced model to predict the soil mineral nitrogen contents in autumn for the entire model region “Wagrien” in Northern Germany (1225 km²). The input data included information on the crops grown each year, predicted using satellite data, publicly available soil type and soil texture and monthly weather data on an 1 km x 1 km grid. We analysed the influence of the main crops grown and of modified crop rotations on the total potential nitrate load for the model region. The impact of changing weather conditions was also examined.

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Abstract number–40 Current phosphorus status of agricultural fields in Germany

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Phosphorus fertilisers play a decisive role in ensuring high productivity in agriculture. However, the excessive use of organic and mineral phosphorus fertilisers in the past is one of the main reasons why less than 50 % of Germany's surface water bodies meet the criteria for good ecological status for total phosphorus under the Water Framework Directive (WFD). In this study, we analyse the status and development of phosphorus balances in agriculture, also taking into account the effectiveness of the measures specified in the national action programme, i.e. the German Fertiliser Ordinance. According to the Federal Statistical Office, sales of phosphate-based fertilisers are declining. This raises the question of how the use of phosphate fertilisers has changed at the level of farms and their soils, and what the supply status of the soils is now. For this, we analysed a data set from practical farms within the demonstration project „Monitoring of nitrogen emissions in crop production (MoNi2)“. Data of phosphorus balances at field scale and soil phosphorus contents from 96 farms in 12 test regions across Germany, comprising a total of 1116 fields and observations for two to ten years were included. First results show overall negative balances with differences between the various farm types (arable, livestock and vegetable farming), with less negative balances and higher soil phosphorus contents for livestock farms.

Abstract number–41 OPTAIN - Optimal strategies to retain and reuse water and nutrients in small agricultural catchments

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The increasing frequency of droughts and heavy rainfall is intensifying conflicts between agricultural water use and other human and environmental demands. Natural/Small Water Retention Measures (NSWRMs) can help mitigate these conflicts by enhancing water quality, improving agricultural resilience, and contributing to sustainable development goals. However, there are knowledge gaps about the effectiveness of these measures across different regions, scales, and climate conditions. The EU Horizon 2020 project OPTAIN aims to address these challenges in 14 European case studies. The project involves local stakeholders through Multi-Actor Reference Groups, which have identified and documented 235 potential NSWRMs, of which 66 from 29 categories have been selected for further evaluation. These measures are catalogued in collaboration with the WOCAT and NWRM.eu databases. To assess the impact of these NSWRMs at field and catchment scale, OPTAIN applies the SWAT+ model with a fully distributed routing scheme, accompanied by further field-scale simulations using SWAP in areas of high data availability. The project developed protocols and R scripts to standardize data preparation, model calibration, and evaluation across case studies, ensuring consistent analysis. Initial simulations in the German case study demonstrate positive effects of NSWRMs, such as low tillage and grassed waterways, in reducing peak water flows, increasing low flows, and enhancing nutrient and sediment retention. Furthermore, the project linked SWAT+ with an economic model using the CoMOLA platform to optimize NSWRM allocations based on environmental and economic criteria. Policy analysis is another important component of OPTAIN, with local and regional policies being reviewed to identify gaps and opportunities for harmonizing water and agricultural policies across Europe. Interim findings, shared through policy briefs, emphasize the need for better integration of agro-environmental policies, increased intersectoral collaboration, and awareness-raising among stakeholders. OPTAIN's overarching goal is to improve the acceptance and implementation of NSWRMs by harmonizing data, methods, and policies across the 14 case studies. While there are significant differences between countries, which pose challenges for comparative studies, the project is working to address these through data standardization and model improvements. The R scripts developed by the project will assist future SWAT+ users worldwide in setting up and calibrating models to evaluate the effectiveness of NSWRMs in water and nutrient retention. Ultimately, OPTAIN aims to optimize the spatial allocation and combination of NSWRMs, ensuring they are both environmentally and economically sustainable, while also promoting policy alignment at local, national, and EU levels.

Abstract number—42 Locally Based River Basin Management Plan: An Integrated Modelling Framework for Ringkøbing Fjord

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In 2023, an Integrated Model Approach with Stakeholder Involvement was used to develop a Locally Based River Basin Management Plan (RBMP) for Ringkøbing Fjord and its catchment. This initiative was enabled by a 2021 decision in the Danish Parliament to test a more localized approach for achieving Good Ecological Status (GES) in Danish coastal waters, in line with the EU's Water Framework Directive. The local RBMP for Ringkøbing was one of four test sites across Denmark.

A local water council was established, comprising 13 interest organizations and four municipalities. Stakeholders included green organizations, agriculture, fisheries, and water companies. Ringkøbing-Skjern Municipality held overall responsibility and coordinated with experts (authors of this paper).

Ringkøbing Fjord, a 300 square kilometer coastal lagoon system in western Jutland, Denmark, averages just under 2 meters in depth. It connects to the North Sea via a sluice and receives freshwater from the Skjern River and smaller streams. The fjord drains a basin of about 3500 km², with agriculture covering 65-70% of the catchment. The ecosystem dynamics of Ringkøbing Fjord are complex. Under normal discharge conditions and sluice operation, a significant population of soft-shell clams exists in the fjord. Salinity can fluctuate due to natural events like high precipitation or management policies such as reduced water exchange with the North Sea through the sluice. These events can lead to low salinity conditions, resulting in high clam mortality. When clam biomass is high, their filter-feeding reduces chlorophyll levels, improving water clarity and promoting the growth of benthic vegetation.

The RBMP 2021-2027, created by national authorities, did not sufficiently account for sluice management and top-down control by clams. Therefore, an integrated fjord and catchment model system was established to address management-related questions concerning the sluice, fjord, and catchment area. This system included: 1) Sluice model, 2) Hydrodynamic and ecological model for the fjord, 3) SWAT catchment model, and 4) Phosphorus model - risk mapping in the catchment area.

The modeling work demonstrated that operating the sluice in a specific way could sustain a high population of clams, enabling them to filter the fjord for chlorophyll and help achieve Good Environmental Status. However, nutrients reductions were still necessary to control epiphytes in the lagoon and the local water council made ten recommendations related to

the fjord and nutrient reductions, emphasizing the re-establishment of wetlands to reduce nutrient loads to the fjord.

Abstract number–43 Stream restoration reduces nitrate loads in agricultural landscapes

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European Water Framework Directive (WFD) reported that stream/river morphological alteration and diffuse pollution are two dominant pressures of European water bodies at the catchment scale. Therefore, stream/river restoration has received increasing attention to achieve the good ecological status targeted by WFD. However, less is known about the spatial and temporal effects of stream morphologic change (i.e., re-meandering) on in-stream NO₃⁻ retention at the stream network scale. This study investigated the effects of seasonality and morphological variations on network-scale in-stream NO₃⁻ retention in the well-monitored Bode catchment (3200 km²) in central Germany. First, we implemented a fully distributed, process-based mHM-Nitrate model in the study area. Second, we conducted a scenario analysis assuming more natural morphological stream conditions by increasing the stream sinuosity according to its relationship to stream power. The parametrization of the model is strongly based on further stream retention process studies in several reaches of the Bode stream network. Results showed that the model well captured the dynamics of daily discharge and NO₃⁻ concentration, with median Kling-Gupta Efficiency of 0.78 and 0.74 for discharge and NO₃⁻ concentration during 2015-2018, respectively. Gross in-stream retention (including gross assimilatory uptake and denitrification) by the whole stream network accounted for 5.1% and 67.2% of total NO₃⁻ loadings in winter and summer, respectively. The summer in-stream denitrification rate in the lowland arable-dominated stream network was about two times higher than in the mountain forest-dominated stream network (204.1 and 102.4 mg N m⁻² d⁻¹, respectively). Similarly, the summer in-stream gross assimilatory uptake rate in typical lowland arable streams was approximately five times higher than that in typical upland forest streams (200.1 and 39.1 mg N m⁻² d⁻¹, respectively). Denitrification always peaked after gross assimilatory NO₃⁻ uptake in the late summer. The scenario representing more natural stream network conditions by restoring the stream sinuosity can increase in-stream net NO₃⁻ retention efficiency up to 25.4%, with increasing efficiency more pronounced for small streams. This study highlights

to consider increasing stream sinuosity as an efficient mitigation measure to increase in-stream retention and reduce NO₃⁻ export at the stream network scale.

Abstract number—45 The Effect of Nature-inspired Farming Systems on Soil Hydrological Functioning and Nutrient Leaching

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Conventional farming systems have a strong impact on their environment. Continuous manipulation of the soil negatively affects soil structure by compaction, soil carbon degradation and enhancing soil surface crust formation, which in turn hampers the hydrological functioning of soils and promotes soil erosion. Application of herbicides and pesticides and leaching of excess nutrients negatively affect soil life, surface water and groundwater quality, which in turn forms an issue for (aquatic) ecosystems and drinking water and irrigation water provisioning services. Therefore, in order to protect the environment, it is necessary to find alternative farming approaches that enhance soil health and soil hydrological functioning. So far, research into the effect of alternative tillage systems and organic amendment measures on soil health, hydrological functioning and nutrient leaching has been inconclusive. Moreover, few studies have assessed the combined effects of tillage, organic matter amendment and organic farming combined. In this study, we present the results of a 23-year long experiment comparing the effects of tillage (conventional tillage and non-inversion tillage (NIT)) and organic matter amendments (artificial fertilizer, manure slurry, and compost addition) in both a conventional and organic farming system. As a “natural” baseline, we also compared the agricultural soils to an undisturbed forest soil nearby. We expect that the undisturbed, natural soil contain the best soil physical parameters (such as a low bulk density and well-developed aggregates), which has been facilitated by limited soil disturbance, high soil organic matter content and a healthy community of soil organisms. This contributes to good hydrological functioning, climate resilient crop production, and limited nutrient leaching. We measured various compounds of nitrogen (N) and phosphorous (P) in the soil and groundwater, C:N ratios, labile and resistant organic matter (LOM and ROM), soil physical parameters such as aggregate stability, presence of soil life such as bioturbators and hydrological functions such as infiltration rates. Moreover, undisturbed soil cores were taken and subject to column experiments, to measure nutrient leaching under different climatic conditions. Based on these results, we conclude to what extent NIT, organic matter amendments and organic practices perform better in terms of soil health, hydrological functioning and soil nutrient leaching, and as such lessen their impact on the environment by contributing to good water quality.

Abstract number—46 Amending Water Quality through Nature-inspired Principles – an Overview

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Globally, water quality is at risk due to pollution via urban and industrial wastewater, agricultural intensification and human interference with natural hydrological processes that control water quality. Moreover, climate change is expected to exacerbate the processes associated with water quality decline. Good water quality is crucial to the functioning of our ecosystems and the ecosystem services they provide, and as such, measures to ensure good water quality now and in the future are necessary. Measures guided by nature-inspired principles (NIPs), are a popular approach in combatting global issues like climate change and biodiversity loss, but it is unknown whether they can contribute to water quality as well. NIPs include any principles in land use and management that incorporate natural processes to achieve their aims such as nature-based solutions, environmental and ecosystem engineering, agroecological principles and better management practices. Part of their popularity lies in their relatively low costs, easy maintenance and their capacity to address multiple environmental issues, such as water retention, carbon capture, and biodiversity loss. However an overview of water quality-amending NIPs is lacking. Therefore, the objective of this research was to create an overview of existing NIPs, how they can be used to improve water quality and what the main working principles behind their effectivity are. We conducted a systematic literature review, focusing on NIPs that aim to mitigate nutrient (nitrogen and phosphorous) pollution. We found that NIPs can indeed contribute to water quality, while also offering benefits with regards to water quantity. NIPs contribute to water quality by improving nutrient retention and water infiltration capacity of soils, and by harnessing natural cleansing processes like phytoremediation. Furthermore, we provide a categorization system according to their spatial distribution throughout catchments and the scale at which they are applied. Lastly, we identify potential effects of climate change on the effectivity of NIPs in improving and maintaining good water quality. Though NIPs are promising with regards to improving water quality, we expect climate change to negatively affect some of the natural processes that support NIPs' effectiveness. However, small decreases in effectivity do not detract from the overall effect NIPs have on water quality, their easy and low-cost implementation, and multiple other benefits for the environment.

Abstract number—47 Evaluating nitrogen removal efficiency in a constructed wetland dominated by diffuse agricultural groundwater inflows using an integrated catchment–wetland model

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Nitrogen loading from diffuse agricultural sources is a significant water-quality concern globally. Constructed wetlands have become an increasingly common approach for treating runoff and drainage from agricultural lands. However, due to the diffuse nature of nitrogen loading from farmlands, tracing flow pathways and accurately measuring nitrogen inputs to wetlands—as well as evaluating their nutrient reduction efficiency—remains challenging. At the Owl Farm wetland in Cambridge, New Zealand, we encountered this difficulty, as direct measurement of wetland inflows was not feasible due to the primary sources being diffuse groundwater seepage and intermittent flows from a subsurface drain. We applied the Soil and Water Assessment Tool (SWAT) to estimate and partition nitrogen inflow from both the drain and seepage sources. A dynamic first-order tanks-in-series wetland model was linked with SWAT to evaluate the wetland capacity for nitrogen removal over a four-year period. The linked catchment-wetland model showed strong agreement between simulated and observed flow and nitrate loads at the wetland outlet, achieving Nash–Sutcliffe efficiency (NSE) values of 0.7 and 0.76, respectively, suggesting that it provides a good representation of the hydrological and nitrogen processes in the upland catchment and the constructed wetland. To estimate nitrogen removal efficiency, we employed two methods: a mixed measurement and modelling approach and a process-based modelling approach. Both methods showed that nitrate-N and total N load removal were exponentially related to wetland outflow rates. Based on the process-based model estimates, the Owl Farm constructed wetland is highly effective in removing nitrate-N, with annual removal rates ranging from 55–80% (averaging 61%). However, this efficiency is highly dynamic, influenced by inflow rates from the catchment; removal rates are highest during low flows and decrease at higher flows, though still maintaining a removal rate of around 20–40% during high-flow periods. Notably, actual nitrogen-load removal in the wetland is greatest during these high-flow periods when input loads peak. This study highlights how a linked catchment–wetland modelling approach can effectively quantify diffuse nitrogen inputs from varied runoff sources and assess wetland nutrient reduction. This tool is particularly valuable for cases where diffuse groundwater inflows, which are difficult to measure, are significant nutrient sources.

Abstract number–49 Using Land Use to Predict the Risk Posed by Mixtures of Pesticide Active Ingredients in Waterways Entering the Great Barrier Reef Lagoon, Australia

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Monitoring pesticides in waterways is challenging due to spatial and temporal variability, logistical constraints, and high costs. In Australia, droughts and flood events can present logistical and safety constraints, while adequate spatial coverage can be costly. To address this issue, a method was developed to predict the combined toxicity and risk of 22 pesticide active ingredients in waterways discharging to the Great Barrier Reef (GBR) lagoon using land use, hydrological, and spatial variables. These relationships enable risk predictions for sites and spatial scales lacking pesticide monitoring data. The relationships explain 60 to 80% of the variation in pesticide risk for four pesticide groups: all 22 pesticides, photosystem II (PSII) inhibiting herbicides, other herbicides, and insecticides. Our findings indicated that 71 to 100% of aquatic species were protected at the basin level. While at a larger spatial scale, the entire GBR catchment area achieved 97% protection of aquatic species. Land uses such as agriculture and urban development were key predictors in the model, highlighting the impact of human activities on pesticide delivery to waterways in the GBR catchment area. While significant spatial variability was observed across different regions, PSII herbicides were generally the highest contributors to overall mixture toxicity, followed by other herbicides and insecticides. This study provided a cost-effective method to assess pesticide mixture risk at multiple spatial scales and provided data to guide actions to reduce toxic impacts on aquatic ecosystems. While specific to the GBR catchment area, this method can be applied internationally to predict pesticide mixture toxicity in unmonitored waterways.

Abstract number–50 Impact of Pesticide Mixtures on Aquatic Ecosystems: A Risk-Based Approach

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Poor water quality associated with land-based runoff is one of the primary pressures impacting the health and resilience of Australia's Great Barrier Reef (GBR). Research shows

that 81% of water samples taken in the GBR catchment area contain complex mixtures of pesticides including herbicides, fungicides, and insecticides. The presence of multiple pesticides, even at low concentrations, has been found to present a cumulative toxic risk to aquatic ecosystems. The Pesticide Risk Metric (PRM) was developed to estimate the toxicity of pesticide mixtures detected in water samples, using species sensitivity distributions (SSDs) combined with the independent action model of joint toxicity to provide an estimate of the cumulative biological effects on aquatic organisms. The SSDs were developed using the same toxicity data and methodology as the Australian and New Zealand Guidelines for Fresh and Marine Water Quality. This means the resulting mixture toxicity estimates can be used to evaluate whether the desired level of ecosystem protection is being met under the Australian Water Quality Management Framework. The PRM has been used to report against the Reef 2050 Water Quality Improvement Plan in the Great Barrier Reef Water Quality Report Card, and is a core reporting deliverable for the Great Barrier Reef Catchment Loads Monitoring Program. The PRM has recently been expanded from 22 to 53 pesticide active ingredients across multiple modes of action, including fungicides for the first time. This presentation will outline the functionality of the expanded PRM and present mixture toxicity estimates from waterways in the GBR catchment area as a case study. In some locations, up to 42% of aquatic species could be affected by pesticide mixtures, with significant spatial and temporal variability observed across different the different geographical regions.

Abstract number–51 The Temporal Response Surface: Assessing the delayed and cumulative impacts of imidacloprid on aquatic ecosystems

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Imidacloprid, a widely used neonicotinoid insecticide, is frequently detected in the waterways of the Great Barrier Reef (GBR) catchment area, often exceeding water quality guidelines for ecosystem protection. Imidacloprid is detected in an average of 54% of all samples collected by the GBR Catchment Loads Monitoring Program, with concentrations remaining elevated for up to five months in some locations. This is unsurprising as it is registered for, and highly relied upon, in a diverse range of crops in Australia. However, a growing body of literature highlights the potential for imidacloprid toxicity to increase over time due to irreversible binding to target receptors within aquatic organisms. Toxic effects may accumulate within these organisms if exposed to extended or repeated pulses of imidacloprid in the waterway,

potentially resulting in greater impacts than previously estimated using relatively short-term toxicity test data (typically four days of duration). To address this gap, we introduce the Temporal Response Surface (TRS), which incorporates exposure duration into the species sensitivity distribution (SSD) approach to estimate the cumulative and delayed toxic effects of imidacloprid exposure. The TRS method reveals that imidacloprid concentrations protective of 99%, 95%, 90%, and 80% of the aquatic ecosystem decrease significantly within the first 30 days of continuous exposure and continue to decline over a 100-day period. This novel, world-first approach provides a more comprehensive assessment of the risks posed by chemicals with delayed and cumulative toxicity characteristics, enhancing and better informing efforts to protect aquatic ecosystems.

Abstract number–52 National nitrogen model for national regulation of nitrogen

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During transport of nitrogen from the field to sea, nitrogen, mainly in the form of nitrate, may undergo natural denitrification in the subsurface or in surface waters, such as streams, lakes, wetlands etc. For Denmark it is estimated that approximately 65% of nitrate leaching from the root zone and 20% of nitrate reaching the surface water system is reduced during transport. The reduction is caused by natural processes but shows large spatial variation at various scales, due to the heterogeneity of the physical and chemical system. Spatial variability means that the effectiveness of nitrogen mitigation measures will also vary spatially, with highest effect in areas with the lowest degree of denitrification. Identifying areas with high and low denitrification potentials is thus vital for optimal management of nitrogen uses and development of cost-effective mitigation programmes.

A national nitrogen model has been developed for Denmark by coupling national models describing the various parts in the terrestrial nitrogen cycle. Nitrate leaching from the root zone is based on the statistical model NLES5 that combines physical data such as soil and climate with management practices such as crop rotation and application of synthetic fertiliser and animal manure. Simulation of groundwater transport, including drainage and nitrogen reduction in the subsurface, is based on the national hydrological model combined with a description of geochemical subsurface conditions important for denitrification. Denitrification in surface water systems is described by individual statistical models for small and large lakes, small and large watercourses, constructed wetlands, constructed mini wetlands and temporarily flooded areas. The model complex is developed to calculate nitrogen transport and reduction from the root zone to the sea, and to calculate denitrification

between the root zone and the sea to produce the so-called national nitrogen retention maps.

A new agricultural nitrogen regulation model is currently being developed in Denmark by the authorities that will exploit the model results for the advancement of a spatially differentiated regulation of nitrogen usages. Important for the new regulation is to explore the scale at which nitrate reduction can be estimated with acceptable certainty. Central to the current development of the national nitrogen model is thus an assessment of the uncertainties in the estimated nitrate reduction by stochastic simulations and assessment of the relation between scales and uncertainties.

Abstract number–53 Literature review and meta-analysis of denitrification rates for unconsolidated sedimentary aquifers

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Globally, nitrogen (N) losses from agriculture are critical as the safe planetary boundary for N has been exceeded. In Denmark and in the European Union, nitrate (NO₃) pollution is the main cause of failure to achieve good chemical status for groundwater. A spatially targeted agricultural N regulation model is being developed in Denmark to further reduce the impact on the aquatic environment. Knowledge about NO₃ reduction in groundwater is crucial for that. The most important biogeochemical process, responsible for NO₃-removal in groundwater is denitrification (reducing NO₃ to N₂O or N₂). Denitrification rates in groundwater can vary few orders of magnitude, however a global overview is lacking. Moreover, no systematic study has been carried out to assess the effect of different site- or study-specific characteristics which could potentially explain this variation.

To fill this research gap, we did a literature review, based on a systematic approach to identifying and screening sources for relevance and performing critical appraisal. A data extraction protocol (denitrification rates and auxiliary potentially explanatory data) was prepared a priori and followed through. Two different statistical methods were used for data-synthesis: 1) meta-analysis based on random-effects model, stratified by study site location, sediment type, method, depth interval, 2) Gaussian finite mixture modelling for a homogeneous sub-set of the data from Denmark. The Danish sub-set allowed for more detailed investigation on the distribution of denitrification rates by location, surface geology, depositional environment, geomorphology, lithology, sediment texture, redox state, and saturation state.

The review included data from 69 studies published in the period 1988–2023, covering study sites in 17 countries, mostly in the Northern hemisphere. Nearly half of the studies were on aquifers in the USA (already reviewed elsewhere), while Denmark was at the second position with 9 studies, thus selected as focus-country. The kinetic order of the denitrification

rates was not reported or discussed in 33 of the studies, however the reporting units were zero-rate-like. The non-first order rates (690 individual measurements or reported descriptive statistics) were converted to mg N/L/y and transformed with a natural logarithm. The majority of the data points were for porous sedimentary aquifers (non-consolidated) with ln-transformed rates in the range -10 to 12.1 with median 2.75 (back-transformed to 15.6 mg N/L/y).

In this presentation we will show for first time results from both the meta-analysis and the gaussian finite mixture modelling and will discuss gaps in knowledge and potential future research directions.

Abstract number–54 Building value in environmental monitoring for more informed decision-making about trade-offs between ecosystem services and disservices from nature-based solutions

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Society increasingly expects that food will be produced in a sustainable, climate-smart manner. Nature based solutions (NBS), including ponds and constructed wetlands are widely promoted by researchers as a class of measures promoting healthy agricultural landscapes. However, a range of trade-offs associated with NBS influence practitioner's decisions about their implementation and use. Making the right decisions about NBS requires, amongst other things, access to data from environmental monitoring programmes. The value of monitoring programmes depends on how well the data they collect and curate can be used to support decision-making. Here, we present a conceptual framework for assessing the value of monitoring programmes based on the relevance of the data they collect to decision maker needs, their overall running costs and their levels of uncertainty in characterizing the state of the environment. We demonstrate how our proposed framework can be used to assess the value of a range of monitoring programmes for quantifying trade-offs between nutrient load reduction and climate impacts from artificial wetlands in agricultural landscapes. We highlight the different information needs of individual

landowners or managers who are responsible for single ponds or wetlands versus the needs of different levels of government who may have national or international reporting commitments. Finally, we discuss the potential for our approach to deliver more effective local and national-scale assessments of trade-offs and potential management responses.

Abstract number–55 Nitrous oxide emissions in agricultural streams: The critical influence of pH

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Nitrous oxide (N₂O) emissions from streams represent a significant yet often overlooked source of greenhouse gas in Danish agricultural landscapes. We conducted a comprehensive assessment across diverse agricultural catchments, measuring N₂O concentrations in stream water under varying hydrological conditions and land management strategies. In this study, we had a particular interest in how pH affects N₂O emissions, which we investigated by examining agricultural and natural streams in regions of Denmark characterized by soils with low pH. For a subset of samples, 16S rRNA sequencing gene data was analyzed to characterize the microbial communities associated with different pH and N₂O levels. Our initial findings reveal that streams in acidic catchments exhibit elevated N₂O levels, which was both the case for agricultural and natural streams. Thus, this study suggests, that pH and water quality play a critical role for the N₂O emissions from streams. A better understanding of the complex relationship between pH, water quality and other drivers is essential for developing effective strategies to quantify and mitigate N₂O emissions in agricultural landscapes.

Abstract number–56 From Literature to Lab: Transformation and Sorption Behaviors of Nitrification and Urease Inhibitors

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Nitrification inhibitors and urease inhibitors have been used in agriculture for decades to delay nitrification, maintain plant-available ammonium in the soil for longer periods, reduce nitrate leaching, and slow down the rapid conversion of urea to ammonia—actions that also positively impact the climate protection. A previous study has detected the nitrification

inhibitors H-1,2,4-triazole and Dicyandiamide (DCD) in surface waters and groundwater, highlighting their potential negative impact on nitrification and denitrification processes especially in wastewater treatment plants, among others.

There are also other inhibitors available, which are currently applied on agricultural fields. The question arises whether the inhibitors and their potential transformation products can occur in surface and groundwaters. To deal with this question, an intensive literature review was performed, and the results were compared with those of a soil column study.

In 40 weeks of soil column study, 48 columns with a diameter of 7.1 cm were filled to a height of 25 cm. The 48 columns consisted of 16 variants including two different soils, two different temperatures, four different applications (three fertilizers, none) and each variant as triplicate. Three fertilizers with four nitrification inhibitors and one urease inhibitor were applied on the soil surface with a concentration of 15 g/m²: ENTEC 26 (3,4-dimethylpyrazole phosphate [DMPP]), ENSIN PLUS (Dicyandiamide [DCD] and 4-amino-1,2,4-triazole [ATC]), Alzon Neo-N (reaction mass of N-((5-Methyl-1H-pyrazol-1-yl)methyl)acetamide and N-((3-Methyl-1H-pyrazol-1-yl)methyl)acetamide [MPA], N-(2-nitrophenyl)phosphoric triamide [2-NPT]).

Water was also applied on the surface with a double groundwater recharge rate to account for two fall/winter cycles. Across all variants, each substance was detected at least once in the percolate, with differences observed between the two soils. By the end of the soil study, MPA and 2-NPT were not detected in either soil, indicating complete transformation. These results align with literature values of DT₅₀, indicating 50% biotransformation in soil within less than 10 days for both substances. DMPP was identified as the most adsorptive substances among the five inhibitors, predominantly found in the upper two of three soil layers. Soil percolate analysis of soil columns without application indicates the prior presence of DCD in both soils. This explains the presence of DCD in the first percolates and even distribution in all soil layers at the end of study. ATC was only found in the percolate of one soil type after 100 days of study until the end. This indicates either a stronger adsorption in the soil and/or a slower biotransformation.

Abstract number–57 Managing the trade-off between agricultural productivity and groundwater protection in Switzerland – a model-based approach

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Nitrate pollution of groundwater is still an issue of concern at many drinking water wells located in the Swiss lowlands, where agricultural areas are the main pollution source. Extensification measures (e.g. conversion of arable land to extensive grassland, reduction of vegetable/potato areas in favor of cereals) are generally considered to be effective to reduce nitrate leaching to groundwater. However, these measures are also associated with large losses in agricultural productivity and can thus only be implemented on small focused areas

within contribution zones of drinking water wells. It is hypothesized here that the trade-offs between agricultural production and groundwater protection can better be managed if more nuanced mitigation strategies are implemented at a broader scale. Such strategies would target at an improved synchrony between plant nitrogen demands and soil nutrient availabilities (e.g. by inclusion of cover crops and optimizing crop rotations, through reduced soil management and demand-driven fertilization practices). Since evaluating the effects of such strategies is anything but trivial given the high complexity of the process interactions and the strong influence of climatic variability, it is the aim of this work to train a mechanistic field scale model that simulates soil water and nutrient dynamics at a field scale in response to soil, climate and management drivers (DAISY model). The calibration builds on an extensive dataset from the lysimeter station Zurich Reckenholz including detailed data since 2009 on nitrate leaching, seepage water generation, soil moisture, water tension, soil temperature, and crop yields for a series of different experiments including non-inversion tillage, cover cropping as well as different fertilization types and amounts. In this presentation, results from calibration and validation will be presented as well as preliminary results of scenario simulations.

Abstract number–58 Exploring intensified catalytic role of biochar in facilitating advanced oxidation of tebuconazole in agriculture drainage

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In agricultural settings, managing pesticide contamination is crucial for both environmental protection and human health. Biochar has emerged as an economical and eco-friendly material for soil remediation, recognized for its strong adsorption and catalytic properties that effectively remove emerging organic pollutants like pesticides. However, in real-world agricultural scenarios, fluctuating hydraulic conditions and the scalability of the application must be considered. To address these challenges, we developed a modified biochar material combined with calcium peroxide (CaO₂), which is a stable source of H₂O₂ that promotes advanced oxidation processes while minimizing potential harm to soil and crops. This CaO₂-coated biochar significantly enhances pesticide degradation by intensifying the generation of hydroxyl radicals (OH·). Our study shows that the coated biochar increases OH· production by over tenfold, achieving 99% removal of tebuconazole—a commonly used fungicide—within 10 minutes. Additionally, the biochar can rapidly capture pesticides from agricultural drainage, with over 80 % of tebuconazole being adsorbed in only 10 minutes. Although the CaO₂ coating reduces the biochar's adsorption capacity by 40–50 %, the overall pesticide removal efficiency is greatly improved due to the synergistic effect of adsorption and catalytic degradation. This rapid adsorption capability makes the modified biochar well-suited for fluctuating conditions commonly found in agricultural settings, offering

a targeted approach to managing pesticide residues and demonstrating potential adaptability for mitigating other environmental contaminants.

Abstract number–59 Monitoring vegetated buffer strips by using remote sensing data: Chances and Challenges in Germany

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Biodiversity in the agricultural landscape has declined in recent decades. One of the main reasons for the loss of biodiversity is the intensification of agriculture. In particular, the use of pesticides is an essential part of intensive agriculture. Pesticides are not only effective against harmful target organisms, but also against non-target organisms and affect the untreated habitats adjacent to the treated areas. Therefore, the creation of vegetated buffer strips is an effective measure to protect surface water bodies from pesticide and fertilizer inputs.

A project between the Federal Agency for Cartography and Geodesy (BKG), Helmholtz Centre for Environmental Research (UFZ) and the German Environment Agency (UBA) was initiated in 2022 to develop methods for the identification, characterization and evaluation of potentially relevant areas and their function in the agricultural landscape, as well as the implementation of these methods in a user-friendly software application.

Using GIS and remote sensing methods, the BKG has recorded the agricultural landscape in Germany with regard to the availability of refugial areas and vegetated buffer strips with a protective effect against the entry of pesticides into surface waters.

The riparian zones were determined by using the software Feature Manipulation Engine (FME). Normalized Difference Vegetation Index (NDVI) was derived from digital orthophotos (spatial resolution: 20 cm) and satellite data (SPOT, 1.5m), which are available throughout Germany, to identify the vegetated buffer strips. In addition to remote sensing data, the land cover model (LBM-DE) and digital landscape model (Basis-DLM) for Germany were used to identify relevant areas.

The application allows to analyze the distribution of vegetated buffer strips and to compare with the corresponding legal requirements. With this application, it is possible to investigate issues relating to the provision of refugial areas and vegetated buffer strips in the agricultural landscape for regulatory purposes and to evaluate the effectiveness of related measures.

Abstract number–60 Pesticide metabolites – a regulatory perspective on an emerging group of contaminants for groundwater and drinking water

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Pesticide degradation products (metabolites) are an emerging group of contaminants for groundwater and drinking water. When applied to agricultural land, pesticides degrade in the soil and leach into groundwater, which is an important source of drinking water. Under EU pesticide regulation, metabolites are divided into two groups – “relevant” and “non-relevant” metabolites. Relevant metabolites have high residual pesticidal activity or toxic properties. They are regulated in analogy to active substances with a harmonized threshold of 0.1 µg/L in the EU Plant Protection Regulation, the Drinking Water Directive and the Groundwater Directive. In contrast, non-relevant metabolites hardly underlie any legal or management frameworks. However, the awareness for this group of contaminants is rising and the regulatory gaps are increasingly being addressed.

Non-relevant metabolites are not harmless. They often have properties that are critical to the environment. Many of them are highly mobile, leach into groundwater in large quantities, remain in the environment for a long time and can hardly be removed from drinking water. In general, there is a lack of knowledge about the long-term consequences when metabolites accumulate in the natural environment, interact with other substances and are subject to further degradation, e.g. by water treatment. There are examples of toxic properties that are only becoming known long after a pesticide has been placed on the market. However, only a non-binding guidance value of 10 µg/L for non-relevant metabolites is currently available for pesticide authorisation.

The German public monitoring programme shows that non-relevant metabolites were detected at 72 % of monitoring sites, and at 27 % at levels above 1 µg/L – with highest detection rates for trifluoroacetate (TFA) and the metabolites of chlorothalonil, chloridazon, nicosulfuron, metazachlor, S-metolachlor and dimethachlor. However, there is no legal threshold value for groundwater in Germany or the EU. The EU Groundwater Directive proposes 1 µg/L (under discussion), which would be a good starting point for managing this group of substances.

The new EU Drinking Water Directive includes a mandate for Member States to set a national guidance value for non-relevant metabolites. In Germany this is implemented in the new Drinking Water Catchment Ordinance and limits their raw water concentrations to 1, 3 or 10 µg/L – depending on data availability and substance properties. This favours catchment management measures such as pesticide reduction and mitigation over “end-of-pipe” drinking water treatment.

Legally binding values provide a basis for adequate regulation of non-relevant metabolites in the authorisation of pesticides. In addition, the long-term protection of our groundwater and

drinking water requires an ambitious strategy to reduce the overall use of pesticides in line with the EU Farm-to-Fork Strategy and respective national implementation strategies.

Abstract number–61 Modelling of soil mineral nitrogen in leachate using APSIM

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Due to nitrogen (N) inputs from agriculture, some groundwater bodies in Germany show higher nitrate concentrations than permitted under the European Nitrates Directive (91/676/EEC). In order to evaluate the effectiveness of mitigation measures, it is necessary to reliably quantify the nitrate loads. Potential nitrate loads can be measured precisely in the topsoil as mineral nitrogen contents. However, it is difficult to determine how these nitrate loads are transported to deeper soil layers beyond the root zone by the leachate. Nitrate concentrations in leachate below the root zone often show only a slight correlation with residual nitrogen quantities in the topsoil (SMN) in autumn. This is because of the multiple and complex transformation and transport processes occurring on the way.

In order to obtain a better understanding of the interactions of the various processes in this context, process-based modelling is a suitable method. In the present study, the Agricultural Production Systems SIMulator (APSIM) model was used to simulate nitrate leaching from the topsoil to deeper soil layers within a crop rotation frequently found on German arable farms. We used detailed soil and weather data as well as yield-physiological parameters from a crop rotation trial with winter wheat, winter barley, and winter oilseed rape, ongoing since 2020 at our research site in Braunschweig to calibrate and validate the model. The experiment included three nitrogen fertilization regimes (0 %, 75 % and 100 % of N demand). The leaching risk of nitrate during winter is high from the sandy soil at the site. A working protocol was used to parameterize plant and soil models that corresponded to the conditions of the field trial. The model results allow an illustration of the site-specific nitrate leaching with special consideration of the nitrogen supply and the influence of the preceding and subsequent crop. They also allow us to observe the temporal course of leachate and nitrate displacement and to interpret the autumnal SMN with respect to nitrate leaching potential. Against this background, also effective measures to reduce nitrate pollution are discussed.

Abstract number–62 Exploring the role of structural and financial factors to implement Natural Small Water Retention Measures in agriculture: insights from a survey to practitioners

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Diffuse pollution from agriculture remains a major threat to the quality of surface and groundwater across Europe, continuing to significantly pressure water usability. Alongside soil erosion, nutrient run-off and leaching, this condition deteriorates the production capacity of agricultural areas and diminishes the potential income for farmers. In response, farmers must adapt their practices to mitigate these impacts, while addressing environmental challenges and complying with a sustainable resource management. Natural Small Water Retention Measures (NSWRMs), which leverage natural processes for pollution mitigation, offer valid alternatives in this direction. Promoted and supported by decision- and policymakers at various levels, NSWRMs represent an opportunity for farmers to wider take-up or adopt new practices to improve water quality and availability. Exploring whether and how structural conditions, financial and technical support may influence NSWRM implementation at farms is crucial for identifying current weaknesses and opportunities, and refining policies to better support farmers. This presentation stems from the activities carried out within the H2020 EU project OPTAIN (“OPTimal strategies to retAIN and re-use water and nutrients in small agricultural catchments across different soil-climatic regions in Europe”). As such, it aims to explore the current adoption status of different agricultural NSWRMs that have already demonstrated or are expected to ameliorate either water availability or quality at farm level. Through a targeted survey conducted in project case study areas, the research collected qualitative and quantitative data and information on farmers’ knowledge, attitudes and practices related to relevant NSWRMs. The results provide a snapshot of farmers’ perspectives on NSWRMs attractiveness and reveal insights into successful practices. In addition, the findings highlight potential bottlenecks, constraints and limitations to wider implementation, offering valuable insights and inputs for policymaker and strategic planners to direct future investments in NSWRMs effectively.

Abstract number–63 Large scale implementation of groundwater protection in Aarhus Municipality

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Aarhus Municipality is the second largest municipality in Denmark with more than 360.000 inhabitants and a with a constantly growing population. The groundwater resource is under pressure both concerning quality and quantity. Pesticides but also pfas and biocides are

found in many drinking water wells. Protection of the resource is therefore crucial.

The municipality has decided to protect the groundwater in two ways: by action plans with both voluntary agreements and bans on not using pesti-cides and with water and nature parks pointed out in the Municipal Devel-opment Master Plan. The goal is to protect about 9.000 ha of agricultural land, but with the water and nature parks also to fulfill the goal of 4.000 ha more nature and forest, and to increase recreational areas, enhance natural hydrology to retain CO₂, and surface water.

The designation of water and nature parks will be agreed upon in the munic-ipal development master plan in 2025. The designation builds on knowledge of mapped vulnerable areas, recharge areas to important abstraction wells, designated areas to afforestation or new nature, areas close to villages to increase wellness of population, carbon rich areas etc.

It is a joint effort by the water utilities and the municipality to finance the establishment of the parks and in several cases companies or the govern-ment are external parties. The politicians have found a substantial amount of money to buy land/swap land to enhance the voluntary commitment and farmer willingness to participate.

The presentation will focus on the process to designate the parks, and also how we plan to calculate the benefits, ie. ha of protected areas, reduction of nitrate leachate, reduction of use of pesticides, carbon sequestration, changes in hydrology, benefits to health etc.

Abstract number–64 Understanding and improving water quality on local catchment scale: an example of cooperative monitoring and research by farmers and a regional water authority.

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Achieving the environmental targets of the European Water Framework Directive and Nitrate Directive is a major challenge in the south of the Netherlands. Agricultural land use is one of the primary sources of nitrate in ground and surface waters. Agricultural nutrient leaching has been reduced in the last 35 years since manure application was regulated by national manure policy. However, the environmental targets for ground- and surface waters are still not met.

In 2018 the regional water authority Aa en Maas initiated a joint research project together

with 7 farmers in the small, freely draining catchment area in the south of the Netherlands. The aim of this project is to help bridging the gap between catchment scale environmental objectives and farm-scale environmental Key Performance Indicators for nutrients. We did this by development and application of new and existing tools and sampling techniques - including deployment of water quality sensors - in local catchment areas in order to understand how agricultural practices affect water quality and what can be done on farm level to reduce agricultural nutrient losses to water and achieve the water quality objectives in the surface water.

In this presentation we will discuss the results of the water quality and soil nutrients monitoring during a 5 year period, including dry, warm years (2020, 2022) and wet years (2024). Both crop rotations and precipitation have a profound impact on the surface water quality. The monitoring results were used in a modelling approach for both water and soil. The study area was modelled with the NDICEA and Vatpy models which simulate the soil water and nitrogen dynamics in relation to weather. With its focus on nitrogen and carbon contents in the soil the NDICEA model has a direct relation with agricultural activities and impact on harvest and crops. The Vatpy model focuses on leaching and soil water dynamics which helps to identify spatial hotspots of leaching in the catchment area, which proved to be useful tool for understanding the local catchment area.

In the last few years we've seen a growing interest among stakeholders in joint water quality monitoring within local catchment areas. Drawing on our research experience we can provide insights into suitable methods and instruments for the farm-scale level, as well as those that should be used with caution. In the near future the regional water authority uses the lessons learned in other monitoring campaigns with farmers in other catchments and we continue the monitoring in the local catchment in order to obtain a long term measurement series for further research opportunities.

Abstract number–65 Impacts of annual weather conditions and available soil data on modelling nitrate leaching from farmland at regional and national scale.

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Nitrate leaching from farmland varies because of numerous hydrological and biological processes driven by farm management, soil characteristics, and weather conditions. These processes affect both water and nutrient transport and chemical and biological transformation processes. Climatic conditions significantly influence nitrate leaching processes by affecting soil temperature and moisture, which in turn impact biological and chemical transformation processes and play crucial roles in crop growth and nutrient uptake. Soil water surplus creates percolations out of the root zone, which, combined with the nitrate

content in the pore water, leads to nitrate leaching out of the root zone.

The variation in the physical properties of the soil affects both the natural drainage and aeration and thereby also the availability of nutrients. An essential tool for understanding soil variability is the existence of soil maps. These soil maps include important features such as soil texture, soil organic matter, bulk density, pH, and soil hydraulic properties. Variations or uncertainties in these parameters can have a high impact when modelling water transport and availability, crop growth, and nitrate leaching.

This study compares the impacts of newly generated three-dimensional soil maps and associated soil characteristics using previously used soil maps and soil data on modelling water balance and nitrate leaching. We aimed to investigate the variability of the soil maps and their resulting impact on model outputs of water transport predicted using the Daisy water transport- and balance- model and NLES5-predicted nitrate leaching. National datasets for fields and farm data were used to predict nitrate leaching using the empirical Danish nitrate leaching model NLES5. The results of 32 years of modelling nitrate leaching using daily weather data (1990 – 2021) on a ten km grid scale and data from Danish farmers for five years (2017- 2021) were used as inputs in the analysis.

Modelling results showed some low regional impacts on both water balance and nitrate leaching of the updated soil data description, but on a national scale, the impacts are minor. On the other hand, the year-to-year weather variations had a significant impact on nitrate leaching levels. Changes in agricultural policies over the five years with new targeted cover crops have a low impact on nitrate leaching levels in the aquatic environment compared to the year-to-year effects of weather, which means that the effects of new measures need to be monitored for long periods to obtain the full effect.

Abstract number–66 Comparing soil hydraulic properties of an agricultural field to non-invasive remote sensing and GPR data

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Soil properties of agricultural fields are one of the main points of interest when investigating the fields for implementing precision agriculture practices. Soil properties can be spatially extremely heterogeneous, resulting in the need for a broader and more detailed study of lateral soil changes. Relying only on data from points of pedological profiling could lead to an overly generalized image of the area. Increasing the number of the investigative pedological points across each field would be costly, overly time-consuming and not to mention, immensely intrusive. In this regard, remote sensing techniques, such as unmanned aerial vehicle (UAV), satellite imagery, and ground penetrating radar (GPR), can be extremely

helpful.

We compared past satellite images of an agricultural field, where areas of poor crop growth were clearly seen, with thermal UAV images, recorded on bare soil, i.e. at the time when there was no vegetation on the field. The soil temperature variation gave information on the varying soil water content across the field. We also recorded 22 parallel GPR profiles across the field (500 MHz antenna) and found that areas of higher signal attenuation correspond well with areas of poor crop growth and lower soil temperatures. In addition, 40 soil samples (undisturbed and disturbed) were collected systematically across the field and were used to determine the gravimetric soil water content, water content at pF 2.0 and dry soil bulk density at pF 4.2. We found that the points where higher water content was measured coincide with areas of higher GPR signal attenuation, poor crop growth and lower soil temperatures. These results show that implementing non-invasive techniques for studying changing soil conditions in agricultural fields can be very effective. By doing so, we can precisely detect spatial variations without the need to increase the number of invasive points of collecting pedological data.

The research was funded by the Slovenian Research and Innovation Agency (ARIS) project no. J1-4412 and programs P1-0020 and P1-0011.

Abstract number–67 Soil rehabilitation and protection by fungi from polyaromatic hydrocarbons contamination

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Soil contaminated with polyaromatic hydrocarbons (PAH) still remains one of the most relevant environmental problems worldwide and a threat for agricultural soils. PAH bind to clays as these have high surface area and in consequence PAH adsorb on finer soil fractions. However, clay particles reduce in size as time goes by, diminishing porosity and transferable species in soil, and with aging of PAH also lose bioavailability, becoming persistent. Under this framework, this work focus on the biological degradation of PAH with fungi and their enzymes, mainly laccase and laccase-mediator systems. Laccase degradation was set up, produced by fungal co- cultivation, using kiwi waste peels as substrate. The produced laccase was applied to PAH contaminated soils to evaluate its

efficiency on enzymatic bioremediation. Therefore, this research opens the path to the definition of biobarriers that may defend agricultural soils from contaminated leaching aqueous streams.

PAH degradation by three fungal strains (*Trichoderma viride*, *Penicillium chrysogenum* and *Agrocybe aegerita*) was evaluated with spiked soil. The effect of soil pH and of different soil amendments was assessed, as well as the enzyme activities during the PAH degradation. All fungi combinations were able to degrade fluorene, pyrene, chrysene and benzo[a]pyrene. The degradation potential was affected by pH, cocultivation and substrate support.

Agricultural residues used as substrate supports for the fungi growth are known to induce or enhance the activities of ligninolytic enzymes such as laccase, MnP and LiP, and to increase the degradation rates of PAH. Results obtained suggest the involvement of ligninolytic enzymes in PAH degradation. Biodegradation assays with a mixture of 200 ppm of PAH were evaluated for 8 weeks. The maximum laccase activity by solid state fermentation SSF (7.43 U/g) was obtained for *A. aegerita* on kiwi peels in 2 weeks' time and the highest MnP activity (7.21 U/g) was reached in 4 weeks, both assays at pH 7. Fluorene, pyrene, and benzo[a]pyrene reached higher degradation rates in soil at pH 5, while chrysene was more degradable at pH 7. About 85 % to 90 % of the soil pollutants were degraded by fungal remediation. Regarding benzo[a]pyrene, 13 % remained in soil after treatment with *A. aegerita*. Despite the increase in the degradation rate of some PAH with cocultivation, a higher enzyme production during degradation was observed when fungi were cultivated alone.

Abstract number–68 The impact of crop rotations on fertiliser application rates in arable land-dominated agricultural area: a case study from Latvia

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Nutrient concentrations and loads in river catchments vary considerably, influenced by meteorological conditions and agricultural practices. Crop rotations, in particular, affect nutrient dynamics through differences in land management practices, including fertilizer application rates and timing. This study examines the impact of crop rotations on nutrient loading in an arable land-dominated agricultural landscape, laying the groundwork for further exploration of crop rotation effects on nutrient balance.

Our analysis draws on selected data from Berze River catchment (882 km²) in Latvia. We identified eight primary crop types, including arable crops, permanent grasslands, and fallow land, and refined the study area to 212 km², focusing on land parcels with crop records from 2018 to 2022. We identified 191 unique crop rotation patterns and selected 35 dominant rotations covering 89% of this area.

Crop distribution among the selected agricultural lands was as follows: winter wheat (57%), winter rapeseed (21%), spring wheat (4.5%), spring barley (4.5%), broad beans (4.4%), corn (4.1%), grasslands (3.9%), and fallow land (0.4%). Crop areas showed fluctuations, with a general trend toward increased winter crop coverage and decreased summer crop coverage. Notably, corn cultivation declined, while broad bean coverage varied from 0% to 15%. Fallow land was prominent in 2018, covering just under 2% of the selected area, while grassland coverage remained stable at around 3.9%.

Based on typical fertiliser rates and crops grown in the area, annual application rates were estimated to range from 83 to 177 kg/ha for nitrogen and from 36 to 90 kg/ha for phosphorus across different land parcels. Due to the crop types and sequences within the rotations, fertilizer application showed an upward trend over the study period, with nitrogen and phosphorus inputs increasing by 10.9% and 6.8%, respectively. This trend corresponds with an increase in nitrogen and phosphorus loads in runoff from the Berze River catchment. Although crop rotations are not the sole factor, they appear to contribute to the observed increase in nutrient leaching.

These findings underscore the influence of crop rotation practices on nutrient load dynamics and provide insights for managing nutrient runoff in agricultural watersheds.

This work was supported by the project “Nitrogen and phosphorus load reduction approach within safe ecological boundaries for the Nordic-Baltic region” (NORDBALT-ECOSAFE, Grant Agreement No. 101060020) funded by European Union's Horizon Europe research and innovation programme (<https://projects.au.dk/nordbalt-ecosafe>).

Abstract number–69 Aligning policies and practice: Addressing governance and capacity gaps in the implementation of ponds and wetlands in Swedish municipalities

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Constructed wetlands have the potential to play a significant role in water management by contributing to flood and drought mitigation, nutrient retention, biodiversity enhancement, and broader ecosystem services. Despite these benefits, their use remains limited in municipal planning. Drawing on research from the PUDDLE JUMP project, this presentation will focus on how national and local policies in Sweden impact the use of constructed wetlands in a catchment-oriented landscape planning context. Special attention will be given to the institutional challenges that municipalities face in bridging governance and policy fragmentations.

Interviews and workshops with regional and national stakeholders complemented by a document analysis provided a detailed understanding of the regulatory landscape and offered insights into the practical implementation and enforcement of relevant policies. The presentation will give an overview of these policies at multiple governance levels, highlighting the alignment and gaps between WFD/FD goals and the processes surrounding implementation of constructed wetlands, as well as insights from interviews and workshops with municipal and county level staff in the Mälardalen region of Sweden on the practical barriers to implementing ponds and wetlands.

Preliminary results suggest that while multiple policies promote the use of constructed wetlands, challenges persist in their enforcement and application, with practices on the ground often diverging from larger policy objectives due to irregular interpretations, conflicts of aims, as well as administrative, capacity and coordination challenges. The findings will contribute to a framework that identifies opportunities for improved policy coherence, multi-level governance and institutional collaboration. The presentation will outline actionable insights that can guide future policy reforms and encourage the more widespread use of constructed wetlands to support sustainable water management and climate adaptation strategies.

Abstract number–70 Linking pesticide use data and water quality

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Small surface waters in agricultural landscapes are particularly exposed to pesticide inputs. Investigations from the German small stream monitoring ("Kleingewässermonitoring" (KgM)) project in 2018/2019 have shown that water contamination by pesticides dramatically increases after rain events due to runoff and erosion of previously applied plant protection products (PPPs), leading to exceedances of regulatory limits and impairment of aquatic ecosystems. As these short-term pesticide pulses likely have their source in previous PPP applications, there is great interest in linking actual agricultural PPP use data with water quality data obtained via chemical and biological monitoring.

In collaboration with the German Nature and Biodiversity Conservation Union (NABU), we have for the first time gained access to detailed records of PPP applications in the stream corridors of more than 100 monitoring sites investigated in the KgM project. The data

contains information on date, quantity, treated area and used PPP, which has to be documented by farmers, but is usually not available to research and public. In combination with the comprehensive water quality monitoring dataset, including measured concentrations of 75 pesticides and 33 metabolites in grab and event-driven samples, we show which insights into substance-specific risk drivers and recommendations for possible management measures can be obtained. Linking pesticide use data and water quality monitoring allows to investigate,

- i) how risk drivers can be identified from the application data in order to prioritise single substances or groups for regulation, research and monitoring,
- ii) which catchment controls, precipitation characteristics or substance properties facilitate pesticide inputs into streams, in order to derive possible mitigation measures, and
- iii) whether application data can be used to identify sources and input pathways of PPP residues leading to critical concentrations in individual streams.

This research is particularly relevant as the revision of the SAIO Regulation will require PPP application data to be collected and made available across the EU from 2028. Our analyses aim to provide information and recommendations for the collection of PPP application data, examples of possible future use, and how knowledge about PPP application can contribute to improve water quality.

Abstract number–71 Optimising the spatial allocation of water and nutrient retention measures in small agricultural catchments.

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Implementation of Natural/Small Water Retention Measures (NSWRM), such as conservation tillage, constructed wetlands or riparian buffers, is known to be effective and to provide easily measurable benefits at the local scale. However, there is less evidence of the multiple benefits and win-win situations of NSWRM at the larger, river basin scale and across sectors. This is especially true for combined implementation schemes.

The EU-H2020 research project OPTAIN evaluates scenarios for the implementation of individual NSWRM using the agrohydrological model SWAT+. However, it also integrates the SWAT+ model and key economic assumptions into a multi-objective optimisation framework to explore the full potential of spatially targeted NSWRM combinations.

Specifically, the optimisation aims to identify spatial NSWRM plans that maximise a catchment's water and nutrient retention capacity while minimising trade-offs with potential implementation/maintenance costs and crop production losses, resulting in a large number of Pareto optimal solutions from which stakeholders can choose those that best match their

preferences. To facilitate the stakeholder dialogue, we developed ParetoPick-R, an open-source R-Shiny application to visualise, analyse, navigate and cluster Pareto optimal solutions, including options to plot hotspot maps of optimal NSWRM implementation. The application can also be used to conduct the Analytical Hierarchy Process with stakeholders to identify NSWRM plans that best match their preferred individual weighting of optimisation objectives.

In our presentation, we will introduce OPTAIN's optimisation approach and the ParetoPick-R application with examples from different case studies. First results from the German case study catchment 'Schwarzer Schöps' (135 sq km) indicate a strongly non-linear relationship between the reduction of in-stream phosphorus (P) loads at the catchment outlet and the net management costs, taking into account the NSWRM implementation and maintenance. The Pareto results suggest that with the right measures (especially grassed waterways and conservation tillage combined with cover crops) in the right place (fields at high risk of soil erosion), it should be possible to reduce average P loads by more than 1 tonne/year and at the same time save management costs if marginal losses in crop production (<2%) are accepted in the overall catchment balance. Despite the high level of uncertainty in many parts of the model-based optimisation experiment, we strongly believe that our approach can facilitate decision making in the context of NSWRM implementation.

Abstract number–72 Eating the metaphorical elephant: Meeting nitrogen reduction goals in Upper Mississippi River Basin states

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The nutrient reduction goals to shrink the size of the Gulf of Mexico hypoxic zone are an enormous challenge, and progress toward the 45% reduction target for nitrogen (N) has been limited. To better understand the scale of this challenge, we looked at potential nitrate-N reductions at increasingly difficult levels of implementation for 1) individual in-field, land use change, and edge-of-field conservation practices and 2) the combination, or stacking, of practices. We used three Upper Mississippi River Basin (MRB) states (Illinois, Iowa, and Minnesota) that have science assessments as part of their nutrient reduction strategies (NRS) and that deliver an estimated 36% of the MRB N load to the Gulf of Mexico for this evaluation. Benchmark-, low-, medium-, and high-levels of implementation were established based on the NRS documents, literature, and professional judgement. Nutrient reductions for each implementation level were calculated for each state and across states on an area-weighted basis using data from the NRS. Overlapping benefits from stacked practices were accounted for by using the Iowa State University N Load Estimate Calculator. Average nitrate-N reductions across the three states ranged from 4% to 17% for individual practices

at high-level implementation. With all practices combined and accounting for practice stacking, combined nitrate-N reductions for the three states were 26%, 40%, and 55% for the low-, medium-, and high-levels of implementation, respectively. This indicates that implementation somewhere between our medium- and high-levels is needed to meet the 45% reduction goal. The results show that edge-of-field conservation drainage practices become increasingly important for nitrate-N reduction as the implementation level increases. Understanding the scale of the N reduction challenge is a necessary step toward meeting it, and implications of the results and challenges to implementation will be discussed.

Abstract number–74 Does the exception prove the rule? How well are small surface waters in Germany actually protected from agricultural pesticide inputs caused by erosion?

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Small surface waters in the agricultural landscape make up the majority of the surface water network. After rain, they are particularly exposed to inputs of pesticides and nutrients. Investigations from the German small stream monitoring ("Kleingewässermonitoring" (KgM)) project in 2018/2019 have shown that water contamination by pesticides dramatically increases after rain events due to runoff and erosion of previously applied plant protection products (PPPs).

The Sustainable Use Directive 2009/128/EC (SUD) requires member states to establish national action plans for the sustainable use of PPPs. The action plans should contain specific targets, target quotas and timetables, also for the protection of water bodies. With the involvement of various stakeholders such as farming organisations, water management associations and the federal states, the German action plan (2013) aims to reduce the risks from PPP use by 30 % until 2030. One measure of the German action plan is to make sure that 100% of surface waters are equipped with permanently vegetated buffer strips of at least five meters width until 2023. In 2016 only about 47 % of the German water bodies are enclosed by permanently vegetated buffer strips.

In 2021 the German insect protection action program "APIS" finally led to a binding national regulation according to which PPPs may not be used within 10 m of water bodies. This distance may be reduced to a 5 m buffer strip, if the buffer strip is permanently vegetated (§4a, PflSchAnwV). Hence this is an 'option model' and the implementation lies within federal states responsibilities. Furthermore, there are various other national legal provisions for the protection of surface waters (Water Resources Act, Fertilizer Ordinance), as well as programs of measures in the federal states in Germany determining the establishment of permanently vegetated buffer strips. However, many of these provisions include opening

clauses and exemptions. In addition, there are different definitions regarding surface waters to be considered important for water management, i.e. which waters are intended to be subject of respective requirements and measures. Unfortunately, often excluded are precisely those small surface waters directly adjacent to agricultural land which may periodically fall dry, but are proven to transport substances from agricultural area into surface water networks after rainfall.

So what protection level against substance inputs do the various legal provisions from different regulatory areas actually provide? To what extent do specific regulations and exemptions influence the achieved protection of small water bodies? This poster classifies the level of protection by the various legal provisions against the background of the German target for buffer strips and shows analyses of the feasibility study at different scales. A GIS tool developed for this purpose in a research project can be presented separately (P. Merita, Theme C).

Abstract number–75 Investigating seasonal Nitrate and Orthophosphate Losses in Surface vs. Subsurface Drainage in Northwest Minnesota

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Nitrogen and Phosphorus are essential yet limiting nutrients for crop production in the Midwest, USA. However, losses of these nutrients from agricultural fields present considerable environmental and economic concerns, mainly via subsurface drainage, which has become a rapidly common practice to enhance productivity. This study investigates nutrient loss dynamics in a 24-hectare field in Crookston, Minnesota, divided equally between surface-only and combined surface-subsurface drainage systems. Under a three-year rotation of soybean-wheat-sugarbeet, the field provided daily water samples from both drainage types over three growing seasons (2022–2024). The analysis focused on nitrate and orthophosphate concentrations in relation to drainage type and rainfall intensity. Initial results reveal nitrate concentrations in surface drainage systems were at least three times higher during the spring, while in summer, higher nitrate levels were observed in combined drainage systems. Orthophosphate levels, meanwhile, showed a slight increase (10–30%) in surface drainage, except in July and August 2023. Peaks in orthophosphate concentration in surface drainage, ranging from 0.18–0.98 mg L⁻¹, were consistently observed in April and October. This study provides insights into nutrient management strategies to mitigate nutrient losses and their impact on water quality.

Abstract number–76 Towards climate-resilient intensive farming with minimal environmental impact; preventing unnecessary losses of fresh water and nutrients at an arable farm in Anna Paulowna, The Netherlands.

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The global climate is becoming increasingly extreme, characterized by intense (local) downpours followed by prolonged periods of drought. This shift poses significant challenges for agriculture, as it can reduce nutrient uptake efficiency and increase fresh water scarcity during the growing season of crops. The agricultural sector plays a vital role in addressing these challenges, as farmers have the potential to prevent flooding and mitigate water shortages. Moreover, the sector plays a crucial role in reducing nutrient runoff to surface waters and meeting Water Framework Directive targets. However, farmers face enormous challenges staying economically healthy during their transition to more climate-resilient and sustainable land management practices. Key to this transition is ensuring affordable access to sufficient high-quality freshwater.

This raises an important question: How can farmers conserve water and nutrients in a controlled way to create a buffer for dry periods while minimizing nutrient losses to surface waters? To address this question, the 'Freshwater Farmers' (Zoetwaterboeren) project was launched at an arable farm in Anna Paulowna, Netherlands. This four-year initiative seeks to develop, study, and demonstrate an integrated water management system that tackles the challenges of water availability, storage, demand, and quality in agricultural settings. Innovative techniques are being tested on the farm, including the harvesting, purification, and infiltration of drainage water, as well as using a woodchip bioreactor for excess water purification. These efforts provide practical solutions for sustainable water resource management, with a thorough study of the farm water to ensure that both quantity and quality needs are met. These measures collectively aim to close the water and nutrient cycles, creating a holistic, sustainable approach to resource management under a changing climate.

This presentation will highlight the project's innovative approaches, including its potentials and barriers, monitoring outcomes, and the possibility to scale these practices to other regions facing similar water management challenges. By sharing key insights and lessons learned, this project aims to contribute to global efforts in sustainable agriculture, climate resilience, and water quality improvement.

Abstract number–77 Modelling the effectiveness of Natural/Small Water Retention Measures in Hungary and Lithuania: Similarities and differences

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Natural/Small Water Retention Measures (NSWRM) are used in agricultural catchments to improve water and nutrient management and increase the sustainability of agricultural production. Such measures can help mitigate the conflicts between agricultural water uses and other human and environmental demands for water, including drinking water or maintaining environmental flow. Within the H2020 OPTAIN project, we analysed several catchments across different biogeographical regions of Europe using environmental models. The project aims to increase the understanding of multiple benefits that spatially targeted combinations of NSWRMs have on the management of small agricultural catchments across Europe, and the conditions under which they perform most effectively.

In this presentation we will compare the results of case studies in Hungary and Lithuania, two very different biogeographical regions (Pannonian vs. Boreal). Riparian forest buffers and cover crops are investigated in both case studies. We hypothesise that the effectiveness of these NSWRMs will vary due to differences in climatic conditions and soil properties. In addition to these two measures, wetlands/ponds and reduced tillage are applied in the Lithuanian case study due to its hydrological conditions and current management practices. In the Hungarian case study, no-tillage, buffer strips, and afforestation are considered as possible measures for implementation and were therefore included in the modelling. To model the effects of NSWRMs, we used the SWAT+ modelling tool to evaluate the current and projected effectiveness. We followed the OPTAIN modelling protocol and applied a suite of scripted workflows in R for building the model setup, its verification, model calibration, validation, and running scenarios.

We are investigating the effects of the NSWRMs on hydrology (water yields), nutrients (nitrogen and phosphorus), transported sediments, and crop yields. We will present the effectiveness of these measures, in each case study. A comparison of the effectiveness of the same measures in both countries will be highlighted, investigating the main sources of any observed differences in performance.

Keywords: SWAT+, NSWRM, water balance, water quality, crop yield.

Abstract number–78 Policy entrepreneurs’ strategies leading to effective hydro morphological measures, Lessons learned from good practices in the Netherlands

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Only 40% of Europe’s surface waters are of sufficient quality for aquatic ecosystem to thrive, threatening biodiversity and human health. Improving the ecological and chemical status of water bodies requires a combination of measures that target both pollution sources and hydro morphological characteristics—the physical structure and hydrological flow of water systems that support aquatic ecosystems. The European Commission has addressed this issue with their most comprehensive water policy instrument yet: the Water Framework Directive (WFD). This legislation aims to connect earlier sectoral regulations within this one framework in order to restore all EU aquatic ecosystems by 2027. However, since the adoption of the WFD in 2000, the Member States have not delivered the main environmental objectives. Scientific studies have identified numerous barriers that help explain the challenges Member States encounter in meeting the WFD objectives within the set timelines. However, a knowledge gap remains concerning how to overcome these barriers. Therefore, this research explores how successful cross-sectoral and regional approaches can serve as valuable case studies for overcoming obstacles in ecological water quality improvement. By analyzing already effectively implemented measures in regional approaches, the study aims to identify the conditions and strategies that empower policy entrepreneurs to implement hydro-morphological measures effectively. Policy Entrepreneurs are change agents throughout the policy process. Drawing on the theoretical framework of ‘policy entrepreneurship,’ the study empirically analyzes the strategies employed by these actors and the enabling or constraining conditions that influenced their effectiveness. The study examines the case of the Drentsche Aa, a water system in northern Netherlands, where many hydro morphological interventions have been implemented successfully. The research explores who the key initiators of these interventions were, how they achieved success, and whether their effectiveness was more reliant on their strategic approaches or the conditions under which they operated. The analysis is based on a combination of literature reviews, policy documents, meeting agendas, and interviews, which are used to identify the policy entrepreneurs, their strategies, and the conditions shaping their approaches in the Drentsche Aa. To explore the broader relevance of these findings for other regions in the Netherlands—such as the river basins in Brabant, where intensive livestock farming poses significant water quality challenges—the results are also discussed with other water authorities. These insights contribute to the elaboration of some lessons learned of how policy entrepreneurs can initiate action to break the impasse in water quality improvements, and the conditions that facilitate successful intervention. At the conference, the results of this study will be presented.

Abstract number–79 National flow-dependent and local through-time source apportionment to help manage diffuse / point source pollution using the CSF-HYPE model for England

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The CSF-HYPE model was set up to help evaluate the effectiveness of Catchment Sensitive Farming programme – the UK government's advice-led diffuse pollution mitigation programme, which started in 2006. The model covers England and has been updated and used across a range of additional purposes to assess potential impacts of climate change, the risk of failure of bathing water standards, and to help project future flow and water quality conditions to help test or meet key drivers. Common to these studies is improving our understanding of relative apportionment of pollution loads across spatial domains, for different flow conditions, and how loads vary through time. We have developed an approach for rapidly re-running the model at national scales with various contributions switch on or off sequentially to understand their individual contribution to the load under different flow conditions. This can be crucial for highlighting seasonality of load sharing, and the potential need for flow-dependent consenting especially in the light of climate change impacts on extremes of low and high flows. These are visualised using national-scale heat-maps depicting the relative contributions from e.g. agricultural versus sewage discharges. Furthermore, the through-time source apportionment for individual basins has been assessed by plotting the instantaneous contributions to the concentrations in-river assuming well mixed conditions and yielding a graphical understanding of temporal variability of source attribution. A series of national and local case studies are described to develop a discussion of how such information can be used at a policy level.

Abstract number–80 Evaluating Agricultural Strategies for Groundwater Protection: Impact of Crop Rotations on Nitrate Leaching on Field Scale in Denmark

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Agriculture contributes nitrate to the aquatic environment, groundwater, lakes and streams, and the marine environment. Surface and groundwater pollution by NO₃-N is a major and

enduring environmental issue on a worldwide scale since nitrate hardly establishes surface complexes with soil particles and is highly water-soluble. This problem is particularly severe in Denmark, where 62% of the land is covered by farmlands, intensifying nitrate pollution risks. Crop rotations with a high share of grassland might mitigate nitrogen (N) leaching more effectively than monocultures, significantly reducing N leaching. However, the renovation phase in grass production is critical as high mineralization occurs and increases the risk of nitrate leaching. In this study, we aim to analyze the effect of introducing a high share of grass-clover pastures in the cropping systems and measure the effects on field nitrate leaching. This is done in local farmers' fields and as a project involving local stakeholders and state environmental authorities. Six fields (S1-S6) with different management strategies were chosen including grass-clover, spring barley with undersown grass, maize with undersown grass, and grain cropping systems over two years (2023-2024) have been measured. In each site, suction cells were installed at a depth of 1 meter with eight replications, and piezometers were installed at 2.5 meters with four replications. Soil water and piezometer water samples were collected biweekly from autumn to spring and monthly during the summer. The nitrate-N concentrations in S1 and S2, which consisted of grass-clover mixtures for three years, were the lowest leaching levels among all treatments, maintaining low concentration levels (less than 4 mg/L) throughout the study period. In contrast, S4, with continuous maize, exhibited a high initial nitrate concentration (30 mg/L), which later stabilized around 10-15 mg/L. Treatments S3, S5, and S6, involving crop rotations with spring barley undersown with grass, winter wheat, and ryegrass, showed moderate nitrate concentrations, indicating a balanced nitrogen retention capacity. In conclusion, the results highlight the grass-clover mixture as an effective cropping system for protecting groundwater from nitrate contamination. Moving forward, we plan to assess how different timings of grass-clover renovation impact nitrate concentrations in the S1 and S2 fields.

Abstract number–81 Effect of uncertainties in manure and fertilizer application on modelled N and P losses to surface and groundwater at different spatial scales

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Agricultural practices result in substantial nitrogen (N) and phosphorus (P) inputs on agricultural lands, primarily through fertilizers and manure. These inputs frequently result in environmental surpluses, with most of the excess lost to the environment via gaseous emissions of nitrogen compounds, nitrate leaching into groundwater, and N and P runoff to surface waters. National and international environmental legislation mandates the monitoring of agricultural impacts on water quality, requiring robust, spatially explicit modeling approaches.

In the Netherlands, two coupled key models are used annually to quantify nutrient losses to surface and groundwater: the INITIATOR model, which simulates manure and fertilizer distribution, and the LWKM model, which assesses N and P losses to surface water and the nitrate concentration in groundwater. Both models generate spatially explicit information to assess environmental impacts from nutrient losses across various spatial scales and to inform effective control strategies. However, there is uncertainty regarding our knowledge of certain model inputs, such as agricultural activity data and emission factors, which may propagate through these models, leading to uncertainty in the estimated N and P losses.

The LWKM model relies on manure and fertilizer rates modeled at a 250m x 250m spatial resolution, meaning that local uncertainties in application rates can directly impact the accuracy of the modeled N and P losses. Currently, uncertainty is not explicitly accounted for in the model calculations. In a previous study uncertainties in N and P manure and fertilizers application rates were quantified by applying a Monte Carlo uncertainty propagation analysis to the INITIATOR model. In this study, the propagation of these uncertainties into N and P runoff to surface water and the nitrate concentration in groundwater are quantified using the LWKM model based on the Monte Carlo-generated manure and fertilizer application results.

In this presentation we address the impact of spatial scale on uncertainty levels, the contribution of different parameter groups to total uncertainty, and model sensitivity to probability distributions and (spatial) correlation values. Our findings are discussed in the context of strategies to reduce uncertainties in estimating nutrient losses, offering insights into more reliable nutrient management practices for protecting groundwater and surface water quality in the Netherlands.

Abstract number–82 Nitrate Mitigation in Drinking Water Supply Management Areas

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To safeguard groundwater from nitrate contamination, the state of Minnesota in the USA has implemented the Groundwater Protection Rule. This rule has two parts, one is a restriction of fall applied nitrogen fertilizer in sensitive parts of the state and in supply areas for municipal public wells (Drinking Water Supply Management Areas; DWSMAs). The second part of the rule is surrounds formulating actions in these DWSMAs to mitigate nitrate levels before they exceed health standards, thereby safeguarding public health and water quality. The regulatory approach in DWSMAs employs a tiered system, ranging from voluntary best management practices (BMPs) to mandatory regulatory measures. The level of the required actions is determined by the nitrate contamination. Local advisory teams, composed of farmers, agronomists, and community members, play a crucial role in developing and

implementing tailored mitigation strategies. By combining voluntary and regulatory measures, this framework aims to achieve sustainable nitrate reduction while fostering collaboration between regulatory agencies, landowners, and other stakeholders. This proactive approach demonstrates a commitment to protecting water resources and ensuring public health.

Abstract number–84 Hydrochemical Processes and Groundwater Quality in the Basement-Sediment Aquifer of Lapai, Central Nigeria

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Nigeria and many Sub-Saharan Africa countries depend largely on groundwater resource to satisfy domestic, agricultural and industrial uses because of its sustainable nature and growing demand arising from increasing population explosion. Understanding the evolution of groundwater is important for preserving and effective use of water resources. Geochemistry and hydrochemical processes of groundwater in the basement-sediment aquifers of Lapai, Nigeria were investigated in this study. Total of 47 groundwater samples from different location within the areas were collected and analyzed for this purpose. Ca²⁺, Mg²⁺, Na⁺, K⁺, HCO₃⁻, Cl⁻, NO₃⁻ and SO₄²⁻ concentrations were considered for the investigation. The abundance of the major cations and anions is Ca>Mg>K>Na and Cl>HCO₃>SO₄ respectively. Hydrochemical modelling, bivariate plots and scatter diagrams were interpreted for the hydrochemical process understanding. The dominant hydrochemical facies are mixed Ca-Na-HCO₃ (n=24), Ca-HCO₃ (n=16) and Ca-Cl (n=7). Silicate weathering, simple dissolution and reverse ion exchange are the dominant hydrochemical processes in the aquifer. Assessment of the water quality suggest that the groundwater is generally suitable for consumption, although there is elevated nitrate in some of the samples which signifies some anthropogenic influence.

Abstract number–85 From Rain to Runoff: Understanding Nutrient Dynamics in Dutch Agricultural Waters

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High nutrient loads from intensive agriculture are a critical challenge to the ecological and recreational quality of Dutch surface waters. Despite regulations on manure and fertilizer use, nutrient concentrations in headwaters dominated by agriculture still exceed water

quality standards. In the period from 2020 to 2023, 41–61% of monitored sites failed to meet nitrogen standards, while 49–53% did not meet phosphorus standards. Our monitoring data underscore the significant influence of weather extremes, particularly on nitrogen levels, suggesting that changing climate patterns play an increasingly central role in nutrient dynamics.

In this presentation, we focus on the impact of extreme precipitation conditions in summer on the nutrient concentrations in agricultural headwaters based on the STROMON approach, revealing insights into both expected and unexplained trends. During drought, crops grow less and take up a smaller fraction of the available nitrogen and phosphorus in the soil. Also, less denitrification takes place, leaving more nitrate available for leaching to groundwater and surface water within the next wet period. Our monitoring results show that during extreme wet conditions, median phosphorus levels rise, and nitrogen concentrations can reach up to twice those of typical conditions. These results suggest that frequent weather shifts lead to nutrient spikes, complicating the achievement of water quality goals.

Additionally, our data reveal other concerning trends: since 2012, water temperatures have increased at an accelerated rate of about 1°C per decade, and chloride levels are rising at various sites, though clear explanations for these trends still lag at this moment. As extreme weather and rising temperatures become more common, our findings point to increased nutrient concentrations leading to higher risk of harmful algal blooms and further degradation of downstream water quality.

Abstract number–87 Nitrogen and phosphorus food system flows in five European livestock intensive catchments

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Nitrogen (N) and phosphorus (P) pose significant water quality issues in many catchments, particularly where intensive livestock farming is the dominant agriculture. System level changes are likely required to meet water quality targets, but those systems must first be understood to allow targeted and effective system change. Here we employ Material Flow Analysis (MFA) to model food system flows, stocks and losses of both N and P from five livestock dominated transboundary catchments in North West Europe. The five catchments are the Neagh Bann (Northern Ireland and Republic of Ireland), river Wye (England and Wales), and three catchment areas of the river Meuse - one in the Netherlands and two in Flanders, Belgium, all are study areas for the EU funded New Harmonica project. The catchments cover varied physiographies but all have high N and P pressures on their

waterways and subsequent widespread exceedance of water quality targets for good ecological status. In all five catchments, MFA analysis revealed that livestock feed was the biggest N and P import, and manure N and P flows (to field and/or exported) were the largest internal derived flow, confirming the dominance of livestock in the catchments. Harmonised MFA-derived system indicators allow for catchment comparisons of food system sustainability including nutrient efficiency, surpluses and losses. Despite nutrient flows being dominated by intensive livestock agriculture in all five catchments, the system indicators reveal some significant differences. For example, overall catchment food system efficiency (converting imported N and P into food products) varied from 35 to 51% for N and 41 to 81% for P; agricultural soil balance surplus varied from 97 to 233 kg N/ha and -6.4 to 10.8 kg P/ha; and overall removal efficiency of N and P from human effluent via the various waste water routes varied from 56 to 84% for N and 51 to 87% for P. Identifying these catchment differences and food system hotspots for inefficiency and loss allow for more targeted policy intervention to help improve water quality.

An example of the impacts of a system intervention (targeting zero agricultural P surplus) on food system dynamics in one of the catchments using an MFA scenario suggests that significant system change will be required in both the agriculture and wastewater sectors to achieve the water quality goals required by the Water Framework Directive in Europe.

Abstract number–88 The necessity for and implementation of the right measures in the right places to combat eutrophication from agriculture

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In order to meet the required water quality standards by 2027, measures to reduce the annual input of nutrients from agricultural sources must be implemented. This is estimated to equate to 1,590,000 kg of nitrogen and 385,000 kg of phosphorus reductions annually. The Swedish support systems for measures to abate nutrient runoff from agricultural lands are financed by the Common Agricultural Policy (CAP) and national funds (LOVA).

Nevertheless, an assessment of the effectiveness of these financing and implementation measures in the appropriate locations has yet to be conducted. This study demonstrates that supplementary funding is required, and that current funding sources cover a significant proportion of the required amount, yet fall short of fully addressing the need for reductions in nitrogen and phosphorus. Additionally, the capacity of the funds to steer and direct measures to the appropriate geographical areas is limited. Moreover, while measures to reduce nitrogen are progressing as anticipated (84% of the target has been reached), those aimed at phosphorus are significantly behind schedule, with only 23% of the projected reductions achieved thus far. A significant proportion of the measures implemented (for example, 20% of wetlands) have been carried out in areas where the environmental status is already classified as good, thereby reducing their environmental impact and resulting in inefficient use of funds. While nitrogen measures are on track, it can be concluded that the

implementation of phosphorus measures must be intensified, with resources allocated to priority areas in order to achieve the greatest efficacy. Potential enhancements to effectiveness could be achieved through structural improvements, including the raising of compensation rates and the expansion of support systems. In summary, the achievement of water quality standards by 2027 will require strategic resource allocation and heightened implementation, especially for phosphorus-focused measures.

Abstract number–90 Exploring Trends and Travel Times: 30 years of Groundwater Quality Monitoring in the Netherlands

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Evaluating temporal trends in groundwater quality benefits from incorporating groundwater travel time data. The Netherlands recognized threats posed by intensive livestock farming to its groundwater and legislation was enacted in 1985 to mitigate agricultural pollution, and monitoring networks were established. With the EU Water Framework Directive (WFD) in 2000, these networks began monitoring a broader contaminant range. The WFD allowed EU member states to choose monitoring setups themselves, resulting in diverse approaches—from high-resolution networks with short-screened observation wells in some countries to long-screened, pumped wells at significant depths in others. While all networks aimed for trend detection, the varied monitoring systems hindered common trend analysis approaches.

A. Enhanced Trend Detection in Shallow Monitoring Networks: Overcoming Heterogeneity. Initial challenges in detecting trends in shallow networks in Denmark and the Netherlands were due to heterogeneity in both groundwater age and redox status within the studied depth range. Effective trend evaluation and detection only materialized after successfully applying ³H/³He and CFC groundwater age dating to identify recharge periods. This presentation highlights advancements in trend quantification and trend reversal based on a Netherlands network with 140 multi-level observation wells, examining trends in the last 15 years of groundwater renewal. We will showcase how trends in nitrate and sulfate in age-dated groundwater have been employed to inform national policies aligned with the Water Framework and Nitrates Directives. Findings show downward trends for nitrate and sulfate from 1992 to 2005, with concentrations leveling off under farmlands, aligning with stabilized leaching loads. The discussion will also cover expanding this work to include pesticides and emerging contaminants like PFAS.

B. Tailoring Trend Detection for Pumped Wells and Natural Springs: Embracing Multi-Tracer Approaches: Recognizing the challenges posed by monitoring networks comprising pumped wells or natural springs, we advocate for approaches that inherently consider mixing processes. Multi-tracer methodologies, such as those incorporating ³H and ³⁹Ar, facilitate the derivation of travel time distributions for mixtures. Drawing insights from a network featuring 90 natural springs, we show that trend reversals manifest within years and decades, with legacy effects primarily manifest in the prolonged tail of nitrate breakthrough

rather than the height and timing of the nitrate peak in receiving waters. Moreover, we demonstrate how multi-tracer techniques help identify proportions of modern water in individual pumping wells, linking them to trends in specific well field sections. Finally, we highlight the impact of using time series of mixed water from multiple pumping wells versus individual wells, elucidating potential obscurities in trend identification with aggregated data.

Abstract number–91 A hydrologically informed agricultural land use intensity index to assess the agricultural impacts on streams and rivers

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The management of freshwaters is challenging due to the concurrent action of multiple drivers, resulting stressors and their impacts that alter freshwater ecosystems' structural state and functional integrity. Agricultural land use intensity exerts multiple stressors on stream ecosystems, impacting water quality and biodiversity through, among other factors, increased fertilizer and pesticide inputs. These diffuse source pollutants from agricultural activities potentially degrade the ecological integrity of streams. To leverage agricultural land use information to an agricultural land-use intensity with the ability to quantify these compound impacts on stream and river ecosystems, we developed a hydrologically informed Agricultural Land Use Intensity Index for Stream ecosystems (LUIS). LUIS is a spatially explicit tool integrating high-resolution satellite-based land-use information with data on crop-specific input for fertilizer (N, P) and pesticide application, hydrological transport pathways and river network structure, capturing both the proximity and magnitude of agricultural pressures on aquatic systems. The modular structure of LUIS allows the assessment of its single components for phosphate, nitrogen, and pesticide pressure, as well as its compound pressure. With its robust and adaptable conceptual framework, it has the potential to be upscaled to larger geographical regions, such as Europe. In initial applications, LUIS was validated for its ability to predict the ecological status of German streams and rivers, accounting for variables such as stream order, network connectivity, soil type, and crop characteristics. Additionally, LUIS demonstrated the relative importance of its three components (phosphorus, nitrogen, and pesticide) in predicting the status of key biological quality elements (BQEs), including benthic invertebrates, fish, and aquatic flora, which are widely used indicators of ecological status. These capabilities make LUIS a

potentially valuable tool for future use by environmental managers and policymakers, supporting targeted interventions to help mitigate agricultural impacts on stream and river ecosystems. By developing transfer functions that link LUIS with stream and ecosystem structure and function, it holds promise as a guide for sustainable land management practices and a resource for informing freshwater restoration efforts.

Abstract number–92 Nutrient input changes in grassland-dominated agricultural lands: effects of crop rotations and land transformations in Latvia

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Nutrient concentrations and loads in river catchments vary significantly, driven by meteorological conditions and agricultural practices. Crop rotations influence nutrient dynamics through variations in fertilization practices and the uptake and removal of nutrients by harvested crops. This study investigates the impact of crop rotations on nutrient loading, focusing on fertilizer use and nutrient uptake in a grassland-dominated agricultural landscape, providing a foundation for future research on sustainable nutrient management. We analyzed data from the Dviete River catchment (243 km²) in Latvia, narrowing the study area to 100 km² with crop records from 2018 to 2022. Eight primary crop types were identified, including permanent grasslands, arable lands, and fallow areas. We documented 371 unique crop rotation patterns, selecting 43 dominant rotations covering 86% of the area. Crop distribution included permanent grasslands (69.0%), temporary grasslands on arable land (15.6%), winter wheat (7.2%), spring wheat (3.6%), oats (2.0%), fallow land (1.1%), spring rapeseed (0.8%), and spring barley (0.8%).

Overall, a trend toward decreasing arable land and increasing permanent grassland indicated a shift to less intensive agriculture, affecting around 10% of agricultural land. The decline in arable land was driven by reduced temporary grasslands and a slight decrease in spring crop coverage, while winter wheat and fallow land shares increased by 3% and 0.7%, respectively, with fallow land nearly doubling in share. Nevertheless, the expansion of winter wheat, combined with a reduction in spring crops, resulted in a 26.7% increase in nitrogen use and a 17.2% increase in phosphorus use on arable lands when considering the combined areas of spring crops, winter crops, and fallow land.

Using typical nitrogen content in seeds and SWAT+ simulated crop yields (4.15 t/ha for spring crops and 6.24 t/ha for winter wheat), we estimated that approximately 17.1 kg/ha of nitrogen remained in the system after spring crop harvests and 64.1 kg/ha after winter wheat harvests, theoretically resulting in a 38% increase in nitrogen inputs that were not removed

by seed yield.

These findings highlight the complex interplay between crop rotations, land transformations, and nutrient management in grassland-dominated agricultural areas. They underscore the need for targeted strategies to optimize nutrient use and mitigate environmental impacts, setting the stage for further research on sustainable agricultural practices and nutrient balance optimization.

This research was part of the EU-funded research and innovation project OPTAIN (<https://www.optain.eu/>)

Abstract number–93 Using turbidity sensors to assess uncertainty in mean suspended sediment and phosphorus concentrations from infrequent water sampling

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When implementing the Water Framework Directive (WFD), average concentrations of nutrients are used as a support to assess the environmental state. These average concentrations are often based on infrequent water sampling, typically monthly, fortnightly or weekly. We used hourly data from turbidity sensors in eight agricultural streams, of which two each in Denmark, Finland, Norway and Sweden. We correlated turbidity by sensor with analyses of total phosphorus (TP) and suspended solids (SS) from water samples, and then used these correlations to create hourly data series of TP and SS. We then employed Monte Carlo analyses (1000 runs) to calculate average concentrations of TP and SS from six different annual water sampling strategies: Monthly, fortnightly and weekly sampling using all data; and the same frequencies using only data from working hours (9-15) Monday-Thursday. The latter strategy is based on the practical constraint that laboratories should not receive water samples later than Friday morning, to ensure that the analyses are done within 24 hours after sampling. We did the calculations for the driest and wettest years of the turbidity data series, and where possible, also a year of average water discharge. Our preliminary results* indicate that the largest span in average concentration was found for monthly sampling, and the smallest span was found for weekly sampling. The dry years had

generally less uncertainty in average concentrations than the wet years. The uncertainty varied between the individual streams. As an example, monthly sampling gave an uncertainty of annual average turbidity of about 40-55% in the two Norwegian streams, but only 20-40 % in the two Finnish streams. Similarly, weekly samples resulted in an uncertainty of annual average turbidity of about 20% in the Norwegian streams but was down to 5-15% in the two Finnish streams. There were only minor variations in uncertainty between the same sampling frequencies, using either all available data or only data from Mon-Thursday during the working hours. Our results should guide managers to choose sensible sampling frequencies when following up the requirements of the WFD.

* This study is still on-going, but will be finalized by February 2025, and therefore all results will be ready before LUWQ.

Abstract number–95 Assessing the effects of conservation tillage practices on water, nutrient, and sediment retention in six European case studies using SWAT+

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An integrated model-based evaluation of the effectiveness of conservation tillage practices was carried out in six small catchment areas across Europe using the Soil Water Assessment Tool (SWAT+). Different reduced-till and no-till farming practices were analysed and compared by biogeographical region. The case studies included Schwarzer Schöps in eastern Germany (136 km²), Petite Glâne on the western Swiss plateau (100 km²), and Upper Zgłowiączka in central Poland (150 km²), representing the Continental region, Felső-Válicka (124 km²) and Tetves (68 km²) in western Hungary, which represent the Pannonian region, and Kråkstad (51 km²) in Norway, representing the Boreal region.

We applied the R scripted workflow developed in the OPTAIN project (Optimal strategies to retain and re-use water and nutrients in small agricultural catchments across different soil-climatic regions in Europe) for preparing input data, model setup, calibration, and scenario simulation. The effectiveness of conservation tillage practices was evaluated based on predicted changes in water quality and quantity in the watercourses, soil hydrology, sediment and nutrient retention on agricultural fields, and crop yields.

According to our modelling results, conservation tillage practices are most effective in reducing sediment losses from agricultural fields (ranging from 24-92%), with greatest reductions in the Pannonian case studies. Significant reductions were also predicted for the losses of nutrients, with greater variation for total phosphorus – TP (0.5-42%) than for total nitrogen – TN (13-29%). The retention effect resulted in lower river loads of sediments (0.1 to-38%), TP (1 to 14%) and TN (2 to -5%) at the catchment outlets. With conservation practices implemented, our models tend to predict an increase in the average soil water content (up to 10%) and a slight decrease in mean streamflow, although these results varied

largely among the study sites. Simulated crop yields were less affected, with small increases and decreases depending on crop type and case study.

Our presentation will compare the results across biogeographical regions and discuss critical model assumptions and limitations.

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Abstract number–96 Impact of climate-change on nutrient dynamics in agricultural catchments: An empirical modelling approach

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The shifts in the weather patterns and occurrence of extreme hydrological events have resulted in further degradation of water quality. Heavy precipitations and prolonged droughts are exacerbating nutrient transfer processes to surface water bodies within the agricultural landscape. In view of more frequent occurrence of extreme hydrological events, climate-smart robust adaptation/mitigation strategies are needed. However, development of any efficient measure requires better understanding of both the conditions and timing of the intensified hydro-meteorological drivers of nutrient-loss events.

The water quality indicators and climatic data in six hydrologically-diverse agricultural catchments (ca 3-30 km²) in Ireland have been monitored on a high temporal resolution basis (10 min) since 2010. An empirical modelling approach was carried out to associate any hydrological event-based pulses of Nitrogen (N) and Phosphorus (P) into surface waters over a 14-year period. Then the probability of occurrence and likelihood of such triggering events were modelled for near, mid, and far future climate change scenarios for moderate (RCP 4.5) and severe (RCP 8.5) emission pathways.

The modelling revealed various combinations of criteria (contributing to N and P losses), in terms of air temperature and effective rainfall at different temporal scales, explaining more than 50% of all nutrient loss events across all the catchments. Comparison between RCP4.5 and 8.5 across three time periods of 2010-2039 (near-future), 2040-2069 (mid-future), and 2070-2100 (far-future), suggested that while the upward trends of nutrient-loss triggering events would continue to increase stepwise in each time period, the percentage increase of events causing nutrient losses would almost double in RCP8.5. The sum of different empirically-driven criteria indicated over 60% increase in the number of triggering events from near-future to far-future in some of the catchments. However, the response of each catchment was unique and influenced by its characteristics, i.e., soil texture and chemistry, drainage status, hydro-geology, farming practices, and weather. Prolonged warm periods and increased hydrological connectivity would result in increasing number of nutrient losses

events as we move toward end of the century. The temporal aspects of weather-related flushes of nutrients also indicated that certain months require specific attention in terms of adaptation, management, and re-evaluation of nutrient transfer pathways. The differences in catchments' responses to weather events and in the frequency of triggering events across climate scenarios also implied that climate smart management practices are needed that are resilient and tailored to catchment specific characteristics and different environments.

This research has been conducted as part of the WaterFutures project (EPA-funded) and in collaboration with Agricultural Catchments Programme (ACP) in Ireland.

Abstract number–97 Implementation of a National Scale Water-AGRI European Innovation Partnership in Ireland

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In Ireland, 54% of surface waters are in good or high ecological status while the remaining 46% are in unsatisfactory ecological status. Agriculture is the main pressure impacting on water quality in Ireland. Despite increased regulations on nutrient management in the agricultural sector in recent years via the Nitrates Directives regulations, water quality is not improving and nitrate levels are increasing in Irelands estuaries and coastal waters. In an effort to support farmers to reduce the loss of nutrients to water, the European Commission, along with the Department of Agriculture Food and the Marine have provided €50M in direct funding to farmers via the Water-AGRI European Innovation Partnership (EIP) programme, to fund supplementary water quality measures in priority catchments. The Department of Housing, Local Government and Heritage are contributing €10M towards the operational costs of the project which was launched in March 2024 and runs until the end of 2027, termed the 'Farming for Water EIP'.

The Local Authority Waters Programme (LAWPRO) are leading the Farming For Water EIP in partnership with Teagasc and Dairy Industry Ireland. A team of LAWPRO scientists are collecting detailed local scale information on water quality issues and pressures in priority catchments. Where pressures from agriculture are identified, they refer the issues and associated data, to a team of dedicated water-quality agricultural advisors from Teagasc and the Dairy Industry, termed the Agricultural Sustainability Support and Advisory Programme (ASSAP). The ASSAP team then visit the farmers in the referral areas and offer them the opportunity to implement a range of 43 supplementary water-quality measures on their farms which are funded under the Farming For Water EIP. The 43 measures cover a range of issues including nitrates, phosphates, sediment, pesticides and sheep-dip.

Every EIP application starts with a bespoke rain water management which the ASSAP advisor designs with the farmer to identify runoff pathways for nutrient loss. A bespoke set of measures is then agreed between the farmer and the advisor based on the nutrient loss risks and runoff pathways identified on that particular farm. Nearly 500 applications for EIP funding have been submitted to date covering over 3,000 measures. The locations of all measures is being collated and mapped in order to link these actions to water quality improvements. A dedicated Research Hub is collecting data on the efficacy of these supplementary measures across a range of landuses, soil permeabilities and scales.

Abstract number–98 Modelling Annual Total Organic Nitrogen Concentrations in Streams using Machine Learning at National Scale

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Total organic nitrogen (TON) constitutes almost 20% of the total nitrogen (TN) riverine loadings to Danish coastal waters. Thus, knowledge about the TON concentration in streams and its spatial variation is essential to accurately assess the importance of TON for TN loadings to coastal waters and eventual sources of TON in the landscape. We used environmental monitoring data from 390 stations across Denmark to calculate indirectly measured annual average TON concentrations along with a wide range of predictor variables. Thereafter, we trained a machine learning model to predict spatially distributed average annual TON concentrations in Danish streams. The annual TON concentration is modelled with a mean error of 0 mgL⁻¹ and a root-mean-squared error of 0.20 mg L⁻¹. Results indicate a mean annual TON concentration in Danish streams amounting to 0.70 mg L⁻¹ with a standard deviation of 0.31 mg L⁻¹. The new national TON concentration model is largely driven by the mean elevation, the percentage of agricultural land, the percentage of tile drained areas, the percentage of lakes, and the percentage of carbon enriched soils. The developed model and national TON maps contribute to our understanding of annual TON concentrations in streams supporting national-scale land-use and water management.

Abstract number–99 Evaluating Nature-Based Solutions for Nitrogen and Phosphorus Reduction: A comprehensive modelling approach in agricultural catchment

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Despite recent efforts to reduce nutrient loading, eutrophication continues to degrade freshwater and marine ecosystems throughout the Nordic region, particularly in the Baltic Sea. Climate change is expected to intensify its impacts, highlighting the need for adaptive, effective nutrient management strategies. Within the EU NORDBALT-ECOSAFE project, we address multiple approaches to maintain nitrogen (N) and phosphorus (P) load within safe ecological limits, focusing on the agriculturally intensive Temmesjoki river catchment in northern Finland (1181 Sq. km). High nutrient concentrations (especially phosphorus) and poor water quality, particularly in tributaries such as river Tyrnäväjoki, cause significant environmental concerns. We explore peatland restoration, winter cover crops, permanent grass cover, and wetland establishment as potential nature-based solutions (NBS) to mitigate nutrient runoff and support ecosystem resilience. Using SWAT+, we (i) calibrate and validate the hydrological model and (ii) compare SWAT+ outputs with Finland's national nutrient-loading model VEMALA. Further, we (iii) examine how simulated nutrient results align with or exceed the "good" or "moderate" ecological status class thresholds for nutrient levels established for lowland river types in Finland and finally (iv) evaluate NBS scenarios to identify plausible settings for N and P reduction under current and projected climate scenarios. The results show that SWAT+ achieves greater accuracy in simulating river discharge and nutrient concentrations than VEMALA, highlighting its potential as a key tool for water management. The initial assessment of multiple NBS scenarios also indicates reduced nutrient levels. These findings offer a strategic basis for effectively implementing NBS in agricultural landscapes, informing adaptive water management practices to meet EU environmental targets in a changing climate.

Abstract number–100 Change to more sustainable dairy and arable farming: an integrated approach with attention for water quality

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In this research a number of standard farm types for the dairy and arable farming sectors have been developed. Based on the objectives of the National Rural Area Program (NPLG) with respect to the themes ammonia emission, biodiversity, water quality and climate (greenhouse gas emissions), packages of measures have been determined and applied at farm level, which should help to achieve ambitious emission reductions. This integrated approach combines the aforementioned themes and shows where objectives on themes strengthen each other or where they work against each other.

Several measures concerning the themes have been investigated but for water quality the

measures loss of derogation, introduction of buffer strips and decrease of the nitrogen application standards are important in the case of dairy farms. For arable farms these are buffer strips, catch crops, decrease of the nitrogen application standards and more grains with less potatoes and sugar beets. In this research the decrease of the nitrogen application standards was only in effect on sandy soils because these soils are more vulnerable to nitrate leaching to groundwater than clay and peat soils.

The environmental and economic impacts at farm level were calculated using the FARMDYN optimisation model. The model was applied to eight dairy farm types (differing in soil type, size and intensity) and to five arable farm types (differing in soil type and cropping plan). It turned out that the applied measures would have strong negative impacts on dairy farm income and would negatively affect dairy farm continuity. An important reason were higher prices to dispose of animal manure, combined with a larger amount to be disposed.

Ammonia emissions went down with 5-10% when applying all three measures. Greenhouse gas emissions decreased with 0-4% and the nitrogen surpluses, seen as an important indicator for nitrate leaching, decreased with 20-40 kg N per ha. On arable farms the impacts on farm income and farm continuity were small and mixed: because of more money for accepting animal manure the financial effects of buffer strips etc. could be compensated. Ammonia emissions increased slightly on arable farms (0-2%) and nitrogen soil surpluses increased with 0-10 kg N/ha.

Abstract number–101 Nitrogen use in the Netherlands in relation to nitrogen use standards

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In the Netherlands the question arises to what extent dairy and arable farmers use all space that is offered to them within the nitrogen application standards. If farmers fertilise with nitrogen below these standards, then a, maybe necessary but limited, decrease of nitrogen application standards would not affect crop yields. A decrease in the standards is foreseen in so called 'nutrient contaminated areas': these areas are mainly located on drier sandy soil in the East and the South of the Netherlands.

Arable farmers on clay soils used nitrogen at 0-5% below the nitrogen application standards in the years 2019-2021 but in 2022 the difference was 10%. Arable farmers on sandy soils remained 8-12% below the standards in the years 2019-2021 whereas the difference was 16% in 2022. Farmers applied less inorganic nitrogen in 2022, most likely due to the high prices for organic fertiliser in that year. Arable farmers on sandy soils took about 65% of the applied nitrogen from animal manure, about 25% from inorganic fertiliser and about 10% from other organic manure (e.g. compost).

Dairy farmers used nitrogen at about 15% below the nitrogen application standards in the years 2019-2021 whereas it was a difference of 20% in 2022. Also dairy farmers differed between soil types. On sandy soils the difference was about 10%, on peat soils about 20%

and on clay soils about 30%. It has to be noted that the nitrogen application standard for grassland on clay soils is rather high with 345 kg N/ha in case of grazing and 385 kg N/ha in case of no grazing. Between the soil types there is little difference in the amount of applied nitrogen from animal manure and the highest use of nitrogen from inorganic fertiliser takes place on dairy farms on clay soils.

It can be concluded that, on average, arable and dairy farmers do not fill up completely their nitrogen application standards. Less application of nitrogen will mean some reduction in the amount of nitrogen, vulnerable to leaching. If prices of fertiliser increase strongly, as was the case in 2022, farmers react by less use of fertiliser. Use of less fertiliser can be invoked by lower application standards but pricing, e.g. with a tax, can have comparable effects.

Abstract number–102 Methods to quantify nutrient load reduction targets for surface water bodies to meet Nitrogen and Phosphorus targets for good ecological status

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High concentrations of nitrogen (N) and/or phosphorus (P) hinder good ecological status in many European surface water bodies. Despite decades of environmental policies, numerous surface waters across Europe still receive excessive nutrient loads from agricultural practices, wastewater discharges, and various other point and diffuse sources. The imperative for load reductions is clear. A good understanding of the water system, nutrient loads and corresponding sources is necessary to determine by how much the nutrient load needs to be reduced in order to meet the Water Framework Directive (WFD) targets set for N and P.

We will present current operating methods to quantify the required load reduction targets (LRT) using an inventory of methods that are applied across the four New-Harmonica case-study nations in North-Western Europe. The basis for the methodology is a detailed source apportionment that quantifies the sources of the N and P loads to the surface water bodies in a catchment or river basin and the retention of N and P in the surface waters. The LRT are based on the exceedances of the target concentrations at the WFD monitoring sites at the catchment outlet and the results of the source-apportionment modelling. The WFD Common Implementation Strategy (CIS) guidance on eutrophication stressed that it may be necessary to undertake measures in upstream surface water bodies to reduce nutrient inputs and transport downstream. At this stage, a balanced division of costs between upstream and downstream areas and between the various sectors has to be decided on, taking into

account the Polluter-Pays principle and Fair Share Proportionality.

The methods we have examined mainly differ in how the total LRT can be distributed among the sectors according to the Polluter-Pays principle and how loads from upstream surface water bodies are incorporated. A distribution of the LRT among sectors provides policymakers with the necessary information to assign targets to each sector for the measures needed to achieve the WFD-targets.

Our analysis shows, among other things, that a detailed and well-validated source analysis is required to distribute LRT in a transparent and properly justified way. The required source analysis should also factor in the anthropogenic component of diffuse pollution from agriculture, seasonal variations in load, and the intricate routing of pollutants from upstream to downstream catchments within the river basin.

Abstract number–103 Sediment color as a predictor for subsurface redox conditions at large scale

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Denitrification is strongly governed by redox conditions, as it occurs only under oxygen-depleted N-reducing or reduced conditions. Detailed spatial knowledge of subsurface redox architecture is therefore essential for modelling of nitrate transport and fate in groundwater and then recharge to surface waters, particularly under new agricultural nitrogen regulations. These regulations aim to implement spatially differentiated mitigation measures and fertilizer limits, based on the characteristics of the sites, highlighting the importance of identifying the redox interface—the bottom of the N-reducing zone. Groundwater chemistry is commonly used to identify subsurface redox conditions; however, it provides only point-scale information and is time and labor intensive to obtain a large set of data. In soil sciences, soil colors are used to infer soil profile development including redox conditions. This study assessed to what extent sediment colors can serve as a proxy for subsurface redox conditions in the context of national-scale nitrogen budget modelling.

Data on sediment color and groundwater chemistry were extracted from Denmark's National Borehole Database (JUPITER). After data cleaning and pre-processing, sediment colors and groundwater chemistry were linked at the screen level, resulting in 43 sediment colors from 8,672 screens nationwide. For each color, the oxic water fraction i.e., the proportion of oxic water screens (nitrate concentrations >1mg/L) was calculated. Red, orange, and yellow, typical oxic colors, had sparse groundwater data, likely because they are prevalent in the unsaturated zone or shallow depths. Black, blue and green colors, typical reduced colors, also had limited groundwater information as they are often found in clay, where groundwater sampling is challenging. Gray, one of the predominant colors of the subsurface, exhibited a

low oxic water fraction (<0.1), while brown, another major color, and gray colors with oxic color nuance (i.e., brownish gray or yellowish gray) showed oxic water fractions that decreased exponentially with depth. These trends were hypothesized that due to low nitrate-reducing capacity of the sediment, their oxic water fractions may be more strongly governed by hydrogeological controls such as travel times.

Our findings indicate that typical oxic and reduced colors are reliable indicators of corresponding redox conditions whereas colors with opposite nuances (i.e., yellowish gray or grayish yellow) display depth-dependent oxic probabilities. The sediment color at each borehole can be translated to 1-D profile of oxic probability, allowing more precise delineation of redox interface at the national scale. Sediment color is relatively easy and quick to collect a large set of data, implying a great potential as input data of large-scale modelling of redox-sensitive processes.

Abstract number–104 Effect of mitigation measures on nitrate in the agricultural lands of groundwater protection areas in the Netherlands: A modelling study

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In the sandy and loess soil regions of the Netherlands, N leaching from agricultural soils has led to groundwater nitrate concentrations in exceedance of the 50 mg/L limit of the EU Nitrates Directive in the past years. Mitigation strategies to achieve the reduction target have been investigated in 34 groundwater protection areas vulnerable to N leaching. In this study, we adopted a modelling approach to evaluate the effect of various mitigation measures on 218 agricultural lands with diverse soil, groundwater, and farming conditions selected from the 34 areas.

SWAP and ANIMO are process-based, mechanistic models that simulate water flows and the transport and transformation of N across the soil-water-atmosphere-plant interfaces. Four types of mitigation measures were modelled: (1) Reduction of fertilisation by 20% or 33%; (2) Adaptation of crop rotation, replacing crops prone to leaching by plants with higher N use efficiency (e.g., continuous silage maize to grassland or rotation of grassland and maize, additional fibre crops following potatoes, etc.); (3) Additional management measures (e.g., reduced grazing, introducing catch crops, recycling of crop residues, etc.); and (4) Shift of farming system from conventional to organic production.

In agricultural lands of the groundwater protection areas, the mitigation effect varied among regions and farming types, with an average reduction between 3 and 35 mg/L in nitrate concentration. By implementing the measure with the greatest effect, the target of 50 mg/L

nitrate can be met in half of the groundwater protection areas. However, any single measure is not sufficient to achieve the reduction target in all areas, suggesting that more drastic or combined measures must be considered.

If the area-weighted average concentration of the entire groundwater protection area, including non-agricultural lands, is considered, then more groundwater protection areas can meet the target by implementing the mitigation measures. However, whether the 50 mg/L target should be viewed as a regional average, or as a threshold for point measurements everywhere, will raise a point of discussion from the policymaking perspective, especially considering that some areas have difficulty in closing the reduction gap.

The modelling process was iterated based on feedback from stakeholders and policymakers to reflect realistic farming practices. The outcome will be used to facilitate policymaking, and for selecting potential measures for further investigation.

Abstract number–105 Nitrogen Use Efficiency in Nitrate Polluted Areas in Germany: How effective are regulatory measures?

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Since 2017, nitrogen policy in Germany underwent major changes in order to implement the European Nitrates Directive adequately, as nitrate groundwater quality is still insufficient. In response to the ruling of the European Court of Justice against Germany, nutrient budgeting approaches were overruled, and countrywide mandatory measures were tightened instead, particularly for farms in so called nitrate polluted areas. These areas were designated by means of a new administrative specification in 2022 and have been valid since then. We aim at better understanding the effectiveness of these measures by analysing the impact of respective designation on nitrogen management of affected farms compared to unaffected farms. Our analysis is based on the nitrogen use efficiency (NUE) on the farm level as an agri-environmental indicator for assessing farm-individual nitrogen performance. We calculate annual NUE values by considering nitrogen input and output parameters at the “farm-gate” as system boundary, based on farm level data of the German Farm Accountancy Data Network. Farms are classified according to the share of the designated (non-)polluted areas of their municipality. Covering around 27,000 observations between the years 2016 and 2023, we aim to investigate the development of NUE in farms in polluted areas before and after their designation, and in comparison to unpolluted regions, as well as potential

adaptations related to nitrogen management. For statistical analysis, we control for average annual NUE change using a robust regression model for panel data. First results indicate an increasing trend in NUE for all farm types, from 58 % to 77 % at the sectoral level. Farms located in municipalities with a high share of nitrate polluted areas show higher NUE both at the beginning and at the end of the observation period compared to control group, with a substantial higher annual NUE growth rate. Further, we investigate effects of the size of designated areas and effect of farm types. The analysis contributes to better understand multi-dimensional linkages between nitrogen management and water quality and supports policymakers in designing effective policy measures in the sense of “polluter pays” principle.

Abstract number–106 Assessment of Rare Earth Element Accumulation by Willow (*Salix* spp.) in Floating Treatment Wetlands.

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Rare earth elements (REEs) are increasingly essential in modern technologies, yet their environmental accumulation and impacts on plant growth, particularly in willow (*Salix* spp.), remain understudied. Lanthanum and neodymium are critical rare earth elements widely used in advanced technologies, including electronics, renewable energy, and aerospace applications. Different wastewater has been reported to have considerable REEs due to urbanization, mining, and industrial activities. Floating treatment wetlands (FTWs) could be a viable solution to purify the wastewater. Willows (*Salix Schwerinii* (SW) and *Klara* (KL)) growth and their potential to accumulate REEs from artificial wastewater amended with different combined doses of La + Nd (10+20+40 µM) was investigated for two months. The tap water without REEs was assigned to the control.

Willow growth height, tolerance indices, dry biomass production, and REEs accumulation in leaves, stems, and roots were examined. Results indicated that plant heights varied between 152 and 192 cm across treatments, with SW and KL exhibiting distinct tolerance levels. Dry biomass for SW peaked at 25 g in low-dose treatments, while KL reached a maximum dry weight of 32 g under control conditions. Tolerance indices ranged from 0.95–1.14 for SW and 0.55–0.96 for KL, underscoring the differing responses of the willows to REEs exposure. Concentrations of La and Nd were found to be highest in leaves and stems at 10 µM and 20 µM but showed marked increases in roots under high concentrations (40 µM). Accumulation patterns revealed that both willows retained significant La and Nd in roots, particularly in 40 µM, suggesting that willow roots serve as primary REE storage sites. The bioconcentration factors for La (6.04–13.81) and Nd (3.82–8.95) across both willow show their tolerance to moderate REEs levels. These findings suggest that willow can be utilized to reduce the concentration of REEs from wastewater sites and, the processed water after proper management could be reused in agriculture. This study also aligns with Sustainable Development Goal 6, which advocates for “clean water and sanitation”. This

research provides insights into the phytoremediation capacity of willow species, suggesting further exploration of their applications for mitigating REEs pollution in impacted ecosystems for longer periods.

Abstract number–107 Application of cell-based bioassays to assess toxicity in agriculture catchments contaminated with mixtures of pesticides

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The potential risk to aquatic ecosystems in agricultural systems in the coastal catchments of Queensland, Australia, has for many years been implied by regular exceedances of published guidelines for the protection of aquatic ecosystems. However, relatively few empirical data are available to validate the toxicity even in some of the more heavily contaminated systems. Traditional *in vivo* direct toxicity assessment (DTA) bioassays are expensive, low-throughput, and limited to apical endpoints, which has limited their application to these waters. *In vitro* bioassays offer a cheaper, faster, and more ethical alternative that can provide increased sensitivity for some environmentally relevant endpoints. We have adapted several *in vitro* cell-based bioassays for use with whole water samples. A batch of cell-based bioassays were used to assess the toxicity of water collected from waterways that are regularly contaminated with mixtures of pesticides.

Eleven waterways were sampled, ranging over 1400 km of the Queensland Coastline from the Atherton Tablelands in the North to the Pumicestone Passage in the South. Ten of the waterways discharge into the Great Barrier Reef World Heritage Area and one discharges into a Ramsar listed wetland. With the exception of one waterway that drains conservation land use, all waterways drain either sugarcane cropping lands or horticultural agriculture. Water samples used for toxicity testing were analysed for a broad variety of pesticides.

The tests applied to these waters included a Pulse Amplitude Modulation fluorometry (IPAM) assay for photosynthesis inhibition, a Bacterial Luminescence Toxicity (BLT) screen for acute toxicity to bacteria, a rainbow trout gill cell (Rtgill-W1) viability assay for acute toxicity to fish, a high-throughput micronucleus assay for genotoxicity and an AhR receptor-responsive chemically-activated fluorescent gene expression (AhR CAFLUX) assay for dioxin-like compounds. These tests were applied to whole water sample with minimal pre-cleanup treatment (sterile filtration).

Results from water collected from ten catchments receiving agricultural runoff from sugarcane and/or mixed horticultural crops showed a strong toxicity signal in four of the five

tests. The IPAM test produced toxicity responses with four of the five waters known to be contaminated with multiple PSII herbicides and in one water in which no PSII herbicides were identified. Three other tests also produced toxicity responses in one to three of the 11 waters tested, although a direct link to analysed chemicals could not be determined. The results suggests that whole water screening using high throughput in vitro tests may have utility of verifying toxicity risk in agriculture landscapes.

Abstract number–109 Storage ponds as a multifunctional tool for irrigation and nutrient removal.

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In regions where the groundwater resources are limited due to water extraction for drinking purposes, alternative water resources must be found if field irrigation is to be implemented. One possibility is to store drainage water from arable fields in storage ponds during wet periods and use the stored water for field irrigation during dry periods in spring and summer. A method that has been used on the Danish Island Samsø since the 1970's. Due to major requirements for reducing the nitrogen discharge from cultivated areas, reservoirs can now serve an additional purpose, namely, to reduce the discharge of nitrogen into the marine water environment.

Storage ponds can support the process of denitrification, where nitrogen compounds are converted into nitrogen gas by microbial activity. Remaining nitrogen in the stored water will, when the water is used for irrigation, be returned to the field. This makes storage ponds a potentially effective solution that addresses two core issues: the lack of water for irrigation and the excess of nitrogen in the aquatic environment. The study aims to obtain indications of the potential for nitrogen removal in storage ponds and will form the basis for future in-depth studies to understand the biological processes.

A monitoring experiment will be conducted at a storage pond on Samsø. Data collection is initiated when the pumping of the drainage water into the storage pond begins in December 2024 and will continue until field irrigation for the 2025 harvest season is completed. The pond has a storage capacity of 113,000 m³ water and supplies irrigation water to 200 ha of cultivated land. Inflow and outflow will be monitored regularly and contribute to simple storage pond water balances throughout the experiment. Water samples will be collected from incoming drainage water every 14 days until no more water is pumped into the storage pond. When the pumping of water for irrigation begins, collection of water samples for outgoing pond water will commence. All water samples will be analyzed for nutrient content and results will ultimately indicate the level of nitrogen and phosphorus removal during the storage period as well as the amount of nutrients recirculated to the cultivated fields with the irrigation water. The results of the experiments will be disseminated to share knowledge about the environmental effects of storage ponds.

The experiment will commence at the beginning of December 2024. Therefore, there are no results available currently. By the time of the conference, preliminary results will be presented.

Abstract number–110 Can local data strengthen assessments of groundwater extraction permits for field irrigation?

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More than 75% of Danish municipalities use the decision support tool BEST when assessing ground water extraction permits for irrigation. The BEST model is based on hydrogeological models able to predict the consequences of groundwater extraction on groundwater-dependent ecosystems and streams. Models are good tools to handle complex processes, but they rely on assumptions and the quality of input data, which may not accurately reflect local conditions. Understanding the local variability in hydrogeological conditions is important to determine the feasibility of groundwater extraction and its impact on streamflow and local ecosystems. This project examines if monitoring and incorporation of local data can enhance the professional assessment of these applications, potentially leading to more informed and sustainable groundwater management decisions. The specific local data required to obtain the most accurate and comprehensive knowledge to support the professional assessment of a permit will vary depending on the hydrogeological conditions. The purpose of the project is to develop a framework for farmers and advisors that can assist in determining whether it is worthwhile to collect local data and, if so, which types of local data would be advantageous to invest in.

The project involves selecting two case areas where farmers have been denied a new irrigation permit or have obtained a permit but with a significant reduction in extraction volume. In each case area a preliminary assessment has been conducted based on available hydrological and geological data, and a test pumping was completed in collaboration with landowners, agricultural advisors, the municipality, well drillers, and consulting engineers. Test pumpings provide data on aquifer performance and the environmental impact of groundwater extraction through continuous monitoring. Monitoring included measuring drawdowns in the pumped and nearby wells. Near-surface geophysical data was collected to provide an overview of subsurface geological structures and assess their connectivity. The data is evaluated using the BEST model to determine if locally measured data can provide a more accurate assessment and a different result compared to the preceding evaluation in the BEST model. This will establish whether there is a basis for updating the model in the specific area.

The results of preliminary investigations, test pumpings and geophysical measurements

should collectively enhance our understanding of which methods are appropriate in various situations, thereby contributing to the development of the framework. Preliminary results indicate that local data can provide a more accurate assessment of groundwater extraction impacts, potentially leading to more precise and reliable permit decisions.

Abstract number–111 Mitigation measures for phosphorus and nitrogen under changing climate: conflicts and synergies

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Nutrient runoff from agricultural areas is a big concern in Norway, because nutrient concentrations and loads significantly affect water quality status in the lakes, rivers, fjords and the coasts. There is a pressing need to reduce both phosphorus (P) and nitrogen (N) losses from agricultural areas through effective mitigation measures. However, whether mitigation measures work simultaneously for N and P remained unclear, hindering the recommendation of the measures for a wider adoption. Also, the influences of the measures on the N:P stoichiometry was unclear, despite it has been suggested by studies as a driver of eutrophication in surface waters. In a new project funded by the Norwegian Directorate of Agriculture, we are analyzing the effects of various mitigation measures (e.g., tillage, nutrient management) on P and N losses, as well as the N:P stoichiometry in surface runoff and subsurface drainage. This project is built upon a large land use and water quality data set collected from all over Norway, consisting of about 20 sites for plot and field studies and 10 sites for catchment monitoring. At the plot/field scale, we found that spring tillage instead of autumn tillage reduced both total P and total N losses in many cases, but the trend was not always the same. Also, the ratio of N:P varied greatly at different field sites and under different management systems. This highlights the potential role of critical meteorological and hydrological events and possibly their interaction with farming operations in affecting the nutrient losses. At the catchment scale, both the levels of total P and total N and the ratio of N:P varied widely by site. This is presumably due to combined effects of climate, landscape, cropping systems and nutrient balances in the catchments. While we are working on the data analyses, we will have more interesting results to present at the conference.

Abstract number–112 Using turbidity sensors to assess retention of particles and phosphorus in a small Norwegian constructed wetland

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Constructed wetlands (CW) are important environmental measures to reduce nutrient and sediment losses from agricultural creeks to downstream water bodies. We installed turbidity sensors in the inlet and outlet of a 275 m long CW in an agricultural creek in May 2024 with surface area of 2500 m² and the catchment area of 4.5 km². The CW consists of a sedimentation pond at the inlet and macrophyte filters in the lower parts. At the outlet of the CW, a turbidity sensor has been in operation since 2018, and we have used data from grab samples to calibrate turbidity with total phosphorus (TP) (R^2 of 0.66, $n=210$) and suspended sediments (SS) (R^2 of 0.73, $n=333$). At both the inlet and the outlet, automatic samplers collected flow weighed composite samples, analyzed for TP and SS. Water discharge is monitored continuously at the outlet. At the outlet, we compared loads of TP and SS based on turbidity data and data from composite sampling over 48 months and found that the total load of SS calculated from the turbidity data was 120% of that calculated from the composite samples, whereas for TP the load calculated from turbidity was 98% of that from the composite samples. We also scrutinized 31 episodes of increased turbidity from May-October 2024. The average retention in the CW during these episodes was calculated to 25% of SS, corresponding to 163 kg of SS, and 10% or 293 g of TP. There was a significant correlation (R^2 of 0.35 for SS and R^2 of 0.27 for TP) between the retention of SS and TP and the time of year the episodes occurred: the later in the autumn the episodes happened, the lower was the retention. Negative retention, i.e., higher SS and TP out than in, only occurred in 3 episodes, all of them in October (retention between -8% and -2%). According to our calculations the episodes contributed a large share of the total loads (90% of SS and 74% of TP) in the whole period of measurement while accounting for only 17% of the datapoints. Those episodes were responsible for 77% of the SS and TP retention in the CW. The work is on-going, and more data will be analyzed by the time of the LUWQ.

Abstract number–113 Can a sewage treatment plant expand even if it increases the phosphorus load to a recipient where it needs to decrease? A case study from Uppsala, Sweden

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The need of expanding the capacity of sewage treatment plants (STP) often conflicts with the regulations of the Water Framework Directive (WFD). In Uppsala, Sweden, the STP has applied for a permit to expand its capacity by 50 %, from 200 000 to 300 000 PE, thereby increasing the load on the recipient. The STP already today has an advanced treatment, with phosphorus concentrations in effluent water of 0.1 mg-P/L. Still, an increase of the load may compromise the environmental quality objects of the recipient, which is classified to moderate status with respect to phosphorus.

The recipient, River Fyris, is an average-sized river (catchment area approx. 2000 km²), with a mixed land-use of forestry, agriculture and some urban areas. Most of the anthropogenic phosphorus load comes from agricultural land (70%). The required load reduction to achieve good status was estimated to c:a 7 Tn-P/year, whereas the increase load from the STW was estimated to c:a 1 Tn-P/year (although an increase of up to 2.4 Tn-P/year would be allowed according to the permit).

In Sweden, the intended legal way to allow operations which conflicts with the WFD is to set a less stringent environmental objective for the recipient in question. However, in practice the prerequisites to apply less stringent objectives for eutrophication are seldom fulfilled, as the potential effects to reduce nutrient leaching from arable land is notoriously difficult to quantify.

The application from the STP was submitted to the Land and Environmental Court in May 2020, and the matter is yet to be settled. Here, we present and discuss the different assessments and analyses that has been made by the Court, by the Regional Water Authority and the Swedish Government during the course of this case.

Abstract number–114 Constructed wetlands intercepting mixed agricultural runoff across diverse landscapes, part 1: Variations in catchment yields and hydraulic loading

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Constructed wetlands (CWs) are a versatile and robust mitigation tool that can effectively reduce multiple contaminants from farm run-off, reducing impacts on freshwater quality and ecosystem health. Provisional design guidelines and performance estimates for New Zealand have been developed based on international data and local data from subsurface drainage treatment CW. However, field-scale information to quantify CW efficacy across different landscapes, flow pathways, and climatic zones is still limited. To better quantify field-scale performance of CWs intercepting mixed surface and groundwater inflows, and demonstrate their applicability, we worked in partnership with councils, industry, and farmers, co-funded by the NZ Ministry for Primary Industries. Comprehensive monitoring was undertaken from 2021-2024 of the flow and water quality at inflows and outflows of six CWs in contrasting landscape settings. Here we describe and report on differences in CW hydrology for four CW at diverse sites around the country where 1–3 site-years of telemetered, near-continuous flow and rainfall data are available for evaluation. The CWs

evaluated spanned a range of scales (e.g., CW sized between 1 – 3 % of their corresponding catchment areas) and landscape types, with annual rainfall totals varying from 1200 to >3000 mm across wetlands and years. This resulted in markedly different proportions of surface run-off (e.g., <5% to >95% of annual outflow volume across different wetlands and years), subsurface drainage, and groundwater hydraulic loading. Seasonal catchment runoff yields and hence CW inflows and outflows were greatest from May to October (austral winter and spring) each year, with surface inflow hydraulic loading rates varying from <1 to > 130 m across CW and years. Inflows showed high year-to-year variability, with wetter conditions during a La Niña year providing elevated hydraulic loading, followed by reduced hydraulic loading under drier conditions in an El Niño year. Combining this high-resolution flow data with contaminant concentrations will enable us to quantify CW load reductions, providing performance data across a much broader range of sites, regions, and farming systems over a range of annually and seasonally varying flows. This will be used to refine performance estimates and update practical guidelines, and be incorporated into modelling tools to better assess the cumulative impacts of mitigation systems at catchment and regional scales.

Abstract number–115 Constructed wetlands intercepting mixed agricultural runoff across diverse landscapes, part 2: Performance estimates for nutrient and sediment attenuation

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Growing and improving the scientific evidence base is crucial to provide farmers with reliable measures of constructed wetland (CW) efficacy so they can assess their cost:benefit as mitigation tools, apply and size them appropriately, and account for their contaminant load reductions in farm nutrient budgets and environment plans. Provisional estimates for New Zealand suggest that, as their relative size increases from 1-5% of their contributing catchment, median annual removal efficacies will increase from ~50-90% for Total Suspended Solids (TSS), ~26-48% for Total Phosphorus (TP), and ~25-53% for Total Nitrogen (TN) in warm regions and ~17-38% for TN in cool regions. However, performance data for CWs receiving mixed surface run-off, surface and subsurface drainage, and groundwater inflows is very limited, particularly in situations relevant to pastoral farming systems and humid oceanic climates, such as New Zealand's (Woodward et al. 2020). To better quantify field-scale performance of CWs intercepting mixed surface and groundwater inflows, and demonstrate their applicability, we worked in partnership with councils, industry, and farmers, co-funded by the NZ Ministry for Primary Industries. We report the results of comprehensive monitoring of flow and water quality at inflows and outflows to quantify

reductions in sediment, nitrogen, and phosphorus over 1-3 year periods at 4 newly established CWs. We used a range of modelling tools to estimate high frequency timeseries for TN, TP, and SS for CW surface inflows and outflows to quantify annual mass loading, export, and treatment performance for each wetland. The annualised load reductions (percent removal) for TN, TP, and SS are reported here and compared against predictions based on the existing CW Practitioner Guidelines performance models. Performance estimates for TN were consistently at or above predictions based on the provisional guideline values in Tanner et al. (2022), whereas performance estimates of SS and TP varied substantially across the CW and year-year. SS performance was lower than anticipated, primarily due to relatively low loads intercepted by the wetlands. Overall, the annual CW performance (annual % load reductions) found in the present study for TN, TP, and SS are well in-line with, and help to verify, the previous provisional estimates for contaminant removal performance intercepting diffuse runoff from pastoral land-use in New Zealand. Outcomes from this work will help provide assurance for regulators to allow farmers to claim CW nutrient reductions to achieve required contaminant loss limits, and for industry and rural professionals to confidently promote their use.

Abstract number–116 Spatial Data Preparation for SWAT+ Model: A Case Study of the Berze River in Latvia

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A hydrologic model can simulate nutrient sources, pathways and transport considering the specific characteristics of water body's catchment area. Hydrological modeling has a crucial role in predicting changes in patterns and volumes of total nitrogen (TN) and total phosphorus (TP) leaching from the catchment leaching from catchments, aligning with the goals of Council Directive No. 91/676/EEC, which aims to protect water resources from agricultural nitrate contamination. The aim of the Nordbalt-Ecosafe project is to ensure that N and P concentrations and loadings in water bodies in the Nordic-Baltic region are reduced and will remain within safe ecological boundaries. SWAT+ model in the project is used to quantify daily concentrations and loads of N and P and nutrient sources, pathways, and sinks.

The model preparation in SWAT+ involves a sequence of steps, with the initial stage focused on spatial data preparation. This phase includes delineating the catchment area of the water sampling site and analyzing catchment characteristics data.

The case study is based on the catchment of the Berze River. Berze River is located in the

central part of Latvia, covering an area of 882 km². This area is divided into 15 sub-catchments, where water quality monitoring has been ongoing since 2005.

The spatial data integrated into the SWAT+ model includes: river networks; locations of 15 water sampling points and one hydrological gauging station; boundaries of 15 sub-catchments; digital elevation model (DEM) with a resolution of 5 x 5 meters; Corine Land Cover 2018 data on land use; soil types within the catchment (categorized into five classes based on their texture); information about crop spanning from 2017 to 2022; digitalized information about lakes and drained areas within the catchment and allocations of wastewater treatment plants. The study outlines the guidelines for preparing these spatial data inputs for SWAT+ modeling in the sub-basins of the Berze River. Spatial information is processed using GIS software, including ArcGIS Pro and QGIS (open-source).

This study was funded by a grant from the EU Horizon project NORDBAL-ECOSAFE (Grant Agreement No. 101060020).

Abstract number–117 Options to achieve the good ecological state of the Wadden Sea: Scenario analyses for the river basins of Elbe and Rhine

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High riverine and atmospheric nitrogen inputs hamper the good ecological state of coastal waters including the Wadden Sea (EEA 2024). The German target of 2.8 mg N/l at the limnic-marine border to the North Sea is currently only achieved in river Rhine, the major riverine source of nitrogen in the Wadden Sea. However, for re-establishing seagrass in the still eutrophic southern Wadden Sea load reductions of about 40% have been proposed (van Katwijk et al. 2024). We use the calibrated and validated mQM model (Nguyen et al. 2022) and a set of scenarios on the implementation of the revised Urban Wastewater Treatment Directive, the Nitrates Directive, the National Emission reduction Commitments (NEC) Directive, and nature-based solutions to quantify possible impacts of current policies on the Elbe and Rhine basins under climate change (cf. Samaniego et al. 2018). The mQM model features a travel time distribution to account for the time lag between N input to soils and surface waters (Ehrhardt et al. 2021). Calibrated and validated for the years 1950–2020, the model is applied until 2050. The results are complemented by the scenario impacts on the atmospheric deposition on the coastal areas. We discuss how policy goals contribute to the ecological state of Wadden Sea and how more ambitious ecological goals could be reached.

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Abstract number–118 Long-term monitoring indicates that land use and soil drainage interactions drive macroinvertebrates and diatoms composition but not diversity in Irish agricultural catchments

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Attaining and keeping good water quality is key for water consumption standards and may allow agriculture to expand production while lessening environmental impacts. Biological indicators respond to potential stressors from diffuse pollution associated with agricultural production by changes in their diversity and distribution of species abundances (composition). These changes may also occur because of demographic processes related with seasonal and inter-annual effects. We assessed the role of main land use and soil drainage on macroinvertebrates, diatoms diversity and species composition while controlling for inter-annual and seasonal effects. We used a spatially replicated and long-term dataset of macroinvertebrates, diatoms diversity and composition in six Irish catchments intensively used for agriculture. Sampling was conducted in small-order streams in the spring and autumn from 2009 to 2023. Diversity and species composition of both groups were assessed in relation to land use type, soil drainage capacity, time of sampling, and season with hierarchical models and multivariate techniques. Macroinvertebrates taxa diversity decreased through time and was higher in the spring than in autumn, and more so in catchments dominated by well-drained soils. The assessed variable did not explain the diatoms species diversity. Both macroinvertebrates and diatoms species composition varied in function of an interaction between the main land use and soil drainage, and main-effects of season and time. While streams in grasslands with poorly drained soils tended to present lower abundances of macroinvertebrates species tolerant to organic pollution, they also presented higher abundances of diatoms species favoured in high to very high nutrients

concentrations. Streams in catchments dominated by well-drained soils presented variable composition with high abundances of macroinvertebrate species both tolerant and sensitive to organic pollution. Similarly, those streams also presented a variable diatom composition with higher abundances of species favoured in low nutrient conditions to a predominance of species favoured from very low to very high nutrient conditions. Macroinvertebrates composition presented a similar distribution concerning season and time, with higher abundances of sensitive species to organic pollution in spring and first samplings, and the opposed in autumn and last samplings. Temporal patterns were less clear for diatoms composition, but spring samplings presented higher abundances of species favoured in low quantity by nutrients concentrations. The assessed catchments may be negatively influenced by diffuse organic pollution as the macroinvertebrates fauna are becoming less diverse and with a predominance of tolerant species. Furthermore, streams from poorly drained grassland are particularly risky to nutrient input given the prevalence of diatoms typical of high nutrient concentrations.

Abstract number–120 Willow Growth Potential and Nitrogen and Phosphorus Accumulation Under Processed Municipal Wastewater

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Short-rotation willow (*Salix* spp.) is increasingly utilized in the Baltic regions for wastewater treatment, nutrient recycling, and bioeconomy development. A four-year field trial (2016–2019) near a wastewater treatment plant in Outokumpu, eastern Finland, evaluated the effects of processed wastewater (WW) on biomass production and nutrient uptake by *Salix schwerinii*. The study aimed to assess the potential of willow for mitigating nutrient pollution, particularly eutrophication, and its contribution to sustainable agriculture and water management.

The findings revealed that WW irrigation significantly enhanced willow growth, resulting in increased stem diameter by 256% and biomass yield by 6510% compared to the control (no WW). The nutrient-rich wastewater promoted rapid growth, with willows accumulating 41–60% of nitrogen (N) and 32–50% of phosphorus (P) during 2018–2019. These results demonstrate the willow's effectiveness in absorbing N and P from wastewater, contributing to nutrient pollution reduction and improved water quality.

Willow survival rates under WW irrigation were high at 80%, substantially better than the control group's 61% survival rate, highlighting the suitability of willow for wastewater

irrigation in cold climates. These findings underscore willow's potential as an ideal species for wastewater treatment in colder regions, offering environmental and economic advantages.

This research supports sustainable development goals by improving water quality, reducing nutrient pollution, supplying renewable bioenergy, promoting water reuse in agriculture, and addressing eutrophication to protect aquatic ecosystems. It highlights the viability of reusing wastewater in agriculture, helping to alleviate water scarcity while promoting sustainable agricultural and forestry practices.

Abstract number–121 Experiences with high resolution UV/Vis-spectrometric sensors to detect peaks and hot spots in river nutrient inputs in the catchment of Füsinger Au (Schlei Fjord, Baltic Sea)

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The Füsinger Au is a primary tributary to the heavily nutrient-loaded Schlei fjord in Germany. Due to minimal mixing with the Baltic Sea, external nutrient inputs via river nitrogen and phosphorus loads, as well as internal eutrophication driven by phosphorus, have to be decreased to achieve the targets of the EU Water Framework Directive.

Data collection in high temporal and spatial resolution is needed (1) to validate the loads conventionally estimated on the basis of monthly grab samples of water quality (2) as well as to gain insight into processes, input sources, and pathways of nutrients within the catchment. Therefore, stationed optical UV/Vis-sensors have been deployed at the Füsing Station. At the same time, mobile spectrometers have been utilized in the Füsinger Au with a sensor-equipped mini-boat. The UV/Vis-Sensors have been tested to detect total nitrogen, ammonium nitrogen, nitrate nitrogen, total phosphorus, soluble reactive phosphorus, SAC 254, and turbidity. Physico-chemical parameters such as pH, electrical conductivity, oxygen levels, and temperature have been measured with multi-parameter sensors. Incremental grab sampling has been conducted alongside spectral monitoring to support sensor calibration, thereby improving data reliability.

The sensors offer good quality, high-resolution data for nitrate nitrogen and total nitrogen concentrations (validation with grab sampling $R^2 > 0.9$). However, total phosphorus measurements are limited in accuracy at concentrations below 0.1 mg/L, and ammonium nitrogen and soluble reactive phosphorus exhibit suboptimal calibration.

For well-calibrated parameters, the data show distinct patterns allowing detection of peaks

and hot spots of nutrient exports. These data are currently being analyzed to understand nutrient mobilization pathways under different hydrological conditions and to examine hysteresis effects in concentration-discharge dynamics.

The findings will support farm advisory programs to demonstrate agricultural nutrient inputs into river systems during peak periods and to develop process-based mitigation measures to combat further eutrophication of the Schlei fjord.

Abstract number–122 The evolution of the nitrate nitrogen residues measured in autumn in Flemish grassland soils since 2004

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Since 1991 the European Nitrates Directive has imposed a maximum nitrate concentration level of 50 mg nitrate per litre to protect ground and surface waters against pollution caused by nitrate leaching from agriculture. To comply with this Directive, the Manure Action Plan (MAP) was introduced in the same year in Flanders (Belgium). The MAP legislation regulates maximum nitrogen (N) fertilisation rates and maximum nitrate nitrogen residues allowed in the autumn (0-90 cm). The nitrate nitrogen residues are measured before the onset of winter as an indicator of the applied N fertilisation rate, but also of the potential N pressure from agriculture as nitrate leaching occurs mainly during the winter period. The nitrate concentrations are monitored in all areas dominated by agricultural land use, by a network of 754 surface water sampling points.

Since its introduction, several successive MAPs were implemented. Legislation became more differentiated and increasingly stringent. Gradually, the crop, the regional nitrate concentration in surface water and the soil texture were taken into account in the maximum N fertilisation rates and maximum nitrate nitrogen residues allowed in the autumn.

The average nitrate nitrogen residue measured in autumn in grassland is low compared to other crops due to the long growing period and high N uptake. Furthermore, split N fertilisation throughout the year makes it easier to take the weather conditions into account. The average nitrate nitrogen residues in both grassland and all fields decreased significantly between 2004 and 2012. In this period, maximum N fertilisation rates were reduced for all crops, except for grassland and gradually the agricultural area became nitrate vulnerable. Since about 2012, the further divergence and tightening of the legislation did not result in a clear positive effect on the average nitrate nitrogen residues. The average nitrate nitrogen residues have been at a stable level, or did even increase. Dry weather conditions had a negative effect on the average nitrate nitrogen residues and account for the average higher nitrate nitrogen residues in 2018 and 2020. The rain amount in spring (April-June) has been shown to mainly affect the autumn nitrate nitrogen residues. The average nitrate concentrations in surface water followed over the years the same trend as the average autumn nitrate nitrogen residues.

Reference:

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Abstract number–123 Testing gypsum amendment for reducing the agricultural phosphorus load to the Baltic Sea

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Eutrophication impacts the ecological state and ecosystem services provided by the Baltic Sea. So far there have been limited measures for reducing phosphorus losses from agriculture, which has contributed to the poor state of the coastal waters. According to field- and catchment-scale studies in Finland, gypsum amendment of fine-textured soils can reduce phosphorus losses by up to 50%. The loss of particulate phosphorus is thought to be reduced by the micro-aggregation of soil particles due to increased ionic strength and by calcium bridging. While stronger phosphorus sorption onto soil particles can explain lower losses of dissolved phosphorus, its availability to plants is not negatively affected.

There is little knowledge whether gypsum amendment works in other Baltic Sea countries. The aim of the Baltic Sea Interreg project GYPREG (2023–2026) and the Finnish NordGypsum project (2023–2025) is to test gypsum amendment in Denmark, Latvia, Lithuania, Norway, Poland, Sweden and Åland (Finland). In the GYPREG project, the performance of gypsum will be tested in e.g. laboratory pot experiments with methodological details adapted for local soils and agri-environmental conditions. In addition, gypsum amendment will be piloted at the field scale. The NordGypsum project involves soils from Finland, Denmark and Norway and investigates the effect of gypsum on soil structural properties under standardized conditions. The projects also make an estimate of the agricultural area potentially suitable for gypsum application in each country and develops a simple decision support tool for facilitating the practical implementation of the measure at regional scale.

Here, we present results from lab tests for identifying soil characteristics that indicate the sensitivity to gypsum treatment, such as aggregate stability and clay dispersion. For example, we have found a lower clay dispersion and a higher moisture content in gypsum amended Finnish clay and loam soil than in corresponding unamended soils. On the other hand, gypsum had little effect on soil aggregate stability. The relation of such soil properties

will be linked to evidence obtained in leaching experiments with soils in re-packed soil columns.

Abstract number–124 Agricultural land lacks resistance to water erosion during the wettest winters of the past decade

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With changing climate and increased frequency of wet weather extremes, increased attention is being directed towards understanding the resilience of agroecosystems and the goods and services they deliver. Within this context, the world's most instrumented and monitored farm (the North Wyke Farm Platform - a UK National Bioscience Research Infrastructure) has been used to explore the resilience of water quality regulation for sediment loss delivered by lowland grazing livestock and arable systems under conventional best management. The robustness of the systems for water quality regulation was explored using exceedance of modern background (i.e. pre-World War II) net soil loss rates during both typical and more extreme winters (December - February, inclusive) over the past decade (2012-2013, 2013-2014, 2015-2016, 2019-2020 and 2023-2024). Exceedances of modern background rates in the pasture system were as high as 2.4X when scheduled ploughing and reseedling for sward management occurred. Exceedances of modern background rates in the arable system were as high as 21.7X. Over the five monitored winters, the environmental damage costs associated with total sediment loss from the pasture system ranged between £1109-1794 / ha, compared with £6051- 9032 / ha for the arable system.

Abstract number–125 Protection of drinking water resources from agricultural pressures: embracing interdisciplinary cooperation to enhance governance approaches

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The remediation of nitrate and pesticide pollution from agriculture in drinking water resources can be characterized as a complex and multifaceted challenge. Despite extensive legislation it appears to be difficult to structurally improve and protect water resources as addressing agricultural pollution requires cross-sectoral approaches. The EU Water Framework Directive aims to build bridges among different relevant sectors, but the often sectoral implementation by Member States prevents its potential from being fully explored. This study aimed to contribute to the body of interdisciplinary knowledge on the driving forces towards water quality improvement from agricultural pollution. Case study research has been conducted in five European countries (Denmark, Northern-Ireland, France, Slovenia and The Netherlands) and builds further on the H2020 FAIRWAY project. The results from the cases were evaluated and discussed in a wider interdisciplinary setting, including experts with a legal, hydrogeological, social-economic or agronomic background.

The cases show a tendency by authorities towards the use of voluntary practices to improve water quality and to meet legally binding objectives. Although the added value of voluntary practices, often introduced in projects, is considerable for creating shared ambitions, their contribution to actual water quality improvement is limited. Implementation of these voluntary practices should be supported by long-term arrangements regarding capacity and means to embed lessons learned in daily practice, and not just for the duration of the project.

Furthermore, implementation should include practical guidance and monitoring of outcomes that enables compliance testing. Such information also serves as input for the evaluation of effectiveness of governance approaches and the formulation of follow-up actions, eventually laid down in binding regulations in case governance approaches are not sufficiently effective. The use of such types of evaluation mechanisms in the policy cycle is not yet common practice.

Processes that enable dynamic interactions among the knowledge domains, e.g., social-economic context, the legal framework, the state of the water system and developments in agricultural practices, also support the identification of necessary actions at the different stages of the policy cycle. Especially in the stages of implementation, monitoring & evaluation, and adaptation, there is a need for further in-depth studies in order to improve effectiveness of governance approaches, e.g. on the role of monitoring & evaluation, licensing and the balance between voluntary and legally binding measures, and the issue of scale in cross-sectoral approaches. During the conference, the results from the case studies will be presented and pathways for future improvement will be discussed.

Abstract number–128 Hydrological and physico-chemical drivers of benthic diatom community dynamics in agricultural stream ecosystems

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Understanding the factors influencing benthic diatom community dynamics in catchments is essential to ensure robust monitoring of stream ecological status, and in assessing how ecological status may evolve with climate change. It is critical as catchment management and monitoring programmes under the Water Framework Directive (WFD) have tended to focus on ‘improving’ ecological status often neglecting the equal importance of the ‘protection’ function of catchment assessment. This study examines hydrological and physico-chemical influences on key ecological functions of benthic diatom communities in Northern Ireland (NI) rivers where agriculture is the dominant land use. Diatoms, a key biological element in WFD assessment of ecological status, are highly sensitive indicators of water quality and have been shown for stream systems outside NI to respond within a 21-day period to nutrient fluctuations driven by agricultural runoff and discharge variability. We use discharge and physico-chemical data collected in three intensively monitored agricultural catchments (<10 km²) in the Upper Bann River system, which inflows to Lough Neagh, to establish physio-chemical and ecologically sensitive baselines that allow for the safeguarding of ecosystem resilience and protection-focused management. To minimise the influence of potentially confounding relationships between water quality, hydrology and weather factors, a high-resolution temporal sampling programme was conducted within each catchment to identify key drivers of benthic diatom communities, incorporating climate (seasonality, weather patterns), catchment characteristics (agricultural land use) and reach-scale variability in agricultural stream ecosystems. Over a three-years period, diatoms were sampled monthly at defined sites in each river by scraping the upper surface of five representative cobbles following standard protocols. Over the same period, stream water nutrient concentrations, water temperature and turbidity were measured on a sub-daily basis at outlet bankside monitoring stations. By analysing high-frequency hydro-physico-chemical data alongside diatom assemblages, we reveal how changes in stream water quality and nutrient pulses following discharge events influence the benthic diatom communities. Our findings demonstrate the importance of managing nutrient inputs in agricultural landscapes, not only to protect aquatic ecosystem integrity and benthic biodiversity, but also to support long-term water quality and ecological resilience in freshwater ecosystems.

Abstract number–129 Enhancing Water Quality in the Great Barrier Reef Catchments through Sustainable Agricultural Practices and Technological Innovation

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Water quality catchment issues within the Great Barrier Reef region are critically influenced by runoff from agricultural land, which is primarily dominated by sugarcane. This presentation examines the intersection of agriculture and catchment water quality in Queensland, Australia. With a specific focus on the innovative measures being developed and implemented by the Reef Catchments Science Partnership to mitigate adverse water quality impacts, particularly the use of pesticides.

A central feature of this partnership is the development of the pesticide decision support tool, designed to assist sugarcane growers in reducing pesticide application and maintaining productivity. By leveraging ground-breaking ecotoxicological research and tailored agronomic extension programs, this tool promotes more efficient pesticide use, thereby improving water quality outcomes.

Furthermore, this presentation underscores the significance of on-ground extension services and agronomic advice in delivering effective water quality programs. It also highlights the importance of a functioning conduit between academic research and agricultural industries to ensure successful knowledge transfer and practical application. These efforts are vital for fostering improved agricultural practices among landholders, ultimately contributing to better environmental stewardship.

Integrating a whole-of-system approach, this presentation emphasizes the dual focus on enhancing agricultural productivity while achieving positive environmental outcomes.

Through collaborative efforts and interdisciplinary insights, this presentation aims to demonstrate that sustainable agricultural practices can successfully coexist with the imperative to protect and preserve the Great Barrier Reef's delicate ecosystem.

Abstract number–130 Extreme weather effects on wetland nutrient retention and maintenance needs

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Since the 1990s, landowners in Sweden have been able to receive subsidies for wetland creation to mitigate nutrient losses from agricultural areas and to conserve biodiversity. Despite large investments in wetland creation, very little money has been set aside to follow up long-term performance. Furthermore, evaluations show that many constructed wetlands are not effective in retaining nutrients and thus not cost-efficient, due to sub-optimal siting and sizing. As wetland nutrient retention varies with annual fluctuations in nutrient loading and age, time-series measurements made over a wetland life-time is needed to allow

evaluations of nutrient retention performance, maintenance need and design recommendations.

A change in hydrological regime occurred in summer 2023, when June was extremely dry and was followed by flooding in late August. Extreme years such as 2023 and a changing climate have increased societal interest in wetlands for water-related ecosystem services including flood prevention, irrigation, providing drinking water for livestock and carbon storage. Increasing frequency of hydrological extremes will also likely affect wetland nutrient retention. How nitrogen and phosphorus retention are affected by these hydrological extremes that will increase in the future can only be answered by the only two Swedish constructed wetlands with intense water quality monitoring during 2023 and since construction (in 2010 and 2011). Besides flow-proportional water samples collected at the inlet and outlet, one of the wetlands has additional sampling between the initial deep area and the following shallow section with emergent vegetation, allowing for evaluation of wetland design.

Here, we present estimates of long-term nutrient retention under a changing climate, we evaluate maintenance needs and provide design recommendations that are resilient to increasingly frequent hydrological extremes. Furthermore, the tools and guidelines we have developed to optimise wetland siting and sizing to increase cost-efficiency can help wetland advisors, catchment officers and different levels of government to increase implementation of long-term sustainable wetlands in an increasingly uncertain future.

Abstract number–131 Loss of organic nitrogen from agricultural fields and catchments

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Worldwide, farming activities exert strong impacts on the amount and molecular composition of dissolved organic matter (DOM), which constitutes an important vector of organic nitrogen (ON) transport from soils to the aquatic environment (Graeber et al., 2015). In Denmark, stream data from the national monitoring programmed NOVANA shows that total ON today amounts to nearly 20 % of the annual N loading to Danish coastal waters. In a newly started research project 'orgANiC' we will investigate the loss and fate of ON forms in five smaller agricultural so-called LOOP catchments in Denmark (Petersen et al., 2021), in fields within

the national pesticide monitoring programme, and longer-term experimental plots at three Danish agricultural research stations. In our project we will measure dissolved ON (DON) and dissolved organic matter (DOM) in soil water, groundwater, tile drainage water, surface runoff and streams by means of utilizing both indirect (total N minus inorganic N) and direct analysis of DON (size exclusion chromatography: SEC). Moreover, we will characterize DOM composition utilizing SEC as well as fluorescence spectroscopy and conduct controlled laboratory experiments to unravel the bioavailability and fate of DON in freshwater (Graeber et al., 2018). The loss of particulate ON (PON) will also be monitored in tile drainage water, surface runoff and streams as these hydrological paths are believed to be of increasing importance with the observed increase in extreme weather conditions. In the presentation we will share our current insights into existing indirect DON measurements from the different hydrological pathways as well as our first direct measurements of DON and PON.

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Abstract number–132 Long-term evidence of nitrogen removal from four decades of wetland restoration in Denmark

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Wetland restoration plays a crucial role in mitigating nitrogen losses from agricultural fields (Hoffmann et al., 2020; Nilsson et al., 2023). Here we conducted a comprehensive study on nitrogen (N) removal in 35 Danish rewetted wetlands, each monitored for at least one year. Our aim was to develop general empirical models for yearly N-removal in rewetted wetlands. Using beta regression models, we characterized yearly nitrate (NO₃⁻) and total N (TN) removal efficiency (%). The model was found to perform best with N load as the only

explaining variable explaining 41% and 46% of the variance for TN and NO₃⁻, respectively. On average, yearly TN and NO₃⁻ removal amounted to 110 and 130 kg N ha⁻¹ year⁻¹, respectively. Despite confirming the effectiveness of rewetted wetlands in mitigating N, our results demonstrate that a decrease in N removal has appeared during the last three decades for wetland restoration projects in Denmark. This trend may be a result of lowered governmental N mitigation criteria for wetland restoration projects to increase the area of land eligible for N restoration schemes. Furthermore, we speculate that future wetland restoration projects emphasizing a more climate mitigation-oriented perspective, will further decrease the average N removal from Danish wetlands. This highlights the need for additional measures to address N losses from agriculture, as current efforts seem insufficient to meet the regulatory requirements of reaching good ecological status in most Danish coastal waters (Thodsen et al., 2023).

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Abstract number–134 Identifying the source of anthropic pressures on in-stream benthic algae communities

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Research and policy on riverine biodiversity decline often emphasise instream structures in terms of ecological status and hydromorphology, overlooking the importance of the broader role of catchment connectivity to the river network for biodiversity. Effective conservation and restoration of riverine ecosystems require addressing the hydrological, sediment and nutrient connectivity of stream networks to their catchments, with particular focus on vulnerable low-order streams which exhibit high sensitivity to land-use pressures and nutrient loading. These streams show pronounced responses to nutrient pollutants (Nitrogen and Phosphorus), which vary in impact depending on the catchment area's topography, connectivity, hydrology, and agricultural intensity. This nutrient export from catchments to the stream network can directly impact the composition and seasonal persistence of

phytobenthos (benthic diatoms) communities, a key biological indicator under the Water Framework Directive (WFD).

This study utilises the Sensitive Catchment Integrated Mapping Analysis Platform (SCIMAP) to evaluate the spatial risk of nutrient pollution across the River Eden catchment, NW England. SCIMAP makes detailed maps of the potential sources of nutrients, their physical mobilisation and their connectivity to the stream network. This analysis is undertaken within a reduced complexity framework to enable landscape-scale results with metre-scale detail. The analysis identifies specific pollutant source areas and their ecological impacts by assessing hydrological connectivity, land cover, and nutrient delivery within an uncertainty framework. It uses diatom communities and biomass (chlorophyll-a) as ecological indicators. Results indicate that effective management and mitigation strategies under the WFD should incorporate ecological data across spatial scales, allowing for targeted, evidence-based interventions. Critically, this study demonstrates that the most effective locations for management measures will differ for different pollutant or ecological endpoints. This result means that any action under the WFD Programme of Measures requires the integration of multiple lines of ecological evidence at the appropriate spatiotemporal scales. This approach offers a more transparent and accurate framework for assessing catchment risk and supporting ecosystem function-focused water management.

Abstract number–135 Examination of flow, sediment and phosphorus relationships using monitored storm event data from a multiscale research platform

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Elevated sediment and phosphorus delivery from agricultural landscapes via storm runoff is a global environmental issue that still requires quality data for its appropriate characterisation, assessment and management. A multiscale (6 ha to 47 km²) research platform with controlled plots under different land use (North Wyke Farm Platform) and nested catchments (Upper River Taw Observatory) have been intensively instrumented in Southwest England to monitor hydrological responses and nutrient emissions from a livestock grazing dominated landscape. Flow rates were continuously monitored at 15-minute intervals. Water samples from a selection of storm events were collected and analysed in the laboratory to determine sediment and phosphorus concentrations. Surface soil samples (top 10 cm) were also analysed to determine the soil P content. The synchronised flow rates, sediment concentrations and phosphorus concentrations were employed to estimate phosphorus concentrations in sediment, establish regression relationships and examine the sediment and phosphorus peak timing related to flows. Preliminary analysis has shown that land conversion from grassland to arable land can

change phosphorus concentrations in sediment significantly. The transition from transport-limited to detachment-limited processes were detected from small field catchments to the larger complex catchment downstream. The enrichment of phosphorus concentrations in sediment, relative to soil P content, was also observed. Event size negatively affects phosphorus contents and is a good predictor of event-based sediment loads. The monitored high temporal resolution data across hierarchical catchments could further improve our understanding about the dynamic nature of sediment and phosphorus relationships, contribute to model development and ultimately achieve better management outcomes in agricultural catchments which are under stress from extreme weather and land use change associated with changing climate.

Abstract number–136 Assessing groundwater nitrate reduction on a national scale in Denmark

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In Denmark, substantial amounts of nitrogen (N) originating from losses in intensive agriculture is leached to groundwater where a significant amount is being removed by denitrification processes. These natural processes occur in the anoxic nitrate reducing environment in groundwater. The extent and the N reduction rates of this anoxic nitrate reducing zone in groundwater have recently been intensively studied in Denmark and are the focus of our presentation.

In Denmark, successful one-size-fits-all national general nitrogen regulation has been implemented since the mid 1980's resulting in a trend reversal of nitrate in oxic Danish groundwater. A clear reduction response on nitrate concentrations in groundwater to the agricultural N regulation has been documented based on monitoring data. However, the environmental positive effect of regulation has been minor and insignificant after 2000. Furthermore, since 2016 focus has been on developing cost-efficient geographically targeted mitigation measures as a supplement to the national wide regulation to further decrease the reactive nitrogen losses to the aquatic environment.

Targeted N mitigation measures require detailed hydrogeological and geochemical knowledge about the redox conditions and the denitrification rates in the subsurface. This knowledge is crucial for modelling the nitrate transport from agricultural fields to streams and coastal areas with the Danish national N model. At a Danish national level, this presentation

will compare the evolution of nitrate in anoxic nitrate reducing groundwater to that in oxic groundwater. The geographical extent of anoxic nitrate reducing groundwater, and factors controlling the reduction of nitrate in the anoxic nitrate reducing zone will be addressed. A new approach for assessing the extent and the denitrification rates in the anoxic nitrate reducing groundwater will be presented. This approach relies on assessment of nitrate trends in oxic and anoxic nitrate reducing groundwater using monitoring wells with multilevel screens with more than 35 years of data on the nitrate evolution and ages of the groundwater dated with CFC or the $3\text{H}/3\text{He}$ method.

Abstract number–137 Nitrate in drinking water and health studies in Denmark

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In this presentation an overview will be given of the considerable number of studies on drinking water and health perform on Danish data during the last approximately 7 years related to agricultural losses of nitrate to groundwater. The interdisciplinary approach to examining the links between drinking water quality and health will be presented, and emphasis will be on presenting some of the most significant results such as the health effect of nitrate in drinking water.

Denmark stands out as an ideal country for performing epidemiological studies on the entire population on the link between drinking water quality and human health. This is due to the extensive tradition for collecting and storing 1) comprehensive individual health data linked to our personal identity number, and 2) drinking water chemical analyses in the public accessible geodatabase called Jupiter. In addition, possibilities for significant contrasts in the drinking water quality across the country make the epidemiological Danish studies even more relevant and interesting.

The geographical contrast in drinking water nitrate exposure originates from 1) the variation in nitrate leaching due to different farming practices and fertilization, 2) the varying geological and geochemical conditions in the groundwater aquifers supplying drinking water, for protection and national removal by denitrification, 3) a very decentralized drinking water supply structure with nowadays more than 2600 public water supplies and approximately 50.000 private wells, 4) normally only simple treatment of the drinking water with aeration and filtration at the water works, and 5) low consumption of bottled water.

These conditions are well-suited for addressing the chronic health effects of long-term low-dose exposures to chemicals in Danish drinking water, and new evidence has initiated a re-assessment of the drinking water standards for nitrate.

Abstract number–139 In-stream sand traps as a measure to reduce transport of phosphorus

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Despite huge reductions in phosphorus (P) losses from point sources over the last decades, most Danish lakes suffer from excess loading of external P. A recent national inventory indicated that two thirds of overall P losses originate from non-point sources. Several measures to mitigate non-point losses of P have been developed and documented including field scale measures (e.g. P mining and no-till cultivation) and edge of field measures (e.g. constructed wetlands and various types of buffer strips). However, in Denmark, the most quantitatively important source of non-point P loss is erosion of stream banks. Consequently, in-stream mitigation measures are needed. Already today, hundreds of sand traps are installed in Danish streams to improve ecological conditions since high levels of sediment smother the stream bed, reducing the habitat of aquatic plants, fish and insects that live in these waterways. To investigate the possible effect of sand traps on in-stream P transport, we carried out a survey of all municipalities in Denmark, with 76 out of 98 municipalities responding. We found that the average size of a sand trap is approx. 75 m² (range: < 50 m² to > 2000 m²) and that sand traps are emptied on average 1.2 times a year, removing app. 52 m³ of sediment per year, however with statistically significant regional differences. We further sampled 24 sand traps and found an average dry bulk density of 1.41 kg l⁻¹ and a P content of 221 mg total-P kg⁻¹ of the sediment. Taking the 76 municipalities as representative of the whole country, it can be calculated that a total of about 97000 m³ of sediment and 30 tons of P is removed annually from Danish watercourses by means of sand traps. We describe sand traps as a P mitigation measure including regionalized effect (kg P removed per m² sand trap) and cost-effectiveness.

Abstract number–140 Novel high resolution monitoring program iFOODis of surface waters in relation agricultural activities and environmental factors in Northern Germany (Baltic Sea)

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To contribute to the improvement of sustainable food production the ongoing 5-year research program iFOODis funded by the German Helmholtz Society aims to establish a monitoring network for the continuous assessment of ecosystem health on land and surface

waters in relation to agricultural activities. The synoptic observation of food crop state, agricultural activity and environmental parameters in the atmosphere, on land and in surface waters shall enable the development of management options based on a scientifically sound data base.

The Schlei region was selected as investigation area. The Schlei fjord itself represents a brackish almost landlocked water body with a surface area of 52 sq km and length of ca. 43 km (SW Baltic Sea region). Its catchment area, a hilly countryside with altitudes of max. 30 m, of about 667 sq km was formed by glacio-fluvial erosion processes. In the 1960s and 70s land consolidation and intensification in agriculture changed the landform and -use. Due to the discharge of municipal waste waters as well as inputs of nutrients from agriculture the Schlei is hypertrophic and represents the most eutrophied German Baltic water body. Its ecological status has been classified as bad within the evaluation scheme of the EU Water Framework Directive.

The measurement-network will be established in 2024/25 including 14 automated suction cup and soil hydrology sites on agricultural fields within the Försing river catchment, which drains about 55 % of the entire Schlei Region, 3 in-situ water quality measurement stations in the Försing River and 2 water quality stations in the Schlei itself. It is primarily focusing on the local hydrological cycle, soil moisture, soil erosion, nutrient leaching, the efficient management of carbon, phosphorus and nitrogen flows in agricultural ecosystems and export into the coastal zone.

This presentation will highlight technical details of the measurement network and give insights into biogeochemical processes and first results. The network will be set in operation in spring 2025, jointly facilitated by the German research institutions, GEOMAR (Kiel), University of Kiel, AWI (Bremerhaven) and the German Aerospace Center (DLR) involving strong relationships to farmers, environmental authorities and non-governmental organizations.

Abstract number–141 Leaky dams as a mitigation option for nutrient losses via agricultural drainage ditches

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Agricultural open drainage ditches are a common feature of Irish agriculture which transport excess water discharges, particularly on land with heavy soils, to quickly alleviate flooding and enhance land productivity. These drainage ditches are typically located at field boundaries and form a 'network' of ditches connected to a nearby outlet or stream. Thus, there is a high risk of agriculturally-sourced pollutants such as phosphorus (P) and nitrogen (N) entering freshwater systems via these connected ditch networks. This risk is greatest

where there is a direct connection between a farmyard and a ditch, which then connects downstream directly into a river.

This study is investigating leaky dams in open drainage ditches as a mitigation measure to attenuate agricultural pollutants. Two farms in a Priority Area for Action (PAA) with farmyards directly connected to a ditch network were selected for case-study in the Agricultural Catchments Programme (ACP) Ballycanew catchment, Wexford (South-East Ireland). The dams were constructed as a “H-Section” from planks of rough timber with a V-notch weir cut into the cross-beam, screwed into pointed posts to stabilise, and were installed in two ditches (one on each farm) in January 2024. Grab water samples are collected weekly upstream and downstream of a series of three leaky dams per ditch for analysis of total phosphorus (P) (TP), total dissolved P (TDP), soluble reactive P (SRP) particulate P (PP), nitrate-N, and ammonium-N.

The SHETRAN hydrological model is used to calculate flows in the ditch network using an hourly time step and meteorological data from the ACP weather station in Ballycanew. The instantaneous nutrient loads of N and P are calculated by extracting the modelled flows at the location nearest to the sampling point in the model's domain. The total loads over the monitoring period are then calculated using a simple load estimation method used for discrete samples. These are converted into loads per unit area using the estimated areas upstream of the monitoring points. Flow-weighted mean concentrations are also calculated using the modelled flows. Analysis is ongoing, with one wet (winter – spring 2024) season of data collected to date. It is envisaged that data gathered over the next time period will provide valuable insight into the efficacy of leaky dams as a cost, time and resource-efficient option for mitigating agricultural nutrient pollution from drainage ditches by reducing nutrient loads discharged into receiving watercourses.

Abstract number–142 Assessment of the relationship between farm structure, farm management, and environmental quality on Dutch dairy and arable farms, and their impact on the nitrogen soil surplus

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Within the Dutch Minerals Policy Monitoring Programme, nitrogen soil surplus is one of the main indicators. The nitrogen soil surplus indicates the amount of nitrogen surplus in the soil, expressed in kilograms of nitrogen per hectare. The nitrogen soil surplus is calculated as the surplus at farm level (sum of all input minus the sum of all output including stock changes) plus the input of nitrogen via deposition, net mineralisation and fixation minus the loss of nitrogen via emission during application (organic manure and fertiliser), resulting from grazing, and stabling and storage. A high nitrogen soil surplus is harmful to the environment

as it can cause, among other effects, eutrophication and acidification. Hence, it is important to know what the course of the nitrogen soil surplus is, and to know the relationship between nitrogen soil surplus and its explanatory factors. We are currently conducting a study on that examines the influence of mineral management on the surplus of nitrogen in the soil on dairy and arable farms. This study will take an integrated look at the relationship between farm structure, farm management, and environmental quality on dairy and arable farms. This study relates to observations from Dutch dairy and arable farms contained in the Minerals Policy Monitoring Programme for the years 1991-2023. Since not all farms appear in the dataset for all the years concerned, this study has an unbalanced panel data structure. Random Effects models and Fixed Effects models are used. The outcomes of the regressions will quantify the influence of farm structure and farm management. The outcomes of the study will help dairy and arable farmers, policymakers and researchers in how mineral use can best be modified to achieve better results, both from economic and environmental point of view.

Abstract number–144 Water quality improvements for the Great Barrier Reef catchments: Can we achieve change through Carrots and Sticks, or do we also need Golden Nuggets?

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Like many receiving waters worldwide, the Great Barrier Reef (GBR) lagoon faces multiple stressors, including climate change, extreme weather events, direct and indirect use, and degraded water quality. Nutrients, sediment and pesticides have been identified as key stressors that can negatively impact the overall health and resilience of the GBR ecosystems. Since 2003, the Australian and Queensland governments have been addressing the decline in water quality through several iterations of The Reef 2050 Water Quality Improvement Plan (Reef Plan), employing both incentives (carrots) and regulations (sticks) to drive change.

The Great Barrier Reef Catchment Loads Monitoring Program (GBRCLMP) has operated since 2005 and tracks water quality across the GBR catchment area. Nutrient, sediment, and pesticide risk data from the GBRCLMP inform the 5-yearly Reef Scientific Consensus Statement and underpin the setting of water quality targets in the Reef Plan. These data also inform the funding prioritisation that supports management practice changes (carrots) and regulations (sticks). The long-term and dense water quality dataset produced by the GBRCLMP also supports the tracking and reporting of progress toward the pollution reduction targets. Therefore, The GBRCLMP is uniquely positioned to inform policy and assess the success (or otherwise) of the carrot-and-stick approach.

Over its 19 years of operation, GBRCLMP data have been used directly in education

programs to encourage best practices and to determine if changes in land management practices are having measurable effects. The GBRCLMP works directly with landholders, traditional owners, extension officers, catchment management groups, and researchers, using a 'bottom-up' approach that allows for data-driven catchment improvements. An international review of the GBRCLMP highlighted its ability to generate real water quality improvements through dynamic engagement and the translation of science into action. The GBRCLMP has, therefore, illustrated a third, effective approach in the fight to improve water quality, affectionately termed 'golden nuggets' of information that can drive meaningful change.

This presentation will display long-term monitoring data demonstrating both water quality improvements and the lack thereof. It will discuss the achievements and limitations of the Reef Plan, highlighting where GBRCLMP datasets have influenced policy and legislation (sticks), informed the subsidising of management practice changes (carrots), and driven the more successful 'bottom-up' approach of data-driven agronomic and scientific extension (golden nuggets). It will discuss elements of the GBRCLMP that make it a success story and highlight the adaptability of this approach to environmental assessment frameworks globally.

Abstract number–145 Are woodchip denitrifying bioreactors a viable edge-of-field N-mitigation strategy for New Zealand farming?: Insights from field-trials and comparisons with constructed wetlands

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Woodchip denitrifying bioreactors (WDBs) are promulgated in the international scientific literature as an established edge-of-field mitigation practice, to reduce nitrogen (N) loads in farm drainage water. Interest in WDBs in New Zealand (NZ) piqued in 2014 when reforms in freshwater resource management introduced nutrient limits. Accordingly, WDB field-trials were conducted in NZ to assess their viability - both practically and economically. We summarise the findings from trials made of a woodchip denitrification wall and two woodchip denitrification beds (one configured within an open drain and one fitted to a tile drain). In addition to N-removal, co-benefits such as phosphorus and pathogen-removal, and greenhouse gas emission as a pollution-swapping phenomenon, were examined. The cost-effectiveness of N-removal achieved with WDBs was compared with costs of constructed wetlands.

The long-term cost-effectiveness of different N-mitigation practices ranked in order were:

wetlands (~€18 kg/N-removed) < woodchip denitrification beds (>€21 kg/N-removed) < woodchip denitrification walls (~€69 kg/N-removed). Between 13 and 26% of the cost is from regulatory compliance (consent application, monitoring and reporting). Increasing market demands for woodchip as biofuel (a decarbonization strategy of the heating industry) and for calf-bedding are driving up the costs of constructing WDBs, making them a less economically attractive/viable on-farm solution. Given the cost of edge-of-field N-mitigation devices like WDBs, and spatial scale and magnitude of proposed N reductions, we consider they are unlikely to provide a scalable solution for making cost-effective N-reductions in NZ catchments of the magnitude currently sought by regulatory authorities.

Abstract number–148 Deficiencies and action perspectives for WFD objective achievement in the Netherlands

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It is unlikely that the Netherlands will meet all the Water Framework (WFD) objectives by the end of 2027. Study shows that agriculture is a main source of pollution and the current instruments that are used to tackle this pollution are mostly of a non-binding nature (Wuijts, S., Van Rijswijk, H. F., Driessen, P. P., & Runhaar, H. A. (2023). Moving forward to achieve the ambitions of the European Water Framework Directive: Lessons learned from the Netherlands. *Journal of Environmental Management*, 333, Article 117424). To reach the WFD objectives member states are required to develop programs of measures (POMs). These programs must entail the basic measures as mentioned in article 11 (3) WFD and, if necessary, supplementary measures as referred to in article 11 (4) WFD. In the Netherlands, the responsibility of achieving the WFD objectives is a shared responsibility between several authorities. The POMs are formally adopted by the Minister of Infrastructure and Water Management. However, the actual drawing up and implementation of the POMs for the regional waterbodies is largely carried out by the regional water authorities. This study focuses on the question whether the regional water authorities have implemented the necessary and most effective measures in the POMs. The study researches what is working well, where risks exist and, which solutions are available. Desk study research has been conducted regarding regional waters in two different regions – part of the Meuse river basin and part of the Rhine river basin - in the Netherlands, that differ in terms of water issues, covering in total 10 different regional water authorities. Furthermore, semi-structured

interviews have been conducted with officials of the regional water authorities. The research shows that most of the regional water authorities focus mainly on the implementation of measures related to altering the hydromorphology, rather than the obligatory basic measures of article 11 (3) WFD, as well as the obligation to review authorizations and permits (article 11 (5) WFD). In general, the use of legal instruments available to the regional water authorities, such as (non-binding) advisory rights, updating permits for discharge activities, regulating activities that have implications for the WFD objectives, or the use of expropriation measures, are not yet fully utilized. Where voluntary measures are part of the POMs, especially in relation to agriculture, there is no to little insight in the effectiveness of those measures, making it unclear to what extent these measures contribute to reaching the WFD objectives. During the conference, the results of the research will be presented and action perspectives will be discussed.

Abstract number–149 Monitoring nitrate leaching under vegetable crops in the Netherlands

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At Dutch farms the nitrate concentration of water leaching from the root zone regularly exceeds the standard of 50 mg/l of the Nitrates Directive (91/676/EC). This is being monitored in the Dutch Minerals Policy Monitoring Programme (MPMP). This network is representative for the major agricultural land use (i.e. dairy farms, arable farms and other livestock farms) of four prevailing soil regions (Sand, Clay, Peat and Loess). However, farm types with a small share of total land use, such as vegetable farms (1-5%, depending on the definition of a vegetable crop), are not specifically monitored in MPMP. Previous studies show that nitrate leaching under vegetable crops such as spinach, cabbage, lettuce etc. in temperate climates can be substantial, because of 1) harvest during vegetative growth period, 2) shallow rooting of certain crops, 3) nitrogen rich crop residues and 4) inability to sow a catch crop due to late harvest.

In order to monitor nitrate leaching under vegetable crops, we started a 3-year pilot in two soil regions (Sand and Clay), with 10 farms in each soil region and six vegetable crop parcels on each farm on average. We selected arable farms from the MPMP with vegetable crops in their rotation, if possible. Of the ten farms in the Sand region, seven are arable farms and three are specialised in vegetables. In the Clay region, the monitored farms are all specialised in growing vegetables. To gain insights into the effects of vegetable crops in a crop rotation for the Sand region, the upper metre groundwater was sampled one time during vegetable crop growth, and two consequent years after vegetable crop growth. As all parcels in the Clay region have tile drainage, 3 rounds of up to 8 tile drain water grab samples were taken in fall/winter of parcels where a vegetable crop was grown in the

previous growing season.

Results of the first monitoring year (2023/2024) show that nitrate concentrations under vegetable crops in the Sand region are, on average, double compared to arable crops represented in the MPMP (170 versus 81 mg/l NO₃). Nitrate concentrations in tile drain water in the Clay region are also higher for vegetable crops compared to arable crops (35 mg/l versus 23 mg/l). Data from the next monitoring years will be used to further increase the understanding of the effects of weather variability and crop rotation.

Abstract number–150 Setting safe ecological boundaries for nutrients for rivers and lakes in the Nordic and Central-Baltic regions

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The current nutrient boundaries for nitrogen and phosphorus used by European countries vary by one to two orders of magnitude across different EU countries for similar river and lake types. In many cases, total phosphorus boundaries exceed 100 µg P/L, raising concerns about whether these limits can support good ecological status for freshwater ecosystems. The main aim of the NordBalt Ecosafe project is to harmonize nutrient boundaries to be compatible with good status for sensitive biota within common types of rivers and lakes in the Nordic region and in the Central-Baltic region, and to explore whether the boundaries should be adjusted due to climate impacts on the nutrients and on the biology. To achieve this, we compiled monitoring data on normalized EQR (nEQR) values for biological quality elements (phytoplankton, macrophytes, benthic invertebrates and phytobenthos) and nutrient concentrations (total phosphorus and nitrogen) from a large set of rivers and lakes. Using a novel statistical technique based on logistic regression, we estimated “safe” nutrient boundaries that give a high likelihood of good status for the biology (=nEQR > 0.6) within various water types. The results showed that the estimated nutrient boundaries were mostly in line with the current boundaries for Norway and Sweden but were stricter (lower) than the existing Finnish boundaries for total phosphorus. Among the Central-Baltic countries, the estimated boundaries were considerably stricter than the current boundaries for high alkalinity, large lowland rivers in Poland. Overall, the estimated (and current) boundaries for the Nordic region were generally more stringent than those in the Central-Baltic region. Additionally, the estimated boundaries were consistently lower for lakes than rivers for most types in both regions. Climate change is expected to affect nutrient inputs to aquatic systems, as well as affecting biology through increased temperature and changes in hydrology. Using climate data for each water body, we explored how total phosphorus concentrations and nEQR values were related to temperature and precipitation, and assessed if and how nutrient standards might need to be adjusted to ensure safe ecological boundaries in a future with changing climate. Preliminary results indicate that

increasing temperature and precipitation can negatively affect ecological status for phytoplankton in lakes. However, the climate impacts are small compared to the nutrient impacts on ecological status.

Abstract number—152 Farmers measuring their own on-farm water quality: experiences and outcomes

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The quality of both surface water and shallow groundwater in the Netherlands does not meet the standards of the EU Water Framework Directive and the Nitrates Directive on many locations. Concentrations of nutrients have declined in the last thirty years, but have stabilized in the last decennium. Recent dry years tend to increase the concentration of nutrients.

Policy makers are looking for strategies to decrease the emission of nutrients to surface water and groundwater. One possible strategy is to give the farmers the opportunity to measure the water quality on their own farm. This increases farmers' knowledge on the relationship between agricultural practice and emissions of nutrients. Potentially this will lead to more efficient practice on farms and thus resulting in both better water quality and (as fertilizer is costly), a better financial result. Taking this idea further, it might be possible to give farmers water quality objectives to achieve, instead of manure application standards. This object orientated approach is seriously examined in the Netherlands for future policy development. Central in this idea is that farmers measure their own water quality.

To examine the potential of water quality measured by farmers themselves, RIVM started a pilot project in which two groups of farmers were involved. All farmers are participants of the Dutch Minerals Policy Monitoring Programme in which the water quality on farmlands is already monitored at a national scale. The two groups contributed to the monitoring plan through interviews and workshops. The resulting monitoring plan was a coproduction of the farmers, citizen science experts and water researchers.

The first group has farms in the lower (wetter) parts of the Netherlands with clay and peat soils. These soils are drained with ditches and therefore monitoring of ditchwater can be performed quite easily with a toolkit for nitrate and phosphate. They monitored surface water once every month at four locations.

The second group has farms in the higher (drier) sandy region. This area is not drained by ditches and nitrate is leaching to groundwater. On these farms, two monitoring wells were installed and farmers measured nitrate concentration in the wells once every month.

We found out that the possibilities for the farmers for measuring the water quality at their farms are limited. Field tests are less accurate than laboratory measurements and the variety of parameters that can be measured is higher in the laboratory. On the other hand, the water quality measurements and the discussions between farmers and researchers lead

to a better understanding of the water quality problem and insights into the natural variations of the soil-water system. Also, it leads to a better understanding of farming processes by the researchers. The measurements by farmers cannot replace the common monitoring of water quality but the additional value is high

Abstract number–153 Satellite imaging insights on autumn cover, catch crop establishment, and nitrogen load in Danish catchments

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Since 2008 farmers have been asked to establish mandatory catch crops on app. 11 and 15 pct. of the potential area without crop cover in the autumn. Catch crops are established in the autumn to take up excess nitrogen from the soil, preventing nitrate from leaching out of the root zone in the period with percolation and ending up in coastal waters, ground water, streams etc.

In February 2016, the Danish parliament adopted the Food and Agricultural Agreement (FAA) in which farmers were allowed to increase their fertilization levels. This meant a risk of increasing the nitrogen load to streams and coastal areas. To counteract this anticipated increase in the nitrogen loads, farmers were asked to adopt catch crops that were targeted to catchments having too high nitrogen loads. The implementation of targeted catch crops is an important mitigation measure to reach good ecological status in Danish coastal waters.

In 2024, targeted catch crops were planned to reduce the total nitrogen load to Danish coastal waters by 3,500-ton nitrogen, equal to around 350,000 hectares of cover crops. However, limited research has examined whether the regulatory requirements for more catch crops have resulted in the expected cut in the nitrogen load. Therefore, the purpose of this study is to investigate the relationship between nitrogen losses to streams and the coverage and growth of catch crops in six small agricultural headwater catchments monitored by the Danish Agricultural Monitoring Program (LOOP). Using high-resolution satellite data (Sentinel-2 and PlanetScope) together with detailed field operation data from the LOOP areas, including crop types, catch crop types, and dates of tillage, sowing and harvesting, this study aims to determine (i) whether there is a correlation between catch crop coverage, growth and the measured nitrogen load to the streams and (ii) whether soil type and climate affect this correlation.

Abstract number–154 Field-level nitrogen leaching and crop yield under extreme climate events

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Despite multiple action plans, further reductions in nitrogen runoff from agriculture into water bodies are still needed in Denmark to meet the Water Framework Directive's quality goals. Hydrological processes strongly impact nitrate dynamics in soil, positioning climate as a critical influencing factor. Extreme events, such as droughts that lead to low nitrogen uptake by crops, and intense precipitation that accelerates runoff and percolation, impact both crop yields and nitrogen leaching. High nitrate levels are often registered during or after drought periods, as nitrogen accumulates in the soil when crops experience reduced biomass growth and then leaches following heavy rainfall. As climate change is expected to increase the frequency and intensity of these events, understanding their impact on nitrate leaching is essential.

Since 1989, Denmark's National Monitoring Program for Water and Nature has tracked daily nitrate measurements from soil water, sampled weekly, from 32 fields with common farming practices in five catchment areas across Denmark. This dataset combines measured nitrate concentrations with detailed information on field activities, crop types, climate conditions, and soil characteristics, enabling an in-depth examination of nitrate dynamics over time across various environmental and agricultural management conditions.

This study aims to explore the impact of extreme weather events on nitrogen leaching and crop yield through spatiotemporal exploratory analysis and its potential interaction with agricultural management practices. Indicators for extreme wet and dry periods will be defined to support multidimensional visual analyses to describe temporal dynamics and interactions among key variables during these periods. Finally, time-varying models will be fitted to reveal shifts in nitrate leaching patterns responsive to extreme climatic conditions.

Our understanding of how extreme weather events might increase nitrogen loading to water bodies remains limited. Intensifying extreme weather could further raise the demand for mitigation measures to reduce nitrogen loads to coastal waters, as the effects of these events on nitrate leaching from agriculture are still not fully understood.

Abstract number–155 Model simulations for climate-robust manure spreading and sowing of catch crops

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Simulations with the Nutrient Emission Model in Flanders (NEMO-model) were used to investigate the impact of (extreme) weather conditions on soil N processes (crop uptake, mineralisation, leaching) and to explore how the timing of cropping activities such as spreading manure or sowing catch crops can be adapted to this. For this purpose, an adapted version of the NEMO-model was created allowing field-scale simulations. This model was then used to simulate 12.000 scenarios with varying main and catch crops, soil types, sowing dates, manure application dates and weather conditions. The results show:

- an important effect of the sowing date of the catch crop on its N uptake in autumn (as expected);
- an important effect of the sowing date of white mustard on nitrate leaching in autumn; this effect is less pronounced for Italian ryegrass;
- an important interaction effect of the sowing/planting date of the main crop (maize or potatoes) with the effect of the catch crop on nitrate leaching in autumn; with a late start of the main crop, the catch crop (Italian ryegrass) should be sown later so as not to jeopardise the N uptake by the main crop;
- significant amounts of nitrate leaching in the spring in some years, mainly depending on weather conditions and soil type; the influence of the manure spreading date seemed less important;
- in some years also significant nitrate leaching in summer, mainly depending on weather conditions and soil, but also on the sowing or planting date of the main crop (maize or potatoes): the later the main crop can start, the more leaching.

The results of the scenario calculations also allowed to determine a theoretical Best Practice for each combination of main crop, year and soil type, consisting of a combination of the optimal times for spreading manure and sowing (main and catch) crops and taking into account both environmental (nitrate leaching, soil compaction) and economic (potential yield loss) effects. This analysis showed that the optimal times for sowing and manuring can vary greatly, depending on the weather conditions and the soil type on the one hand and on the importance attached to the various assessment criteria (emissions to the environment, soil quality, economic return) on the other hand. Throughout the process, the uncertainty of the model and weather data was investigated and key bottlenecks for the translation of this research into a general tool for policy makers and farmers were identified.

Abstract number–156 The challenges with reconciling field-based measurements into balanced sediment budgets on a national scale

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To minimise the unintended impacts of agriculture on surface waters it is necessary to quantify inputs of sediment and associated nutrients from different catchment sources. The UK has an extensive history of investigations into sediment sources, soil erosion rates, connectivity and sediment yields. However, these have, to-date, been poorly reconciled with each other to assess the consistency between measurements and form a generalised sediment budget to guide catchment management.

A review of published soil erosion rates and catchment sediment yields suggests that they are typically comparable. However, measurements of connectivity suggest that most eroded topsoil is stored within the catchment rather than transported to a watercourse. These findings are challenging to reconcile given that most early sediment source tracing work suggested that inputs from agricultural topsoils typically dominate the sediment load of most rivers. The limited measurements of channel bank erosion rates available suggest that they are high in relation to catchment sediment yield and could plausibly reconcile the other measurements, on the assumption that previous sediment source tracing data is largely inaccurate or that sediment sources have changed due to targeted management. However, high uncertainties remain with this reconciliation given the highly limited measurements of catchment connectivity and channel bank erosion available.

Against the above background, lake sediments can be used to reconstruct historical changes in sediment delivery to watercourses. Existing reconstructions show some significant increases in sediment yield after agricultural intensification in the 1950s. However, such increases are not found in many lakes. At present, lake investigations are mostly limited to upland areas with few studies focused upon lowland agricultural catchments where intensification has been most concentrated. Accordingly, ongoing strategic research is carrying out a national survey of lake sediments to improve existing quantification of background pre-intensification sediment yields as well as to identify the extent to which intensification has increased them allowing for further reconciliation of national sediment budgets.

Abstract number–157 Flexible timing of agricultural practices depending on weather conditions

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This study aimed to estimate the optimal timing of manure spreading and catch crop sowing depending on weather conditions, to enable adaptable agricultural practices with minimal environmental impact under changing weather conditions. To do so, establishing relationships between weather conditions and key sustainability indicators regarding nitrogen losses, soil compaction and yield is essential. The key sustainability indicators considered are nitrogen uptake by catch crops, residual nitrate in the soil, nitrate leaching, soil moisture content (to estimate soil compaction risks) and potential yield loss.

First, an extensive field trial dataset was used to calibrate the Flemish Nutrient Emission Model (NEMO) for surface water on parcel scale. Second, a large number of scenarios was simulated by this model, with a wide range of sowing dates and dates of manure application for different combinations of main crop, catch crop and soil, using weather data from 2004 to 2023 as inputs. These simulations resulted in a dataset with a large variety in the sustainability indicators as well as in a series of weather indicators (precipitation deficit, cumulative temperature and SPI index over different time periods). Finally, the relationships between the calculated sustainability indicators and the weather indicators were established for each combination of main and catch crop, soil type and sowing or manuring date by stepwise regression analysis.

Among others, the results show that weather conditions around the sowing date of catch crops are very important for their nitrogen uptake. Further, nitrogen uptake of the catch crops generally declines with delayed sowing, but the rate of this decline varies significantly between catch crop types as well as between years, depending on actual weather conditions. Another result is that the calculated soil moisture content, used as an indicator for estimating the risk of soil compaction during manure spreading, showed greater variability across years (due to weather fluctuations) than across different manuring dates within the same year. More results of other sustainability indicators will be presented on the conference.

With the established relationships between the investigated sustainability indicators and weather conditions, this study aimed to form a base for a decision-support tool helping farmers to determine optimal timings for catch crop sowing and manure spreading in order to minimize environmental impacts. However, despite the clear trends, the model uncertainty is still an issue and more simulations are required to incorporate additional factors.

Abstract number–158 A Machine Learning approach for modeling Nitrate Leaching from Agricultural Land in Denmark

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Nitrate leaching from agriculture land can lead to degradation of aquatic and terrestrial ecosystems, and has immense negative impact for human, biodiversity and nature. It also causes farmer extra expense due to the nitrogen nutrient loss. To identify efficient mitigation strategies and methods for nitrate leaching, we need an efficient model tool to precisely estimate the nitrate leaching. However, nitrate leaching involves complex biogeochemical processes, posing big challenges in modeling, as not all involved processes are fully understood. Here a Machine Learning (ML) approach is useful to give better knowledge and predictions. ML models are data driven, enabling us to build models for detailed and complex nitrate leaching processes.

In this presentation we conduct a comparative study of six ML models, to identify the best model for predicting annual nitrate leaching based on information as nitrogen fertilizer and manure application, biological nitrogen fixation, crop and crop rotation, soil type and drainage under Danish climate conditions.

Extra-trees model and multiple linear regression model are identified as the best models among the six models. The extra-trees model has achieved the best prediction accuracy with a coefficient of determination (R^2) 0.63 and a Root Mean Squared Error (RMSE) 23.3 kg N ha⁻¹. The multiple linear regression model has achieved the second-best prediction accuracy with a coefficient of determination (R^2) 0.48 and a Root Mean Squared Error (RMSE) 27.6 kg N ha⁻¹. Both models have achieved a much better prediction accuracy than the existing NLES5 model. It is concluded that both models can be used to provide estimates for annual nitrate leaching for the most important agricultural crops and N applications under Danish farming condition.

Abstract number–159 Pesticides in Dutch sources for drinking water supply

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For decades, pesticides are widely considered as a major threat for the quality of groundwater and surface water sources of drinking water. We present the results of a comprehensive inventory of observed pesticides and metabolites throughout the sources of drinking water in the Netherlands (2018-2022). For surface water we distinguish between observations in intake water and pre-treated dune filtrate, which are two major sources for drinking water production. For groundwater, we distinguish between observations in observation wells, individual abstraction wells and the abstracted groundwater as a whole. We also present the Removal Requirement Index to monitor the level of required purification treatment.

According to the data, pesticides have been observed at all intake points of surface water and temporarily exceed the quality standards at more than half of the intake points. The Removal Requirement Index shows how the mixture of pesticides develops over time and indicates a gradual improvement of surface water quality over the period 2015-2022. High temporal variability makes conclusions on trends highly uncertain, however.

Regarding groundwater, the data confirm the diffuse presence of a number of pesticides and metabolites in phreatic, limestone and confined aquifers. The number and identity of observed pesticides differ between observation wells, abstraction wells and mixed water, however. The data suggest an increasing number of polluted well fields compared to a comparable inventory for the period 2010-2014. We speculate on the consequences for early warning monitoring and how to protect drinking water sources more effectively.

Abstract number–160 Assessing nutrient hotspots in Denmark’s agricultural fields: A focus on the livestock sector

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Livestock production is a major contributor to reactive nitrogen (N) and phosphorus (P) losses which, without effective management and mitigation, result in nutrient pollution with serious environmental impacts. Livestock manure is particularly rich in these nutrients and excessive application can cause eutrophication of water bodies and impair soil health. Accurate spatial analysis of N and P distribution across agricultural fields is essential to identify areas at higher risk of pollution and to implement targeted mitigation strategies. However, high-resolution data on livestock nutrient loads are often limited, making it difficult to carry out detailed field-scale assessments. This study addresses this challenge by applying spatial autocorrelation analysis to identify pollution risk areas at the highest possible spatial resolution. Focusing on Danish agricultural fields, we assessed the nitrogen load contributed to each plot by the livestock sector. Two geospatial statistical methods, HotSpot analysis (Getis-Ord G_i^*) and Cluster and Outlier analysis (Anselin Local Moran's I), were used to reveal areas of nutrient accumulation and to identify spatial patterns of pollution risk. The HotSpot analysis was effective in highlighting priority areas requiring immediate attention for nutrient reduction, thus assisting decision makers in pollution mitigation. Subsequently, the Cluster and Outlier analysis allowed us to identify areas where nutrient loads were similarly concentrated, creating clusters of high or low values. The results provide a valuable geospatial tool for policy makers and environmental managers, offering a detailed understanding of spatial nutrient dynamics at the field level. This

approach, which combines high-resolution spatial data with advanced geospatial analysis, supports more sophisticated implementation of environmental measures aimed at minimising nutrient losses from the livestock sector and promoting sustainable agricultural practices.

Abstract number–161 A new approach for identifying catchment phosphorus impact risks and quantifying the underlying processes

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Acknowledging the biophysical and anthropogenic complexity of diffuse phosphorus (P) pollution, catchment management would benefit from a standardized, systematic and objective method to evaluate P transfer and impact risks at the catchment scale. For that reason, P transfer indices (Mobilisation index and Delivery index) were recently introduced. The method uses ratios of high and low percentiles of P concentrations and mass loads. Using a large dataset of high-frequency hydro-chemo-metric data from 23 catchments in North-western Europe, we present a pooled catchment approach to establish a relationship between the Mobilisation and Delivery indices with the catchments' baseflow and flashiness indices. While hydrology largely controls P transfer, the deviation from this hydrological relationship highlighted the presence of other influences, such as intrinsic P retention, and point source or legacy P controls. The method distinguishes the type of dominating mobilisation and delivery risk (runoff, point source and/or legacy P) and of intrinsic retention (poor solubility and/or poor hydrological connectivity). The P mobilisation of 12 catchments was dominated by hydrological controls. Five of the catchments, with large flat areas, high storage capacity and/or with a high P sorption capacity, had a potential to retain 39% - 68% of reactive P (RP) corresponding to an annual retention of 0.02 - 0.32 kgRP/ha. The relatively highest intrinsic P retention was in a karstic limestone spring contribution zone rich in calcium. Six of the catchments manifested point source influences to a varying degree, which elevated the RP mobilisation by 16% -77% and corresponded to an equivalent of 0.02 – 0.12 kgRP/ha per year. While hydrological controls dominated P delivery in all catchments,

two catchments manifested 72% - 76% reduced delivery due to poor hydrological connectivity (0.02 – 0.13 kgRP/ha). Finally, eight catchments had a higher Delivery index in relation to the Mobilisation index, and these catchments were those with above average hydrological flashiness. We propose that these catchments are, to a varying degree, influenced by legacy P (river scouring and/or resuspension). This also highlights that mobilisation risk could be independent from delivery risk owing to landscape hydrological connectivity.

The proposed approach can guide pollution management by identifying and quantifying the underlying dominant P impact risks of a catchment. The approach can further be useful to identify catchment typologies based on P risk classes for upscaling and for understanding the stresses imposed by climate and land use changes.

Abstract number–162 Effects of different drainage systems on subsurface runoff and nitrogen leaching

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Most of agriculturally used soils in Norway are drained to enhance trafficability and crop growth conditions. An increase in precipitation, especially in winter and spring, as predicted by climate model simulations may require improved drainage systems. While improved drainage can be beneficial for crop growth and thereby for N uptake, it can also increase the risk for nitrogen leaching. To test the drain performance and concomitant nitrogen leaching of different drainage systems, a monitoring field site with three different systems was established in 2019. In the field, an area of about 1280 m² is drained by four drainpipes at intervals of 8 m in a depth of about 80 cm. This drainage system is widely established in Norway and, therefore, here called ‘traditional system’. The second system (here called ‘torpedo system’) consists of six traditional drainpipes supplemented by mole channels at intervals of 4 m in about 50 cm depth perpendicular to the drainpipes draining an area of 1920 m². The third system (here called ‘slit system’) consists of traditional drainpipes supplemented by gravel-filled channels at 4 m intervals between the plough layer and 50 cm depth perpendicular to the drainpipes, also draining an area of 1920 m². Discharge was measured separately for all 16 drainpipes by tipping-buckets from spring until the frost periods each year, from 2019 to today. Monitoring of nitrogen losses started in 2023 by the installation of two nitrate-nitrogen sensors. Preliminary results show high variability of annual sums of drainage discharge between the different drainage systems as well as between the drainpipes of the same system and between the years. Results indicate that certain drainage systems perform better than the others under certain circumstances. For example, discharge measurements of the years 2020 and 2021 showed that the torpedo drainage system worked slightly better than the slit system when the soil was already wet, or when a heavy rainfall event occurred. However, the slit system drained slightly stronger than the torpedo

system when soil's water content was increasing slowly. Detailed analysis of discharge and nitrogen concentration measurements of the years 2022, 2023, and 2024 are pending, and results will be presented at the conference.

Abstract number–164 Monitoring and Assessment of Nitrogen Leaching in an Irrigated Orchard Farm under Semi-Arid Climate

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¹*University of California, Davis*

Nitrate contamination in groundwater, driven by inefficient fertilizer application and low nitrogen use efficiency (NUE), poses a significant risk to water quality in. This study presents the calibration of a vadose zone crop model to simulate nitrate (NO₃-N) leaching in response to a best management practice (BMP) aimed at improving NUE in a 57-ha commercial, irrigated almond orchard farm in California. Using a comprehensive dataset from landscape monitoring and vadose zone observations, a novel approach is taken to optimize soil hydraulic parameters, root solute uptake parameters, and atmospheric boundary conditions. The water balance is calibrated separately from model parameters by comparing ensemble estimates of precipitation and evapotranspiration (ET) from multiple sources with measured changes in soil moisture storage. Simulations are validated using groundwater nitrate concentrations measured from a dense network of 20 monitoring wells installed in the orchard. Results indicate that simulated leaching concentrations and travel times are most sensitive to changes in the water balance driven by uncertainties in the measurement of ET and precipitation. Observed heterogeneity of nitrate in groundwater was explained by sub-orchard scale spatial variability in NUE and cycles of orchard-block tree replantings. Soil-type heterogeneity affected modeled solute travel times but did not significantly affect measured groundwater concentrations. Simulations indicated the BMP can reduce nitrate leaching concentrations by up to 40%, with observable benefits in groundwater expected over a 10-year period due to slow solute movement in the vadose zone and mixing in groundwater.

Abstract number–165 Extreme Weather Impacts on Nitrate Leaching to Groundwater: A Field Scale Assessment in the Central Valley

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Nitrate groundwater contamination is a major problem worldwide, including in the United States. Innovative monitoring techniques are needed to assess the effectiveness of conservation practices e.g., 4R nitrogen management, irrigation scheduling, irrigation nitrogen credit, etc. The goal of the Central Valley field scale assessment CEAP project is to assess the effectiveness of conservation practices using three approaches of nitrate leaching monitoring, including i) deep vadose-zone monitoring system (VMS), ii) groundwater monitoring, and iii) field-scale nitrogen balance assessments. Three sites with a VMS have been established in the Central Valley for three major crops, including processing tomatoes, citrus, and almonds. I will present results from the field crop site on processing tomatoes and cucumber growing seasons in this presentation. We showed that the deep VMS technology could detect deep percolation and nitrate leaching to groundwater when heavy rainfall from atmospheric rivers in the winter followed drought and summer growing seasons. Measurements from the VMS and groundwater observation wells showed that nitrates reached shallow groundwater in 10 days and caused the groundwater nitrate concentration to exceed the drinking water limit (10 mg/L NO₃-N). The field mass balance approach provided results comparable to those of the VMS but with larger uncertainty. Similar monitoring protocols are being implemented in citrus and almonds. Additional years of monitoring are needed to confirm if conservation practices adopted at these field sites reduce nitrate leaching to groundwater.

Abstract number–166 Navigating Human Dimensions in Agricultural Practice Adoption: From Individual Perceptions to Collective Water Quality Improvements in the Great Barrier Reef catchment, Australia.

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The human dimensions of environmental management need to be accounted for in policy and programs seeking to improve water quality that flows from the catchments to the Great Barrier Reef (GBR). The GBR is one of the world's largest coral reef, wetland and estuarine systems located off the coast of Queensland, Australia. Farming and other land-based industries play an important role, working hard to reduce soil, nutrient and pesticide run-off and improve the quality of water flowing to the GBR.

Significant investment programs through Australian and Queensland governments, as well as other private investors have been in place since early 2000s. Shaping these policy and programs to better respond to the human aspect requires understanding of how motivations,

barriers, and perceived group norms and ability among farmers influence their engagement with innovative and sustainable farm management strategies.

This presentation will draw upon insights from the Human Dimensions monitoring program, a core component of the Paddock to Reef Integrated Monitoring and Modelling (Paddock to Reef) Program. Significant data has been captured that tells the story of the nuanced drivers to the adoption of land management practices to improve GBR water quality through successive rounds of social monitoring.

There is a suite of methods employed to engage the agricultural community, and the Behavioural Insights team in the Office of the GBR and World Heritage, responsible for the Paddock to Reef Human Dimensions program, is tasked with distilling the data into actionable insights that resonate with land managers and program investors. Examples of how these insights have been applied to program and project design to enhance practice adoption and water quality outcomes will be highlighted.

The Human Dimensions program's approach underscores the relationship between behavioural science approaches using insights from robust social monitoring, and policymaking and on-ground changes. The inclusive and collaborative strategies employed by the Behavioural Insights team elevate the role of human factors in achieving water quality outcomes for the GBR.

Abstract number–167 The establishment and use of local coastal water boards is tested in Denmark to find bottom-up solutions for RBMP 2027

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The Danish EPA has in the 3rd River Basin Management Plan (RBMP) under the Water Framework Directive set target nitrogen loads for each coastal water for how to reach the reduction needed from coastal catchments to be implemented in 2027. In this context four locally based pilotprojects have been initiated to engages stakeholders to find local solutions for the RBMP. One of these new pilots are focusing on the Hjarbæk estuary situated in Limfjorden being one of the coastal water bodies in Denmark that needs the highest reductions in nitrogen loadings to be achieved before 2027 (ca. 65 %). This new project involving a coastal water board with all main stakeholders in the region being represented was initiated in February 2023 and has delivered proposals for 2 scenarios by the end of 2023 that can assure that the Hjarbæk estuary reach the target of achieving good ecological conditions.

Because of the high reductions in nitrogen loadings needed it is necessary to reduce all sources and both nitrogen and phosphorus to reach the goal. Focus in the RBMP has so far been to reduce the total nitrogen (TN) loadings. In the locally based scenarios phosphorus has gained greater focus. Our calculations show that every ton of phosphorus that is removed corresponds to removing 22 tons of nitrogen in Hjarbæk Fjord. To be most cost-

effective the effort will be carried out based on the principle of achieving the greatest possible effect per area unit. For that a detailed mapping of nitrogen (N) attenuation in the catchment have been conducted at a scale of ca. 15 km² (ID15 sub-catchments) including mapping of both N-retention in groundwater and surface waters as well as N-delays in groundwater in Karst sub-catchments. The mapping shows huge differences in N-retention in both groundwater and surface waters within the ID15 sub-catchment (<20 % to >80 %). The local engagement of stakeholders representing all sectors in the catchment and estuary have worked together to set up two scenarios that includes: i) marine mitigation measures such as mussel farming and eelgrass planting; ii) reductions in point source loadings; iii) use of a new portfolio of N mitigation measures to be adopted at source (e.g. catch crops, early seeding, set a side, afforestation, etc.); iv) use of transport mitigation measures from field to surface water (several types of constructed wetlands, riparian buffers and restored wetlands); v) the possible use of different phosphorus mitigation strategies in the catchment (lowering bank erosional P-losses, buffer strips, afforestation, etc.).

Abstract number–168 Nutrients state and trend for the Danish water bodies from 35 years with national monitoring

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The national monitoring program for water and nature, NOVANA has over the last 35 years produced data on water quality and quantity. NOVANA includes groundwater, surface water in streams and lakes and marine coastal waters, but also wastewater, species, nature etc. NOVANA was launched in 1989 before the implementation of the Nitrates Directive and the Water Frame Directive (WFD) and has continuously adapted to align with EU-monitoring obligations.

Nitrate in groundwater together with the deteriorated ecological conditions in many lakes and marine areas caused by excessive inputs of Nitrogen and Phosphorous are major issues of concern in Denmark. On a national scale, the Nitrates directive, the WFD and other national political objectives have played important roles for consecutive national action plans aiming to reduce leaching and transport of Nitrogen and Phosphorous to the aquatic environment. In the first part of the monitoring period, a clear response from the action plans was seen in Nitrate concentration in groundwater and in the transport of Nitrogen and Phosphorous to lakes and marine areas.

The positive development has, however, levelled out during the recent 15-20 years in both groundwater and surface waters. And in addition to this, temperature increases have counteracted expected improvements in the marine environment from obtained nutrient

reductions.

The objectives in the WFD are therefore still not met in most of the Danish water bodies and further political initiatives need to include excess nutrient transport associated with climatic changes as increase in temperature and precipitation and the occurrence of more extreme climatic events such as drought and heavy rainfall.

We will present the nutrient state and trend for the Danish water bodies, demonstrate the effects of implemented mitigation measures and briefly address the future challenge to incorporate effects of climate change.

Abstract number–169 Looking into buffer zones with different vegetation cover – monitoring subsurface runoff - results from TOTBUFFER project

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Fertilizers and pesticides contribute to the pollution of water resources. The areas along streams are affected by climate change as stream bank failures often occur following floods or during prolonged rainfalls. In addition to BMP (best management practices) on the fields, grassed cover buffer zones are one of the most common measures for improving water quality in Norway's agricultural catchments. Increased focus on buffer zones is important in a future climate perspective, both for food production, natural diversity and water quality.

The efficiency of vegetation cover is composed of a variety of factors; therefore, effectiveness of these measures are to a large degree site specific. Recently, increased attention is given to the buffer zones efficiency, depending on both conditions in the catchments and the design of the buffer zones itself. However, most research is focusing in investigating the effect of buffer zones looking mostly at the surface runoff.

According to our knowledge there is no previous research investigating the efficiency of the buffer zones with flower mixture. We focus on these types of vegetation as they also stimulate increased biodiversity. Moreover, previous investigations show that more than 50%

of simulated runoff infiltrates into buffer zones with grass and bushes, while within buffer zones with trees there all the water infiltrates into the soil.

Herein we show the results of the 3-year investigation of the differences (and similarities) between subsurface runoff patterns within the buffer zones with different vegetation cover, and consequently, with different root system. We used the runoff simulation setup combined with electric resistivity monitoring (ERT). The results show significant differences in hydrological response between experimental plots cover with grass, trees and bushes, confirming the importance for considering the subsurface processes when looking at the buffer zones efficiency.

Abstract number–170 Looking into buffer zones with different vegetation cover – monitoring of the surface runoff - results from TOTBUFFER project

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According to our knowledge there is no previous research investigating the efficiency of the buffer zones with flower mixture. We focus on these types of vegetation as they also stimulate increased biodiversity. Moreover, previous investigations show that more than 50% of simulated runoff infiltrates into buffer zones with grass and bushes, while within buffer zones with trees there all the water infiltrates into the soil.

Herein we show the results of 3 years monitoring surface runoff from buffer zones with different types of plant cover (grass and flower mixture). The idea was to monitor real live

surface runoff from the field with autumn tillage (as “worst case scenario”). The results show significant differences, especially in the runoff quality. The visual differences are confirmed by water quality analysis.

Abstract number–171 Watershed scenarios for implementation of the EU Water Framework Directive and the Danish Tripartite Agreement targets for green transition in agricultural landscapes

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This paper reviews selected examples on scenarios for a green transition of agriculture to reach watershed Nitrogen pollution reduction targets, in combination with other defined goals in Danish landscapes. This include results from research behind the Danish coastal councils, in particular on solutions for the critical Inner Limfjorden watershed, in perspective of the new Danish Tripartite Agreement between the Government of Denmark and leading agricultural, industrial and environmental organizations, to pave the way for an historic new approach to how land is used in Denmark. Landscape scale solutions are key to reach these targets, and state of the art research and modelling approaches within the Land-CRAFT.dk Pioneer Center for Landscape Research in Sustainable Agricultural Futures, and the Sustainscapes.org Novo Nordic Challenge Center for Sustainable Landscapes under Global Change will be presented, together with recent landscape scale measure guidance synthesized within the UN-ECE Task Force on Reactive Nitrogen.

Abstract number–172 Dynamic Water Quality Monitoring in the Kielstau Catchment: Optimization of High-Frequency UV Sensor Performance and Nutrient Hysteresis Analysis

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Water quality pollution in lowland areas with agriculture-based economies urgently needs to be addressed, particularly in the context of increasing nutrient losses from intensive farming

activities. The European Union Water Framework Directive (WFD) aims to achieve a "good" ecological status for water bodies by 2027. However, in agricultural lowlands dominated by arable land and grasslands, nitrogen and phosphorus are transported into surface waters through surface runoff and subsurface drainage systems, leading to eutrophication, disrupting aquatic ecological balance, and reducing biodiversity. Additionally, nutrient migration and transport in soil and water bodies in these agricultural lowlands are often complex and exhibit hysteresis effects. Therefore, high-resolution, long-term data monitoring and dynamic management are essential in these areas.

In response, this study aims to (1) optimize the calibration of high-frequency sensors to improve monitoring accuracy and data reliability, (2) conduct source apportionment of pollutants through daily sampling and analyze their seasonal variations and transport pathways, and (3) perform nutrient hysteresis analysis using high-frequency data. The Kielstau catchment, located in northern Germany, serves as a typical agricultural lowland site with nutrient rich input pathways and relatively flat terrain. The catchment spans approximately 50 km², with ample annual precipitation, and its land use is primarily arable and grassland. About 38% of the area is covered by subsurface drainage, with six wastewater treatment plants and two biogas facilities contributing significantly to nutrient inputs.

In this study, a BlueScan UV/Vis spectrometer was installed in the Kielstau river, recording water quality data every ten minutes, supplemented by three daily laboratory samples taken at fixed times: midnight (00:00), 8:00 a.m., and 4:00 p.m.. The system mainly detects total phosphorus, soluble reactive phosphorus, total nitrogen, ammonium, nitrate, total organic carbon, as well as physicochemical parameters like pH, electrical conductivity, dissolved oxygen, and temperature. Additional grab samples are used to calibrate sensor performance. By analyzing both high-frequency and periodic sampling data, this study aims to reveal pollutant migration pathways, dynamic seasonal variations in nutrient transport, and verify hysteresis characteristics. The findings will provide scientific support for catchment management, assisting in the formulation of targeted nutrient reduction measures.

Abstract number–173 A Source:Pathway Prioritisation Index for diffuse P mitigation in agricultural catchments.

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In agricultural landscapes where diffuse losses of phosphorus (P) are an issue for water quality, policy makers, advisors and agri-environmental scheme managers need a robust process to target support and interventions on farms.

In Northern Ireland over 75% of the area is agricultural land use, 96% of which is grass-based livestock production across ~26,000 farms. High levels of P are returned to land as slurry/manure and the excess accumulating in soil is a source for loss to water. Strong relationships exist between this soil P excess and low flow soluble reactive P concentrations in rivers. Furthermore, the combination of topography, soil P and high rainfall in the region means that storm-event losses via runoff pathways account for the majority of P loads to rivers each year. Critical source areas (CSA) where P source pressures and pathways for delivery co-occur must therefore be addressed as a priority if reductions in river P concentrations and loads are to be achieved in the region's rivers, of which only 31% are at good status.

The national Soil Nutrient Health Scheme has transformed the level of data available and which can be applied to this challenge through field-level soil sampling of all farms (~700,000 fields) and 1m LiDAR-based modelling of hydrologically sensitive areas (runoff pathways) for all agricultural land (>10,000 km²). These data sets have enabled a whole-landscape risk ranking method for diffuse pollution management to be developed based on CSA principles and that can be directed centrally and rolled out locally as part of catchment level agri-environmental schemes and in targeting advisory and advisory services to farmers. The approach starts at the macro-catchment or river basic scale using available land use, agricultural metrics and water quality monitoring data to identify sub-catchments (meso-scale) with diffuse source pressures. This then shifts to a small-scale CSA assessment, where the upslope contributing areas draining to each delivery point are delineated where runoff enters a watercourse. Within these micro-catchments the source pressure is summarised as an area-weighted average of soil test P from field level data and combined with a pathway metric of runoff risk into a dimensionless source: pathway prioritisation index (SPPI) ranging between 0-1. This is then mapped for the catchment and used to target interventions in a tiered treatment approach, where highest SPPI areas are addressed first, generally accounting for ~1% of identified CSAs, followed by monitoring of change, and further tiers until targets are achieved.

Abstract number–174 Agro-environmental measures – a catalogue framework for communication about efficiency and functionality

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In many research and collaboration projects, catalogues are produced that describe agri-environmental measures and their efficiency and functionality. The catalogues gather knowledge among partners and contribute to the sharing of experiences. The catalogues are published as reports or in web-based interfaces, or in a combination of both. When the project ends the information in the catalogue is seldom updated.

In water management planning information about environmental measures is essential in the

whole scale from farm to EU-level. The farmer and agricultural advisor want to know about applicability on the farm, the national authority need information about environmental efficiency for the planning of policy measures as regulations and subsidies but also for the evaluation of already implemented measures. In parallel, the business sector requires information about measures for environmental accounting on their products.

Here, the potential to combine various needs and information into an active and continuously updated catalogue is explored. Measures from field to stream are included, for example in soil and crop management, in drainage systems, and in streams as wetlands and buffer zones. Main focus is water and nutrient retention but aspects as soil carbon balance, climate gas emissions, increased landscape diversity and biodiversity are included. The information is evidence based combined with experiences from landowners and users. A matrix systemize the aspects and show existing gaps.

The catalogue framework is developed with partners in national and international projects, and in collaboration with Swedish stakeholders at local and national level. The outcome is a prototype showing a selection of measures that are linked to the Swedish national water management system.

Abstract number–175 Installation of a woodchip bioreactor as an area specific approach to reduce nitrate loads from agriculture

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According to the Water Framework Directive, water bodies should be in good ecological and chemical status by 2027. One of the main pollutants in agricultural areas is nitrate. In the South-eastern part of the Netherlands, nitrate concentrations often exceed the limit values in surface water. Area-specific measures need to be taken to protect the water quality. A way to reduce nitrate emissions from agricultural fields is the installation of woodchip bioreactors which are connected to tile drainage systems. Internationally, for example in Denmark, Belgium and the USA, this method has proven to be very effective in reducing nitrate concentrations in drainage water. However, when residence times are too high, negative side effects may prevail. This includes the production of nitrous oxides, sulfide and ammonia, and leaching of heavy metals.

In 2023, a woodchip bioreactor has been installed in an agricultural, drained field, situated in a lowland river catchment in the southern part of the Netherlands. The purpose was to demonstrate the effectiveness of this measure in low-lying and flat agricultural areas and to optimize the control of side effects. The reactor is connected to 4ha arable land on sandy soil and is located in Westerbeek, Noord-Brabant. The influent of the bioreactor is connected to the tile drainage system and is fed during drainage season. The effluent is connected to a small stream. Online nitrate sensors and discharge measurements are installed at the in- and effluent of the bioreactor to measure the loads and determine the removal efficiency. Inside the reactor, several piezometers were installed to monitor the biogeochemical processes taking place. This was done to determine potential side effects of the bioreactor during operation and the effects of extended residence times due to temporarily limited flow rate. During the start-up in autumn, extra measuring wells with online nitrate, pH and temperature sensors were situated instream (both up- and downstream) to measure the potential side effects of the inflow of standing bioreactor water in the stream.

An extensive sampling campaign was carried out in 2023/2024 which showed considerable removal of nitrate (between 40% and 80%). At specific moments, some leaching of sulfide, ammonia, phosphorus and iron was observed. These leaching events appear to be related to start-up of the reactor and flow rate. The formation of nitrous oxide will be determined during operation in 2024/2025.

During operation, the bioreactor faced difficulties of clogging and a reduced flow rate. Side effects during start-up were monitored and were minimized as much as possible. The woodchip bioreactor proved to be a good area-specific measure to reduce nitrate loads in small streams, but care has to be taken on possible side-effects of the bioreactor on the stream.

Abstract number–176 Assessing PFAS Contamination in Dutch Groundwater: Insights from Age-Dated Depth Profiles

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Groundwater is an important resource in the Netherlands, supplying two-thirds of the country's drinking water. However, these resources are under pressure from the high population density, industry activities, and intensive agriculture, leading to pollution by emerging contaminants such as per- and polyfluoroalkyl substances (PFAS). PFAS are a group of synthetic chemicals that have been used since the 1950s in various industrial and consumer products. These substances have recently become a major concern because of

the possible adverse health effects and their persistence in the environment. This study investigates the presence of PFAS in age-dated groundwater from two multi-level wells in the province of Noord-Brabant, the Netherlands.

Groundwater samples were collected from two multi-level wells: one located in an agricultural area and the other in a forest. These wells consist of 17 filters at depths up to 25 meters below the surface, which allowed for the creation of detailed depth profiles. Several filters of these wells were previously age-dated with tritium/helium, which allows to link the PFAS concentrations to specific infiltration years which helps to get a better understanding of the leaching behaviour of these substances.

The results indicate that PFAS are present at all sampled depths, with groundwater ages reaching up to 40 years. The highest concentrations were found for the short-chain PFBA, which was detected in all samples and had a maximum concentration of 59 ng/l. Other short-chained PFAS, such as PFBS, were also frequently detected. Longer-chain PFAS such as PFOA and PFOS were also detected, but these were mainly present in the shallow samples within the most recent infiltration periods. The presence of PFAS in the well in the forested area shows the likely influence of atmospheric deposition. The concentrations in the agricultural area were generally higher, pointing to possible other sources such the leaching of PFAS-containing pesticides. Pesticides were also sampled for this well, showing the long-term influence of agriculture on groundwater quality.

This study underscores the widespread presence of PFAS in groundwater. The sources for the PFAS contamination point towards atmospheric deposition and the usage of PFAS-containing pesticides in agriculture. Linking PFAS concentrations to detailed age-depth profiles offers valuable insights into both historical and current contamination levels, as well as the leaching behaviour of these substances in groundwater.

Abstract number–177 Interaction of steady state flow and geochemical processes controlling the phosphorus release in anaerobic soil columns

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Rewetting of organic lowland soils may result in a large and prolonged phosphorus (P) load to the downstream systems as legacy of iron (Fe) associated P is reductively dissolved. We hypothesize that the remaining P sorption capacity in anaerobic soils determines P mobilization. To study P mobilization and transport under steady-state flow, a convective discharge experiment was conducted. Sixty undisturbed soil columns were taken from to

different soil depths (5-25 cm, 25-50 cm) in 6 Danish lowlands characterized by wide variability in P, Fe, and Al oxide contents. The column experiment used oxygen-free deionized water flowing at a rate of 1 mm per hour over a period of 28 days. The cumulated effluent was analyzed for different P forms, Fe, dissolved organic carbon, ammonium, nitrate, and other solutes on day 5, 14 and 28 during the experiment. The active flow volume and non-equilibrium flow conditions were determined with the help of a tritium tracer. Upon completing the leaching experiments, the soil columns were dismantled for determination of relevant soil properties. The carbon (C) content of the soil varied from 1.2 - 43.9% in topsoils and 1.3 - 49.1% in subsoils. Anoxic conditions in the peat soil, causing reductive Fe(III) dissolution with great range of Fe(II) effluent concentrations, 0.01-0.50 mmol L⁻¹ in topsoil, 0.01-0.11 mmol L⁻¹ in subsoil. Total P (TP) concentrations in the effluent were 0.01 – 0.12 mmol L⁻¹ and 0.01-0.03 mmol L⁻¹ in topsoil and subsoil, respectively. The most bioavailable form of P, molybdenum reactive P (MRP) contributed to 34 – 97 % in topsoils. Less P release was observed from the C-poor, mineral dominated soils. The saturated hydraulic conductivity (K_{sat}) varied greatly across various sites and within the sites ranging from 0.04 - 156 cm d⁻¹. Hydrology turned out to be a major factor controlling TP release, as the soils with low values of K_{sat} turned out to be the higher P releasing columns. Moreover, the results showed low P release to the aqueous phase, if the residual sorption capacity (RSC) of the soil was above 100 mmol kg⁻¹. The results of this study will be used to improve the models predicting the P export from organic lowland soils.

Abstract number–178 The impact of regulation for water quality in Ireland: perspectives from Irish dairy stakeholders

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To achieve good ecological status in our waterbodies by 2027 all sectors including agriculture will have to play a role. Currently member states rely on a Nitrates Action Programme to introduce legislation with the aim of water quality protection and improvement. However, after many revisions and additions to these statutory instruments, we have not seen any significant improvement in water quality. This paper argues that regulation alone is not sufficient to improve the status of our waterbodies, and a more comprehensive and inclusive approach needs to be considered. While stakeholders recognize the goal of improving water quality and generally accept the need for regulation, a purely regulatory approach does not fully account for the complexity of water quality issues and agricultural practices. Local conditions and the value of farmers' practical, on-the-ground knowledge are difficult to integrate within a standardized regulatory framework. For agriculture, the challenge rests in designing an approach that meets with farmer's needs, incorporates farm-

level complexity, enhances existing support approaches and complements the existing regulatory framework. On-farm behavioural change, which is meaningful and long lasting, is key to achieving our regulatory commitments and a positive impact on water quality improvements. This study used a mixed methods approach to examine farmers' responses and preferences regarding various farming options needed to stay compliant with the latest policy updates in Ireland's 5th Nitrates Action Programme. Key informant interviews (n=16) were used to rank the regulatory changes in terms of those which they considered most important in delivering water quality improvements. The impact of the top three measures at farm level was then assessed through farmer interviews (n=42). Findings indicate the regulatory approach does not provide sufficient support to assist farmers. The main themes, which emerge from this analysis, were collective responsibility, control and ownership, environmental necessity, legal compliance and resource complexity.

Abstract number–180 Impacts of Climate Change on Nitrogen Use Efficiency in Germany

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Efficient use of nitrogen in agriculture is key to achieving goals in nitrate groundwater quality and climate mitigation. Despite substantial decreases in nitrogen use in Germany in recent years and the tightening of mandatory measures for farms located in regions with high nitrate concentration in groundwater, increasing impacts of climate change might counteract progress in nitrogen use efficiency. The few existing studies that directly investigate the relationship between climate change and nitrogen use efficiency suggest, that particularly in years with drought periods in spring and summer, nitrogen use efficiency is low because of the difficulties to adapt nitrogen application rates to unpredicted extreme events. In our analysis, we investigate how much nitrogen use efficiency varies yearly on German farms by calculating trends in nitrogen use efficiency and annual deviations. In a regression analysis, we test how much of this deviation can be attributed to the weather conditions and different extreme weather events. We also identify differences between farm types and farm management systems as well as regional differences in the contribution of various factors to nitrogen use efficiency and regional hot spots to identify farms and regions with the greatest

need to adapt fertilization practices to climate change. In addition, we investigate whether we can observe adaptive behaviour on farms in years with extreme weather conditions. We built upon the literature that investigates the impact of extreme weather events on yields and test the transferability of methods to the case of nitrogen use efficiency. We use calculated annual farm-level nitrogen use efficiency based on farm-level data from the German Farm Accountancy Data Network, covering around 27,000 observations between 2016 and 2023, and weather and soil moisture information from the German Weather Service. The analysis contributes to a better understanding of the impact of climate change on efforts to increase groundwater quality and climate mitigation via increases in nitrogen use efficiency and to identify entry points for adaptation on the farm level.

Abstract number–181 Closing the Gap: Are the Measures Achieving Water Quality Objectives in Ireland?

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Ireland's recent Water Action Plan is focused on getting "the right measure, in the right place". For this to work, implementing bodies need to identify if the water quality measures are working, and if not, why not?

The Irish EPA has forecast the water quality outcomes based on measures planned for the WFD 3rd Cycle including the number of waterbodies that are likely to achieve their 2027 status objectives, and those that are likely to show improvements, so that an assessment can be made of the gap to achieving Water Framework Directive (WFD) environmental objectives. Out of 4,842 water bodies assessed, 54% are currently meeting their quality objectives. This leaves a significant number (over 2,200) requiring improvement. This analysis forecasts that between 150 and 300 "At Risk" waterbodies are likely to meet their targets due to planned measures. In previous years, improvements made in some areas were also offset by declines in water quality elsewhere, so there may be no net improvement once again.

This analysis identifies three key gaps hindering progress: the measures gap, the effectiveness gap, and the evidence gap. These gaps highlight the need for more targeted actions, a better understanding of measure effectiveness, and further investigation into waterbodies where data is lacking.

There is limited scientific evidence demonstrating the effectiveness of the proposed measures in stabilizing, restoring, and maintaining water quality to the levels required for favorable conservation status. Uncertainty exists regarding the technical effectiveness of the measures, both individually and collectively, in halting the decline in water quality. Policy changes are being implemented, for example, the reduction in the maximum stocking rate

and allowable chemical application rates, without a scientific quantification of the expected outcomes. The challenge ahead is to develop the evidence to evaluate the effectiveness and sufficiency of measures to achieve the desired water quality improvements.

Abstract number–182 Prioritising investment in nutrient management reform for farms in the catchments of the Great Barrier Reef

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Agricultural practices in the catchments adjacent to the World Heritage listed Great Barrier Reef (GBR) have contributed to degraded water quality, which has detrimental effects on GBR ecosystems. Catchments that are dominated by sugarcane, the largest single cropping land use in the GBR catchments, contribute over forty percent of the dissolved inorganic nitrogen (DIN) load to the GBR. Government responses to address water quality from agriculture have included incentive schemes that invest in grower practice change, introduction of voluntary industry best management practice programs as well as regulation of practices such as fertiliser application rates. Expert opinion states that these efforts have reduced the likelihood of excessively high rates of inorganic fertiliser being applied, resulting in an improvement in nitrogen use efficiency (NUE). However, monitoring and modelling shows that further reductions are needed to achieve water quality targets set in the Reef 2050 Water Quality Improvement Plan.

As growers may be reluctant to further reduce fertiliser application rates, there has been an increasing focus on alternative approaches to improving NUE. In the Australian sugarcane industry NUE is commonly calculated as kg of nitrogen (N) applied as inorganic fertiliser divided by yield (tonnes harvested). The contribution of organic sources of N, such as legume break crops or the mill by-product 'mill mud', applied as a soil ameliorant, has been less certain and therefore less routinely accounted for. Industry has reported a preference to improve NUE by addressing yield constraints such as micronutrient deficiencies or disease management.

The objective of this study was to compare the relative water quality benefit of NUE improvements achieved by reducing inorganic fertiliser inputs versus by increasing yields. The benefits of reducing inorganic fertiliser rates to account for the mineralisation of organic N sources were also evaluated. The study used APSIM, the Agricultural Production Systems sIMulator, validated using ten years of field monitoring data from sugarcane in a GBR catchment and laboratory measurements of mineralisation. The results confirm that NUE is not a good predictor of losses of DIN from a farm, and while increasing yields will reduce

DIN losses the benefits are not equivalent to the same NUE achieved by reducing fertiliser inputs. Water quality improvements can be achieved through improved accounting of N from organic sources in NUE calculations. Results were considered within the context of prioritising investment to achieve targets for water quality improvements while maintaining agricultural productivity.

Abstract number–183 Identifying site-specific opportunities for implementing nutrient reduction measures in catchments

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EU member states are struggling to reach the targets of the EU Water Framework Directive, which demands most surface waters to be in good ecological status by 2027. One of the main pressures on European streams, rivers, lakes and coastal waters comes from excess inputs of nutrients from diffuse, agricultural sources. In most catchments, combinations of different nutrient reduction measures will be necessary to achieve nutrient reduction targets that are estimated based on current nutrient loads and thresholds for good chemical and/or ecological status of streams, lakes, and receiving coastal waters. In many countries, national guidelines for the use and dimensioning of nutrient reduction measures exist but guidance on their placement within a catchment is often lacking and implementation of measures is not planned at relevant spatial scales (e.g. catchment scale).

Therefore, the Horizon Europe project NORDBALT-ECOSAFE is developing a new tool for identifying site-specific opportunities for implementation of nutrient reduction measures. Main inputs are geo-spatial data, nutrient source areas and transport pathways simulated by the Soil and Water Assessment Tool (SWAT+), and potentially information about local land use planning. Using GIS-based analyses of the main inputs, placement opportunities can be identified for different nutrient reduction measures. The resulting maps are used to estimate the effect of individual measures on nutrient loads using SWAT+ and to develop possible catchment management scenarios with various combinations of measures, which are subsequently simulated in SWAT+. Catchment-specific nutrient reduction targets defined by comparing the safe ecological boundaries quantified in NORDBALT-ECOSAFE for different types of water bodies to the baseline nutrient loads simulated by SWAT+ are used to estimate the performance of the different catchment management scenarios in achieving a sufficient reduction in nutrient loads. Finally, the most effective scenarios can be discussed with stakeholders to identify those that are viable regarding both their effectiveness and stakeholder preferences.

In this presentation, the Odense Fjord Catchment in Denmark is used as a pilot case to

demonstrate the application of the new tool. It will also be tested in the remaining five NORDBALT-ECOSAFE case study areas in Norway, Sweden, Finland, Latvia, and Poland.

Abstract number–184 Integrated Water and Nature Parks: A Nature-based Solutions Strategy in Aarhus Municipality for Improving Water Quality and Climate Adaptation

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The Aarhus Municipal Plan 2025 designates 8,000 hectares for Water and Nature Parks, half on current agricultural land. The climate agreement 'A Climate Neutral Aarhus 2030' adds 4,000 hectares, totaling 16,000 hectares or 34% of the municipality's area. These parks aim to protect drinking water, establish peri-urban nature, enhance biodiversity, and retain nutrients and water. Analyses by CONCITO indicate significant socio-economic benefits from converting agricultural land to nature and forest areas, demonstrating advantages of integrated nature-based solutions (NbS) in municipal strategies.

A key synergy effect is reduced nutrient leaching to groundwater and surface water, addressing the need to improve Aarhus Bay and freshwater environments, while supporting UN Sustainable Development Goals. To evaluate and optimize NbS measures, Aarhus Municipality uses NatureInsight, developed by Scalgo and Arup. Its hydrological model simulates NbS effects on water flow in catchments, capturing potential synergies in water and nutrient management.

NatureInsight represents NbS measures as storage volumes interacting with hydrographs based on parameters like inflow limits, transport velocity, and outlet dimensions. This evaluates interventions that reduce nutrient loading and manage downstream climate impacts in Aarhus' water systems.

The tool supports optimization and planning, comparing NbS measures and informing early-phase evaluation of strategies and policy decisions. This approach aligns with conference themes on hydro(geo)logical processes, drinking water and nature protection, and eco-technological measures for water quality (themes B, F, and H). It offers a holistic approach to agriculture and water quality, focusing on policy-making and multi-stakeholder collaboration.

Aarhus' integration of Water and Nature Parks into municipal planning demonstrates a progressive approach to environmental challenges, improving water quality, climate resilience, biodiversity, and public well-being. NatureInsight showcases data-driven decision-making in environmental management, providing a model for municipalities implementing NbS strategies in peri-urban areas.

Abstract number–185 Impact of various management measures on soil water regime in three European biogeographical regions

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Within the EU Horizon project OPTAIN (OPTimal strategies to reTAIN and re-use water and nutrients in small agricultural catchments across different soil-climatic regions in Europe, optain.eu) project, the effects of Natural/Small Water Retention Measures (NSWRMs) on water regime, soil erosion, and nutrient transport are evaluated at both catchment- and field-scales for present and future climate conditions. The goal of this study was to assess the effectiveness of selected management-based NSWRMs on soil water retention using the field-scale SWAP soil hydrological model and to compare the results with those simulated by the catchment-scale SWAT+ model. Improved water retention and reduced surface and subsurface runoff are indicators of reduced nutrient and soil particle losses towards the surface and subsurface water bodies. The field-scale assessment was based on the adaptation of the two models to seven pilot sites across three European biogeographical regions and on combined NSWRM – projected climate scenario analyses. The SWAP model was calibrated for all the pilot fields with good or satisfactory results. The impact of four in-field NSWRMs - reduced tillage, shifting to grassland, afforestation and drought tolerant crops - on the water balance elements was evaluated. The scenario results indicate that the effects of measures on soil water retention and other water balance elements have some regional pattern, but can be strongly dependent on local conditions (e.g. soil, crop, slope). According to the scenario results, for most of the cases the studied NSWRMs contributed to reducing evaporation, surface and subsurface runoff and percolation to deeper layers, which resulted in increased soil water retention or plant water uptake within the fields. The cross-validation of the field-scale SWAP and catchment-scale SWAT+ models was a challenging

task and could only be performed for selected water balance elements (evaporation, transpiration and drainage outflow). Comparable results were obtained in most of the cases for the baseline scenario, but the differences between the soil water balance elements simulated by the two models increased when implementing the different measures.

Abstract number–186 Nitrogen retention in Danish surface waters – a new model

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In the ongoing effort to reduce river nitrogen (N) loads to the coastal waters there is a focus on the cost effectiveness of mitigation measures, which is largely involving source or transport control measures. The cost effectiveness of agricultural mitigation measures to a large degree is dependent on nitrogen retention (Nret) between agricultural fields and coastal waters. The percentage of the nitrogen lost from fields that reaches Danish coastal water varies significantly between catchments (from <20% to >80%, (Højberg et al., 2021). In Denmark, the largest Nret is found in ground water, with a national average of approximately 65% for Nret calculated using the National Nitrogen Model v2020 (NNMv2020) (Højberg et al., 2021). The nitrogen retention in surface waters is much lower and modelled to be about 21% of the incoming load to freshwater (Højberg et al., 2021). Nevertheless, the surface water Nret varies substantially in the landscape depending on which Nret environments such as rivers, wetlands, lakes the water and N will pass through on the way through the surface water system. For example, N passing through a wetland or a large lake result in high Nret percentages, while retention is lower when nitrogen only passes through the river network.

The new version of the NNMv2024 includes a range of new models for a suite of surface water environments that have been developed: for rivers & streams, reestablished wetlands, lakes (large & small respectively), flooded areas, and constructed wetlands. The models are based on in-situ measurements of denitrification and monitoring data used for establishing mass balances for each compartment (e.g. lake, wetland). Along with the new and updated models in NNMv2024 the Nret in both groundwater and surface water will be calculated on a local scale (< 1500 ha previously used, however, the final scale has as yet not been decided upon). This new Danish NNM model will enable managers and decision makers to target mitigation areas on a geographical scale much finer than the catchment scale previously used (ca. 1500 ha), thereby enabling more environmentally and economically efficient interventions.

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Abstract number–187 Predicting nitrate leaching using Nmin soil measurements on farm parcels.

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Excessive use of animal manure and fertilizer threatens the quality of ground and surface waters in agricultural areas in Europe and other parts of the world. A proportional balance between agricultural production and environmental protection is a prerequisite to achieve and sustain the quality of soil and, groundwater and surface water. Therefore, the Dutch Ministry of Agriculture , Fisheries, Food Security and Nature aims for the development of a policy that sets environmental goals for farmers. Setting environmental goals rather than fertilizer application limits safeguardss the autonomy of farmers in their farm management, while simultaneously aiming to reduce nitrogen emissions to the environment.

A promising research development is the use of N-mineral soil measurements as a proxy for the leaching of nitrate to groundwater. By taking a simple composite soil sample, N-mineral soil measurements are relatively easy to obtain compared to current sampling methods of phreatic groundwater to monitor nitrate concentrations, which is performed by sampling groundwater from temporary boreholes.

In a preliminary study, data of N-mineral measurements in soil and nitrate concentrations in groundwater were used to create models that describe the N-mineral variability and predict the nitrate concentrations. The models use field measurements combined with spatial information like soil type, hydrological data, crop type, land use, elevation, among others.

Using Machine Learning (Random Forest and XGBoost) we compared these models among eachother. The final model could explain 64% of the variance, with an RMSE of 62 mg/L. This model performs better compared to other known models based on (multiple) linear regression methods. Interestingly, preliminary results indicate that spatial co-variates related to soil type could be more relevant than the actual soil measurements of N-mineral in predicting the nitrate concentration in groundwater. This is probably due to the high variability in soil measurement results.

In this presentation we present the latest results of this ongoing research, and we will discuss how N-mineral measurements can be used for policy development in order to achieve aforementioned goals.

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Abstract number–188 Strategies for climate adaptation in water quality and quantity management across Nordic countries: The Danish Cases

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Climate risks in agriculture are primarily associated with water, with extremes such as drought and flooding presenting significant challenges. Effective water management, addressing both availability and quality, is crucial. The PRECILIENCE project aims to test and demonstrate improved water retention, storage, irrigation, and drainage practices with farmers across diverse Nordic agroecological zones. Strategies should be addressed by a multi-actor approach to ensure a broad variety of perspectives, engagement and ready-to-implement solutions through a collaborative effort between scientific and practical stakeholders.

Our work in Denmark will be based on two case areas that differ in terms of geography and challenges related to water management during wet and dry seasons:

Lemvig is in the northwestern Jutland. The region faces significant challenges, including elevated groundwater levels and increasing competition for water resources. This competition spans various needs such as irrigation, industrial purposes, and water supply. In Lemvig, proposed solutions involve developing synergies and symbiotic relationships where pumping associations provide water to Power-to-X (PtX) plants. The reject water from these plants can potentially be reused for irrigation, which necessitates the storage of large volumes of water. Additionally, technical solutions such as the use of Leca nuts are suggested to facilitate water infiltration and retention. Challenges with water management during both dry and wet periods will be examined from a farmer's perspective and based on a selection of farms. The study aims to identify possible water management solutions, including the feasibility of symbiotic relationships with PtX, while considering the advantages, disadvantages, and barriers.

Samsø is an island situated in the Kattegat Sea. Pressured groundwater resources and absence of available groundwater for irrigation purposes have since the 1970's motivated farmers to establish storage ponds for collected drainage water. The study will focus on examining the existing water reservoirs on Samsø to understand what can be learned from current practices. Additionally, the potential for these reservoirs to act as measures for

nutrient removal will be investigated, possibly including monitoring activities. The research will also identify challenges and explore potential water management solutions on selected farms, considering multifunctional approaches where feasible.

This presentation outlines how a multi-actor approach in the PRECILIENCE project is addressed in a Danish context.

Abstract number–189 Towards an integrated view on Safe Ecological Limits from the Wadden Sea catchments to the Wadden Sea

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The Wadden Sea is the largest coherent intertidal area in the temperate world and a World Heritage Site since 2009. The Wadden Sea is strongly influenced by major European rivers like the Rhine and Elbe. Eutrophication started during the early 1950s, reached a maximum during the 1980s. Political decisions and improved management lead to decreasing eutrophication and an improved environmental conditions like decreasing phytoplankton bloom and a partial return of seagrass in the northern part. We suggest safe ecological limits for the Wadden Sea based on N limited spring blooms and seagrass recovery in the southern part of the Wadden Sea. To reach this, reductions in N loads of at least 30% (compared to levels during the 2010s) are needed. We compare these reduction needs to reductions needed in three case studies in the catchment each with its own environmental issues: The Rhine catchment with eutrophication problems especially in the catchment, the Elbe with eutrophication problems especially in the main stem and in the upper estuary (O₂ depletion) and the Hunze catchment (a small river and lake close to the Wadden Sea) with issues concerning algae blooms and submersed vegetation. A short summary of the environmental problems and suggested reduction needs will be given. These three case studies show that each has its own local environmental challenges hampering a unified approach on reduction goals. In particular, the question whether N or P is limiting is case-dependent. Some suggestions towards an integrated view on terrestrial, aquatic and marine eutrophication will be discussed.

Abstract number–190 Effectiveness of Natural/Small Water Retention Measures in the Boreal biogeographical region

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Reducing diffuse nutrient losses to water bodies remains a major problem in the agricultural areas of the Nordic countries. The transition towards a bioeconomy and ongoing climate change raise questions on the future of water quality and freshwater ecosystems and what kind of adaptation strategies could be implemented to maintain both food and environmental safety.

The objective of our study was to evaluate the effectiveness of Natural Soil Water Retention Measures (NSWRMs) under current and future climate conditions in retaining water, soil particles and nutrients within the landscape. The hydro-biochemical model SWAT+ was implemented in the Krakstad catchment in southern Norway using the novel approach developed within the EU H2020 project OPTAIN. This approach enables an improved spatial representation of NSWRMs in the landscape. Available discharge and water quality monitoring data were used as reference data for model calibration. The effectiveness of reduced tillage, grassed waterways, sedimentation ponds established in the forested areas and buffers on water retention and nutrient loads was evaluated.

Our simulation results indicate that conservation tillage, which maintains stubble on the soil surface during winter, has the strongest impact on reducing soil and nutrient losses towards surface water bodies. Grassed waterways, established in existing erosion prone gullies, could also significantly contribute to water and nutrient retention within the landscape. The implemented NSWRMs did not appear to increase the soil moisture content in early spring even under future climate conditions, which is an important aspect for ensuring soil trafficability and the timing of sowing spring cereals.

Abstract number–191 Linking Crop Rotations and Nitrate Leaching Potential: A Multiyear Study of Agricultural Land Use Effects on Groundwater Nitrate Levels

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Diffuse nitrogen losses from agriculture are a major contributor to elevated nitrate concentrations in groundwater, posing significant environmental and regulatory challenges. After Germany's conviction by the European Court of Justice in 2018 for persistently failing to achieve the targets set by the Nitrates Directive (NiD). Germany revised its national implementation of the NiD, the Fertiliser Application Ordinance in 2020. A wide range of new nitrate mitigation measures were introduced, including the designation of "Nitrate polluted Areas". However, despite these efforts, groundwater nitrate concentration measured by the

official groundwater monitoring network in Germany remain elevated in parts of the country. In Germany, besides site factors like weather, climate and soil characteristics, studies to identify driving factors of nitrate concentration in the leachate have focused primarily on short-term factors such as immediate land use, nitrogen (N) input, and N surplus. These approaches often overlook the significant time lag between changes in agricultural practices and monitored nitrate concentrations, a delay attributed to the long travel times of nitrate through soil and aquifers as well as potential N legacies, which can span several years or even decades. This highlights the necessity of a more comprehensive analytical framework that incorporates historical data to better predict nitrate concentrations measured at monitoring wells.

To bridge this gap, this study aims to conduct an analysis of land use patterns, crop rotations, and land use changes over a nine-year period within the catchment areas of groundwater monitoring wells. By utilizing detailed field data from the Integrated Administration and Control System (IACS), this research will identify predominant crop rotations and their associated nitrate leaching potential. Emphasis will be placed on understanding how different cropping systems contribute to long-term nitrate loading in groundwater, and how historical land use changes may impact the time course of nitrate concentrations.

This analysis is expected to offer valuable insights into the long-term effects of agricultural practices on groundwater quality, providing a critical step toward developing a robust model framework for predicting nitrate levels in leachate. Such a framework would not only enhance the effectiveness of existing mitigation measures but also inform future policy adjustments, ensuring better alignment with environmental standards and sustainable agricultural practices.

Abstract number–192 Best management practices to deliver load reduction targets in NW Europe under a changing climate – findings from the New-Harmonica project.

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Best Management Practices (BMPs) to minimise the environmental impact of agricultural nutrients are embedded within policy measures and agri-environmental schemes across NW Europe.

Since research into BMPs commenced in the early 2000s phosphorus (P) has been a focus as the main cause of eutrophication in freshwater systems. Buffering measures and

constructed wetlands were among the earliest measures implemented to mitigate P loss through pathway interception. “Next generation” developments of these measures continue to be popular and are deemed effective when sited correctly. The importance of P source control, however, should not be overlooked as excess inputs to soils and reducing accumulated P are ongoing issues. Measures for nitrogen (N) are more source-focussed by comparison and include optimal fertilisation levels and improved slurry/solid manure management and application techniques. Denitrification is the main control option once N reaches the soil matrix, although other important measures include the use of catch and cover crops and applying runoff barriers and buffer strips. However, pollution swapping is an important consideration for nitrogen measures.

Research within the New-Harmonica project has undertaken a review of BMPs appropriate to meeting load reduction targets in four case-study catchments in NW Europe; the Flemish and Dutch Meuse, the Wye in England and Wales and the Neagh-Bann catchment on the island of Ireland. Shortlisted key BMPs have been modelled for each catchment within a set of plausible implementation scenarios. The objective was to determine a suite of BMPs, reflecting developments in research and optimised to the landscape, land use and climate of the four catchments, that would be sufficient to achieve the necessary load reductions. The expected performance of measures under 2050 climate projections was also evaluated, with drier, drought-prone summers and increased volume and intensity of rainfall in autumn and spring likely to affect processes of nutrient release and loss.

Across the four catchments there was considerable alignment in shortlisted options. Similarities in land use and farming practices between the Neagh-Bann and Wye catchments have led to P mitigation being a priority, and between the Dutch and Flemish Meuse where both N & P are the object of BMPs to achieve “Good” WFD status targets.

Stakeholders in each catchment were asked to review and score the potential of each BMP scenario set to address water quality issues in their respective areas. Source control measures generally ranked higher than those targeting runoff and erosion control, such as buffer strips.

Abstract number–194 Mapping Nitrogen and Phosphorus Hotspots in Irish Agricultural Lands Using Raster Data and Geostatistical Techniques: Implications for Water Quality

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The intensification of agricultural practices in Ireland has led to increased applications of nitrogen (N) and phosphorus (P) fertilizers. Excessive nutrient loads pose significant risks to water quality, leading to eutrophication and biodiversity loss in aquatic ecosystems.

Therefore, understanding the spatial distribution and transfer pathways of these nutrients is essential for developing targeted mitigation strategies. The objective of this work was to map the spatial distribution of N and P loads per hectare across Ireland's agricultural regions

using advanced geostatistical methods. In order to identify nutrient hotspots through spatial analysis techniques. Whereby, the possible impacts of high N and P concentrations on water quality and agricultural sustainability can be assessed. Moreover, to inform policymakers and stakeholders to improve nutrient management and mitigation practices through evidence-based recommendations.

In this study, raster data representing soil nutrient concentrations and land use patterns across Ireland were used to model N and P hotspots. Here, we used Empirical Bayesian Kriging (EBK) to interpolate nutrient levels, and predict concentrations in un-sampled locations. Furthermore, Boolean spatial analyses was applied to combine raster layers and identify areas exceeding critical thresholds for N and P concentrations, thereby delineating nutrient hotspots. This integration of EBK and boolean operations enhances the precision of hotspot detection, and offered improved accuracy over traditional kriging methods.

Correlation analyses was then conducted between identified hotspots and indicators of water quality degradation, such as occurrences of algal blooms and elevated nitrate levels in groundwater.

Accurately mapping and identifying nutrient hotspots will provide valuable insights for implementing targeted nutrient management and mitigation strategies in agricultural systems. The findings are expected to contribute to the development of best management practices (BMPs), and to support policy initiatives aimed at reducing nutrient loss to watercourses. Therefore, this study advances the understanding of how advanced geospatial techniques can assess and extrapolate land use impacts on water quality in Ireland. The anticipated outcomes will be used advance our understanding of landscape heterogeneity and land use practices on water quality, and to guide efforts in mitigating nutrient pollution at national and regional scales.

Abstract number–195 Cooperating in agricultural transition and emission reduction by regional deals

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Transition towards a more sustainable agriculture can improve soil quality and decrease emissions of nutrients and pesticides. Close cooperation between farmers, drinking water companies and local water authorities is needed to follow a suitable transition path. This transition can be supported by tools evaluating the impact of land use change and management measures.

In the eastern part of the Netherlands farmers and drinking water company work on agreements to reach common goals in recharge areas. It is intended to use a combination of tools for monitoring land use, monitoring soil and water quality, prioritizing management measures, and evaluating agreed goals. The starting situation can be assessed by a detailed description of land use, soil quality, and water quality. A first assessment was made with a GIS analysis of the recharge areas, groundwater data analysis from the Early

Warning monitoring network and soil quality analysis with the Open Bodem Index tool. A transition towards a sustainable agricultural system without adverse effects on soil and water quality will probably generate less income for farmers. Sustainability implies also a stable and reasonable (financial) contribution to the environmental services farmers offer without direct income. A reward system should be created which really stimulates the desired transition. On LUWQ2025 we present our ideas and dilemmas. What can we expect from funding on EU, national or regional level? Can stakeholders participate in funding for specific goals in protected areas? Farmers claim optimal results if they can choose their own way to reach specific goals. Which reward system is capable to support this freedom? And how can we make arrangements which last for at least 10 years? Can arrangements be coupled to hectares instead of farmers? Our first experiences in setting up such a system will be shared and discussed with participants of LUWQ2025.

Abstract number–197 Harmonized approaches for transboundary groundwater vulnerability assessment in the Estonian-Latvian region

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Groundwater is a critical resource that supports ecosystems, agriculture, and drinking water supplies. Transboundary aquifers, which cross national borders, present unique management challenges as pollution or overexploitation in one country can significantly affect the quantity and quality of the shared resources. The Estonian-Latvian transboundary area demonstrates challenges due to its reliance on both unconfined Quaternary aquifers, vital for local ecosystems and rural water supply, and confined first bedrock aquifers, essential for centralized water systems. This study addresses the need to develop harmonized methodologies to assess groundwater vulnerability and pollution risk, enabling sustainable resource management across borders.

The index-based DRASTIC and modified DRASTIC methods are applied to evaluate the natural vulnerability of unconfined and confined aquifers, respectively. The DRASTIC-L method is used to incorporate land use data into the analysis, providing insights into how anthropogenic pressures influence groundwater pollution risk. To enhance the reliability of the vulnerability assessments, the results are validated using pollutant travel time calculations. By integrating these approaches, the research creates a comprehensive framework that accounts for the hydrogeological complexity of the region.

The results show variability in aquifer vulnerability across the study area. Unconfined Quaternary aquifers are most vulnerable in regions with sandy sediments, shallow groundwater tables, and high recharge rates. Conversely, confined aquifers benefit from protective layers of Quaternary sediments, however, vulnerability varies based on sediment

thickness and hydraulic conductivity. Pollution risk analysis shows that areas with intensive agricultural activity and highly permeable sediments are at the greatest risk, which highlights the importance of land use management in groundwater protection.

The findings highlight the critical need for precise vulnerability assessment techniques tailored to regional geological characteristics. While natural vulnerability maps provide valuable insights into an area's vulnerability to groundwater contamination, integrating pollution risk maps is essential to account for the influence of human activities.

In addition to enhancing methodologies for assessing groundwater vulnerability and pollution risks, this study highlights the importance of international cooperation. Since groundwater flow does not know national borders, protecting this shared resource requires a joint effort to ensure its protection and the availability of clean drinking water for current and future generations.

Abstract number–198 The Network for Monitoring Agricultural Loads and the Effects of Mitigation Measures in Finland

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Agriculture is the most significant contributor to nutrient loads in surface waters in Finland. Current estimates of agricultural nutrient loads are largely based on indirect methods, including modelling and assessments of agriculture's share of total loads of large, mixed land use catchments. Due to insufficient monitoring, evaluating the impacts of water protection measures and load variations remains challenging. To address this, the Finnish Environment Institute, in collaboration with its partners, initiated the development of an agricultural load monitoring network in early 2024 based on several existing monitoring sites.

The network consists of small agricultural catchments across Finland and reference catchments in their natural state. Monitoring methods include water sampling and high-frequency water quality and flow measurements. The primary objectives are to quantify agricultural loads of suspended solids, phosphorus, nitrogen, and organic carbon and to

assess the effectiveness of water protection measures. Catchment sizes in the network range from 70 to 8,000 hectares, with diverse soil types, agricultural practices, and geographical locations.

High-frequency sensor data proved to be critical in detecting changes in water quality and quantity, outperforming biweekly water sampling strategies, which missed high-concentration peaks. For example, high nitrate concentrations were detected following fertilizer application and intense rainfall events, while suspended solids and phosphorus peaks were observed during snowmelt in spring or mild winter conditions.

The implementation of mitigation measures, such as structure lime, gypsum, and two-stage channels, reduced suspended solid and phosphorus loads. For instance, structure lime reduced particulate bound phosphorus concentrations in subsurface drainage flow by 40-70 %, and 12 % at the catchment scale. The floodplains of two-stage channels trapped 2.1-3.5% of suspended sediment and 0.7-2.3% of total phosphorus loads per 1000 m² of floodplain area per year in clayey catchments.

In the near future the monitoring network aims to expand high-frequency monitoring and examine in more detail the relationship between field management practices, nutrient loads, and the impacts of measures implemented within these agriculture dominated catchments.

Abstract number–199 Detection of nutrient input pathways along the shores of a shallow lake with optical sensors

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The European Union Water Framework Directive's (WFD) target to achieve a "good" ecological status for water bodies by 2027 has not yet been met for most lakes in Schleswig-Holstein, Germany. High nutrient inputs and internal loading are among the main causes for this status.

The aim of this study was to determine nutrient input pathways into a lake with a higher spatial density of measurements along the lake shores. Langsee is a eutrophied shallow and polymictic lake. It is connected to the river system of Füsinger Au, the largest tributary to the Schlei fjord, Baltic Sea. The northern shore is already classified as a nutrient-contaminated area under the Fertilizer Ordinance. To capture nutrient input pathways into Langsee, mobile UV/Vis-sensors were mounted on a small boat and paddled along the water bodies. The sensors were calibrated with data from the river system and measured nitrate nitrogen, total

phosphorus, soluble reactive phosphorus, SAC 254, turbidity, and caffeine as an indicator for waste water inputs. Physicochemical parameters such as pH, electrical conductivity, oxygen levels, and temperature were recorded with multi-parameter sensors. Location data were continuously recorded and synchronized with the sensor measurements. At the same time, grab sampling was conducted to assist with sensor calibration for reliability.

The Langsee measurements successfully captured all targeted parameters. Spectral measurements and grab sampling showed moderate correlation for orthophosphate and total phosphorus but poor correlation for nitrate nitrogen with the river samples calibration. Given the different matrix conditions in lakes versus rivers, the discrepancies between spectral and grab sample data were recalibrated with an additive constant, developed by minimizing the squared differences between the grab samples and corresponding spectral values using Brent's method.

By combining results from physicochemical parameter measurements with land use maps, including the locations of pipe inlets and distinct land use patterns, valuable insights into the nutrient dynamics of Langsee were gained. Nutrient hotspots were identified based on measurement peaks, with some unexpected results observed that did not align with adjacent land use patterns. The reasons behind these variations are being further investigated, considering the hydrological conditions, the characteristics of the shallow lake, and sensor performance under complex field conditions. This first deployment of mobile sensors in Langsee showed promising results and, with further improvements, could reliably support future restoration and environmental management plans to improve the lake's water quality.

Abstract number–201 Particulate and dissolved phosphorus removal in agricultural drainage waters with a compact filter system

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Phosphorus (P) losses from tile-drained agricultural fields significantly threaten surface water quality and biodiversity by contributing to eutrophication. Conventional edge-of-field filter systems primarily target dissolved reactive phosphorus (DRP) and less particulate phosphorus (PP), although both P forms are present in drainage waters. To address the spatial and temporal variability of these different P forms, a more integrated filter approach is needed.

This study assesses the performance of a dual-unit filter system designed to capture both DRP and PP in agricultural drainage water over one drainage season. The system consists of a lamella-type sediment filter and a porous reactive filter in the form of iron-coated sand (ICS) to retain PP and DRP, respectively. Drainage water from an arable field with loamy soils near Odder, Denmark, was pumped continuously into the filter system from October 2020 to May 2021. The hydraulic load to the sediment filter amounted to 12000 m³. A representative fraction of 10% of the discharge from the sediment filter was then led through the reactive filter.

Our results showed promising yet variable P removal rates. The sediment filter and the reactive filter retained, respectively, 42-75% and 29-79% of the PP and DRP loads. The total monthly phosphorus (TP) removal efficiency of the system ranged from 34% to 88% averaging 70% overall. Our findings suggest that a filter system combining separate units for PP and DRP retention can significantly improve P removal from drainage waters and thus contribute to reducing the risk of eutrophication in surface waters.

Abstract number–202 Nitrogen-input into groundwater and surface waters in Germany

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In Germany, a system for monitoring the effects of nutrient management strategies was recently launched. With this system, Germany will in future report annually to the EU Commission on the progress and success of nutrient management strategies. However, due to residence and flow times as well as transformation processes in the soil and groundwater nexus, the effects of agricultural measures on nitrogen emissions and subsequently on monitored data on nitrogen emissions is sometimes not obvious.

For this purpose, the nitrogen model system mGROWA-DENUZ-WEKU has been included into the impact monitoring system to simulate the N-inputs from diffuse sources via the pathways water erosion, wash-off, artificial drainage, groundwater, interflow and atmospheric deposition. N inputs via these pathways represent the indicators that will be used for compliance checking for nationwide annual impact monitoring reporting to EU-COM.

The presentation will on one hand outline the challenges to implement the N model system Germany-wide, considering the regional hydrological specifications (features) of the 16 Federal German States. On the other hand, Germany-wide model results will be presented and how these results are included into the monitoring system to document the effects of nutrient management strategies across Germany.

Abstract number–203 Addressing Phosphorus Pollution in Interconnected Danish Lakes: A Spatial Environmental-Economic Analysis

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Danish lakes are regulated to fulfill the Water Framework Directive to achieve good ecological status by 2027. However, 76% of these lakes currently fall short of that goal. Monitoring data reveals that, there has been minimal progress since the 1990's, with recent increases in nutrient concentrations.

This study presents a spatial, integrated environmental-economic modeling approach, TargetEconP, to identify cost-effective phosphorus (P) reduction strategies in Danish lakes. Recognizing the interconnected nature of lakes, we apply a "lake-chains" concept, acknowledging that interventions in one lake can have cascading effects downstream. TargetEconP incorporates extensive spatial datasets on agricultural production, costs and effects of measures, and the potential to implement measures at agricultural land and in or near streams. It builds on the nitrogen-focused TargetEconN model for coastal catchments, which is further developed for P in the Biodiversa funded project FreshRestore, and as part of public consultancy projects funded by the Danish Ministry of Environment. The model includes 447 lakes and their catchments, most connected in chains, and over 20 measures, both nature-based and technical.

Applying P reduction targets from the Danish Water plans for 2021-2027 for 208 Danish lakes, we hypothesize that targeted strategies across lake-chains can improve P abatement cost-effectiveness. Given uncertainties in estimating P reduction efficiencies, we explore scenarios with varying efficiencies for land retirement on organogenic soils, restored wetlands, and wetlands especially targeted to phosphorus abatement. An additional sensitivity analysis examines the impact of varying degrees of connectivity between lakes. The total P reduction target is 142,165 kg. Baseline costs are 422.37 million DKK, achieving a P reduction of 112,007 kg. Scenarios with varied reduction efficiencies show cost deviations of -8% to +14% from the baseline, with target compliance deviations from -14% to +15%. Sensitivity analysis reveals that a variation of -30% to +30% in the P transport coefficient affects cost by -8% to +21% and target compliance by -19% to +34%.

Our results advance the literature on integrated environmental-economic modeling, offering insights for policymakers and researchers on cost-effective P reduction strategies. We propose a strategic combination of measures selected for their cost-efficiency in reducing P, while acknowledging that current measures are insufficient to meet Denmark's P reduction targets. The results underscore the importance of spatial modeling that considers the interconnectedness of water bodies as well as heterogeneity between catchments in effects and costs of measures.

Abstract number–204 Spatially Differentiated Assessment of Denitrification Conditions in Groundwater across Germany

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To comply with nitrate-specific environmental standards, the capacity for nitrate removal in groundwater is a crucial factor. However, few studies address the spatial heterogeneity of this process and its associated impacts on a regional scale. We advance a procedure originally developed by Wolters et. al (2022) to derive spatially continuous estimates of denitrification conditions in groundwater based on the interpolation of measurements of the redox-sensitive parameters oxygen, nitrate, iron, manganese and DOC. We applied this procedure to Germany, using measured values from more than 23,000 groundwater monitoring sites from 2010 to 2022. Discrete ranks were assigned to the concentrations of each parameter based on their redox class. These ranks were averaged over the available time period and over each parameter, resulting in a classified mean value describing the nitrate degradation conditions in groundwater at each site. The interpolation of the measuring sites was spatially confined by using a Germany-wide data set consisting of 144 hydrogeochemical reference units. An optimized, iterative inverse distance weighting approach was chosen for interpolation within each hydrogeochemical reference unit. Plausibility analyses have shown that the method presented here is suitable for the regionally differentiated derivation of denitrification conditions in groundwater. For regions with denitrifying groundwater conditions, the results provide an explanation for frequently observed discrepancies between high nitrate emissions from the soil and low nitrate concentrations in groundwater of intensively used agricultural areas.

Abstract number–205 Impact of derogation from the Nitrates Directive on water quality: comparison of five European countries

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In Northwest Europe, agricultural activities significantly influence the quality of shallow groundwater and surface water in agricultural areas. The EU Nitrates Directive (91/676/EEC) aims to protect these water bodies from nutrient pollution by limiting nitrogen use in livestock manure to 170 kg per hectare annually in nitrate-sensitive zones. Since 2005, several countries, including the Netherlands (2005-2026), Ireland (2006-2026), Northern Ireland (2007-2022), Belgium (Flanders) (2013-2023), and Denmark (2013-2024), have received derogations permitting higher manure applications under specific conditions.

When applying for derogation, Member States (MS) must demonstrate that it will not

negatively affect water quality. In these countries, climatic conditions, higher grassland yields, and greater nitrogen losses to the air theoretically ensure that additional manure application does not lead to additional nitrate leaching. This is due to their temperate climates, characterized by ample rainfall and relatively wet soils.

The derogation allows for the application of higher amounts of livestock manure under certain conditions. A monitoring network should reveal the impact of derogation on nitrogen and phosphorus losses from soil and on water quality. Despite differences in the design of the monitoring networks of MS, all networks have long-term measurements on derogation farms.

In this study, we are collecting an overview of the different histories of derogation of the countries, including the rationale for their applications, the design of monitoring networks, and their similarities and differences. For this purpose, we are analyzing long-term time series data from derogation monitoring networks in the Netherlands, Ireland, Northern Ireland, Belgium (Flanders), and Denmark. These datasets provide insights into nitrogen and phosphorus losses from soil and their impact on water quality.

Our first observations indicate that, although there are differences between countries, nutrient concentrations on derogation farms do not significantly differ from national trends. However, there has not been enough improvement in the overall water quality at the national level.

This study aims to provide insights from long-term monitoring of water quality and agricultural practices under derogation regimes, focusing on how these practices impact environmental sustainability. The full results will be presented at the LuWQ2025 conference.

Abstract number–206 Monitoring and Evaluating Targeted Mitigation Approaches to Improve Water Quality: Measures for Water

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The preliminary findings of the research project “Measures For Water” presented here. The project intends to evaluate the effectiveness of practical on-farm mitigations solutions which align with the €60m Irish government WaterEIP, that has been responsible for advising farmers on how to incorporate nature based solutions (NbS) and other targeted measures into farmed landscapes. These can include a bespoke, “treatment train” approach where a cluster of mitigation measures targets both sediments, particulate forms of nutrients and dissolved nutrients. A coupled approach (linking catchment scientists and socio-economic experts) draws on catchment modelling approaches using the Catchment Runoff Attenuation

Flux Tool (CRAFT) to provide the evidence on the necessary scale and effectiveness of NbS measures. This has been evaluated at the scale of the Agricultural Catchments Programme (ACP) research catchments (circa 10 km²) in the SE of Ireland. The modelling outputs (reductions in sediment and nutrient loadings as a function of both the number and efficiency of the modelled measures) can provide a form of look-up enabling catchment managers to assess the aggregate effects of these measures. This will ultimately feed information back to a common assessment, linking into the socio-economic assessment component of the project which will analyse the willingness of farmers to adopt these measures and any barriers to this process.

Abstract number–207 Large-scale land use changes ahead: Reducing nitrogen loss to the aquatic environment, greenhouse gas emissions from the agricultural sector and restoring nature in “a green Denmark”

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While policy-focus in Denmark has been somewhat fluctuating, but constantly remained at a high level since the 1980s when it comes to reducing nutrient loads to Danish coastal waters, political demand for climate action, reducing the impact of the intense agricultural production, has only been sky-rocketing over the last few year. One political agreement has been hunting the other, only increasing ambitions and targets over time.

In 2024, negotiations reached new level and forum, as the government invited main stakeholders to join the so-called “green tripartite”, resulting in an agreement in June 2024. In this agreement on “a green Denmark”, the Danish government, the biggest farmers organization “Danish Agriculture & Food Council” and, amongst others, the “Danish Society for Nature Conservation” agreed on a number of actions and measures over the next few years, which inevitably will lead to large-scale land use changes of historic scale.

While political discussions with the parliament are still on-going (in November 2024), the following key initiatives are expected to be cornerstones of the follow-up-agreement by the political parties:

- Reducing greenhouse gas emissions from the agricultural sector through CO₂e-taxes on e.g. emissions from livestock and drained peatlands from 2030 and 2028, respectively
- Establishment of Denmark's Green Area Fund (approx. 5.4 billion €), supporting efforts in strategic land purchases, including 250,000 hectares of new forest by 2045 and restoration of 140,000 hectares of rewetted peatlands by 2030

- Reducing nitrogen loss with a focus on farm-level and targeted emission quotas, administrated in a new nitrogen regulation from 2027
- Subsidies for technological transition, including a dedicated subsidy pool for biochar and methane-reducing feed additives

The initiatives will transform 15% of the existing Danish agricultural land into forests, restored peatlands, and more, while simultaneously cutting greenhouse gas emissions from the agricultural sector by 60% by 2030. Moreover, the agreement foresees higher engagement and contributions from both municipalities and coastal water councils in catchments facing especially large challenges.

The presentation will give a follow-up on the agreement and report on the status of the various initiatives, including the work of the ministry, which has been newly established for this specific purpose in 2024.

Abstract number–208 Historical and Future Nitrogen Sources, Retention, and Exports in the Hunze and Rhine River Basins

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This study simulates the long-term nitrogen (N) flux from source to mouth in the Hunze and Rhine river basins by integrating models of hydrology, nutrient inputs, and in-stream retention. It investigates the spatial and temporal dynamics of N sources, retention, and exports across the basins. Decades of concerted efforts to mitigate agricultural and sewage-derived nutrient pollution have led to significant improvements in water quality, bringing concentrations close to the target of 2.5 mg/L. However, since 2000, the decline in N concentrations has stagnated, with elevated levels persisting during winter months. By providing a spatially explicit allocation of N sources and analyzing future reduction scenarios, this study identifies strategies to achieve efficient and cost-effective nutrient reductions that align with environmental targets. The findings offer valuable insights to guide evidence-based and socially acceptable policies, contributing to the long-term goal of sustainable water quality management in these complex river systems.

Abstract number–209 From 20 years of water quality and quantity monitoring at a river scale towards modelling in the future

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In order to perform modelling tasks and simulate potential impact of changes in climate, agricultural land management, and wastewater treatment or implementation of water and nutrient retention measures in agricultural landscapes there is a need for representative and reliable data sets on water quality and quantity relevant for a river of interest. Water quality monitoring activities at fifteen sub-basins of the Berze River was started in 2005 and continues until present. Water samples have been collected on a monthly basis and analysed for total nitrogen, nitrate nitrogen, ammonium nitrogen, orthophosphate phosphorus, and total phosphorus at an accredited laboratory. One river gauging station is in operation at the outlet of the Berze River since 1927 providing data sets on discharge measurements on a daily basis.

In recent years geospatial information on hydrological network including subsurface drains, collectors, open ditches, rivers, reservoirs, and lakes, land use, soils, agricultural crops, livestock facilities, small hydropower plants, wastewater treatment plants and digital elevation models have become more accessible and applicable to interpret the results of water quality monitoring and perform modelling tasks.

Overall, the results of water quality monitoring show positive trends in nitrate nitrogen and total nitrogen concentrations in fifteen sub-basins of the Berze River, while orthophosphate and total phosphorus concentrations tend to decrease over the time period of 20 years. Drought and flooding conditions have a direct and indirect effect on nutrient concentrations in rivers. Land use patterns in terms of share of agricultural land, forest and semi-natural areas, wetlands, water bodies, and artificial surfaces at the sub-basin level have impact on nitrogen and phosphorus concentrations in rivers.

The monitoring data and geospatial information collected, systematized and analyzed has become of high importance to perform modelling tasks within the NORDBALT-ECOSAFE project in order to simulate the effects of buffer strips, crop rotation, application rates of mineral and organic fertilizers, and implementation of constructed wetlands on water quality and quantity, where the modelling results will be shared and considered by policy makers at the Ministry of Agriculture.

This study was funded by a grant from the EU Horizon project NORDBALT-ECOSAFE (Grant Agreement No. 101060020).

Abstract number–210 Water levels and dissolved organic carbon in deep-drained peatlands treated with subsurface irrigation

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Agriculture on deep-drained peatlands causes high greenhouse gas emissions due to intensive mineralization of the peat by low groundwater tables. Facing the ongoing climate

change, carbon emissions from the agricultural sector have to decrease by appropriate methods by now. We tested subsurface irrigation on a grassland with organic soil to reduce further mineralization of the remaining peat by raising the water level. Still underestimated are the consequences for water quality due to a raising water level in drained peatlands. Our project also focuses on the long-run development of soil water contents which are probably controlled by water fluctuation. We compare a treatment site (TS), running subsurface irrigation (SI) by pumping groundwater, with a conventional managed reference site (RS). The experiment run from 2019 to 2025, where water samples are taken every second week from three soil depths (15, 30, 60 cm) of both sites by permanent installed suction plates (3 plots each). The water analyses involve pH, electrical conductivity, cations and anions, but the preliminary examination focused on dissolved organic carbon (DOC) in soil water. The water level at both sites follows seasonal fluctuations, more pronounced at the RS (-1.27 to -0.06 m) than at the TS (-0.81 to -0.02 m). With the exception of the 60 cm horizon of the RS, DOC concentrations also follow a seasonal trend with a maximum during summer and autumn. Depending on the depth, the mean DOC concentrations in the RS are higher in 15 cm (335 mg/l) and lower in 30 cm (269 mg/l) than in the TS (260 mg/l and 333 mg/l respectively). In 60 cm, the DOC concentration increases with time at the RS, whereas the concentration decreases at the TS. We identify the effect of SI by carrying out t-tests: During the pumping period (summer/autumn), the water level at the TS decreases less than at the RS. The DOC concentrations increase on average 26 mg/l (30 cm) more at the TS than at the RS during the pumping period. No effect was found for the 15 cm horizon. In conclusion, SI intensifies DOC concentrations in the 30 cm horizon, but decreases DOC concentrations in deeper horizons.

Abstract number–211 Long-term Salinization of Production Aquifers in Irrigated Agricultural Landscapes

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Global food systems increasingly rely on agricultural production with irrigation, including irrigation with local groundwater. While overdraft and nitrate have been identified as key threats to groundwater-dependent agricultural regions, limited work has been conducted on the potential long-term salinization of aquifer systems dominated by local irrigation pumping as the major groundwater outflow. Recent work has defined the fundamental concept of “anthropogenic basin closure and groundwater salinization” (Pauloo, Fogg, Guo, and Harter, 2021): the salinization of aquifers where irrigation return flows act as a significant recharge source and groundwater pumping for irrigation is the dominant groundwater outflow from the aquifer. Even in aquifers with seemingly sustainable water level conditions, the partial recirculation of groundwater used for irrigation leads to accumulating salt concentration in the aquifer system. Here we present an analysis of decade-, century-, and millenium-scale

salinization in one of the largest alluvial aquifer systems on Earth that is dominated by irrigated agricultural activities and a wide range of hydrologic and water management conditions. The 50,000 sq.km Central Valley aquifer system in California, USA, serves several thousand community wells, over 20,000 agricultural irrigation wells, and over 50,000 domestic wells. About 30,000 sq.km of this region are irrigated with either surface water, groundwater, or both. In response to groundwater salinization concerns, a collaborative stakeholder driven process known as CV-SALTS (Central Valley Salinity Alternatives for Long Term Sustainability) was formed in 2006 to develop a Comprehensive Salinity Management Plan for the basin. As a part of this effort, we have developed a detailed understanding of current salt loading from the mixed agricultural and urban landscapes in this region and adopted the NPSAT simulation framework, a numerical tool to assess long-term dynamics of nonpoint source pollutants through three-dimensional flow and transport simulations of the integrated hydrologic system, to account for recirculation and accumulation of salts in the groundwater system. Our results confirm the premise of earlier, conceptual analyses and provide additional insights into the spatio-temporal distribution of risk for salt accumulation in this vulnerable aquifer system. The salinization risk is significantly delayed and tempered by the travel time in the vadose zone and within the groundwater flow system, modulated by the depth and pumping rate of wells, the fraction of available groundwater recharge used for groundwater irrigation, irrigation efficiency and resulting recharge rates from the agricultural landscape, salinity in surface water irrigation, and other factors. While delayed, it poses a significant long-term degradation risk that may severely impact future food production systems in this region unless measures are implemented to address salt accumulation.

Abstract number–212 Effects of regulations and other drivers on nitrogen use in Germany

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Between the years 2016 and 2023, the purchase of mineral nitrogen fertilisers in Germany has dropped by more than 40 %. In this contribution, we analyse the possible drivers of this unprecedented reduction of nitrogen input in the farm sector. Potential drivers discussed by researchers, policy makers and practitioners are drought events in 2018 and to a lesser extent in following years, changes in the fertiliser market such as price developments and the shortage of supply due to Russia's war of aggression against Ukraine, and effects of German fertiliser legislation. In 2017, the Fertilisation Ordinance implementing Nitrates Directive in Germany has been substantially reformed. The calculation of the surface balance was made more stringent, and exceeding a certain threshold level of nitrogen surplus was defined as infringement punishable by a fine. Further, rules for N application in autumn, storage capacities and slurry spreading technology were tightened. After the judgement of the European Court of Justice against Germany, the surface balance was

abolished, and nutrient planning became the key for good farming practice. We analyse national time series data on fertilizer purchase, prices, and N balance, and data of the German Farm Accountancy Data Network (FADN). Our results show that price changes do not explain the drop in fertilizer inputs until 2022. Between 2016 and 2021 the price relation of N fertiliser and agricultural products was even advantageous for higher N use. This changed abruptly with the fertiliser supply shortage and price increase in 2022 and 2023. The drought event in 2018 had an impact on N inputs, but can not explain the almost continuous decline between 2016 and 2021. Using FADN data on farms below or above the threshold level of nitrogen surplus in 2017/2018, we can show that farms not in compliance with Fertilisation Ordinance 2017 reduced their N mineral fertiliser input to a much higher extent compared to those farms compliant with this rule. For farms in infringement with the threshold level of N surplus account for about two-thirds of N fertiliser reduction in the whole farm sample. Binding rules for fertiliser planning introduced in 2020 do not yet show clear effects. We conclude that rules limiting the farm N surplus can be effective, and recommend to strengthen N balance-based policy approaches in Germany and beyond.

Abstract number–214 Approaches in climate adaptation for water quality and quantity management: A Nordic comparison of farm level action towards water resilience

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Increasingly, the Nordic farms and agricultural landscapes face various weather extremes challenging longstanding design and effectiveness in agricultural water management strategies. Adaptation to new patterns in precipitation, water availability, runoff and drainage affect crop growth, yield quantity and quality, as well as effectiveness in of multiple “best management practices” for environment and water quality ambitions. With high investment carried by farm enterprises for the measures for climate resilience, the costs are mounting, whilst effectiveness is challenging. The classic dilemma is becoming more urgent: what transformative measures are needed for water management that can operate under extreme weather, whilst maintaining high productivity in crops whilst and fulfilling water quality and quantity ambitions?

This presentation outlines a multi-actor approach in the PRECILIENCE project to address

challenges of extreme weather to adapt agriculture in Nordic- Baltic (DK; FI; NO; SE) through water management, at farm to landscape level. The aim is to explore feasibility across the technology continuum, from soil health management, and erosion control, surface/subsurface drainage, to irrigated technologies with green-grey infrastructure and storage for recirculation and reuse of water and nutrients. We share an outline of joint protocol, for technology testing and evaluation across regions and agro-ecosystems, with explicit effort to address both water quantity and quality potential impacts. We discuss the notion of transformative and adaptive capacity of agricultural water management technologies currently in use and being innovated (piloted) by farmers and communities. The project results are expected to inform on technology effectiveness and capacity to transform productivity and sustainability in view of current and future extreme weather, whilst sustaining high performance to meet environmental and water quality standards.

Abstract number–216 Comparing of agricultural systems: sustainability vs. intensification in mountain farming using the ARMOSA Model.

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This work emphasizes the critical role of small-scale mountain farming systems, focusing on coffee, cocoa, and arable crops cultivated within the FAO Business Incubator and Accelerator for Mountains and Islands initiative. Mountain agriculture is defined by its unique, sustainable practices adapted to challenging terrains and climates. Small-scale farmers, who produce about one-third of the world's food, are essential for food security. Smallholders contribute 90% of global cocoa and 80% of coffee production, but 44% of small-scale coffee farmers live below the poverty line, highlighting their economic challenges.

Indigenous communities, comprising 476 million people across 90 countries, play a key role in preserving traditional farming and environmental practices, safeguarding over 80% of global biodiversity. Their traditional knowledge and stewardship are essential to sustainable agriculture.

Mountain agriculture, despite lower yields compared to intensive systems, offers critical ecological services. This work evaluates the hidden costs of speculative agricultural intensification, which prioritizes profit over environmental health, using the process-based model ARMOSA (Analysis of cRopping systems for Management Optimization and Sustainable Agriculture). ARMOSA is a quantitative model that assesses the environmental performance of various cropping systems, focusing on water dynamics, nitrate leaching, runoff, soil erosion, greenhouse gas emissions, and changes in soil organic carbon stocks. We evaluated 82 cropping systems across nine countries in South and Central America,

Asia, and Africa, using ARMOSA to compare existing agricultural systems with a constructed baseline scenario. The baseline represents a profit-driven approach with intensified agricultural practices, such as increased fertilization, deeper tillage, larger fields, and simplified crop rotations. Both systems were modeled under identical conditions using the same soil and weather data.

The model simulations showed that nitrogen leaching in current systems ranged from 0 to 90 kg N ha⁻¹ y⁻¹, while intensified systems shows a leaching increase in 80 of 82 cases. In average the leaching increase was 28 kg N ha⁻¹ y⁻¹. Erosion in current systems averaged 2.8 t ha⁻¹ y⁻¹ but rose to 7.9 t ha⁻¹ y⁻¹ under intensification. Greenhouse gas emissions approximately doubled. When considering the economic costs of these negative externalities, the yield gains in intensive systems are outweighed by their environmental and economic costs.

Abstract number–217 Catchments as the first stage of treatment

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Intensively farmed areas contribute largely to water quality degradation worldwide. The intensification of agriculture in many European nations has heightened the risk of water bodies failing to achieve the 'good ecological status' objective set by the EU Water Framework Directive (WFD). In England and Wales, diffuse agricultural pollution poses a major threat to Water Framework Directive (WFD) compliance in rivers and streams. Key concerns include elevated nutrient levels, oxygen depletion, and sedimentation, negatively impacting in-stream habitats. Soil erosion, particularly from bare or compacted arable fields, exacerbates the transport of diffuse pollution through surface runoff.

The Ouseburn River in Newcastle upon Tyne, UK faces significant water quality challenges, including diffuse pollution from agriculture, urban runoff, and habitat degradation. This contributes to its "moderate" classification under the Water Framework Directive (WFD). This study investigates the effects of two nature-based solution features – a retention pond and a re-meandered section of one of its tributaries – on water quality parameters, including nutrients and microbial contaminants. The primary objectives were to assess the effectiveness of the pond and the meander in reducing pollutants and improving water quality in the upper Ouseburn.

Statistical analyses of field data compared upstream and downstream locations in both systems for parameters such as total nitrogen (TN), total phosphorus (TP), ammonium, and microbial indicators (e.g., *E. coli*, faecal coliforms). The results show that the retention pond significantly reduced nutrient and microbial concentrations, highlighting its effectiveness. In contrast, the reshaped meander exhibited only minimal changes in water quality, suggesting that it has limited capacity to reduce contaminants. This research contributes to developing

sustainable water management strategies and offers insights into mitigating agricultural impacts on water quality in rural catchments.

Abstract number–218 Optimising Agronomic Practices for Nitrogen and Carbon Management in Intensive Livestock Farming: A modelling analysis on the Lombardy Plain.

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A regional modelling analysis of carbon- and nitrogen-related processes was conducted in the Lombardy Plain with intensive agricultural production to test the effect of optimised agronomic practices (i.e. inclusion of a cereal or Brassicaceae as an autumn-winter cover crop in the crop rotation; underground or surface distribution of livestock manure) on livestock farms. The ARMOSA simulation model was used to estimate the potential effect of agronomic soil management on organic carbon dynamics and nitrogen losses through leaching, volatilisation and nitrous oxide emission.

The simulated scenarios were defined with the aim of representing the currently adopted and potentially improved cultivation contexts in 36 representative soil scenarios. For each representative soil, two organic carbon values (0.7% and 1.9%) were adopted for the first soil layer, resulting in 72 soil parameters. Crop rotation data and long-term meteorological data, specific to each municipality, were superimposed on this layer. This made it possible to cover the entire Lombardy plain.

High-yield crops are essential to maintain SOC and nitrogen levels, especially in fine-textured soils with better water retention and reduced nitrogen leaching. Coarser soils, where nitrogen is more prone to leaching, particularly benefit from cover crops, which help conserve nitrogen through organic matter inputs.

Mustard sown in September grows rapidly in the autumn, experiencing frost by the end of November, but with high annual variability. Rye has slower growth with low variability of nitrogen retention over the years. The short growing periods of these cover crops effectively reduce nitrogen leaching, with mustard and rye producing comparable benefits despite their different growth dynamics. Increasing the frequency of cover crops in rotations could further mitigate nitrogen leaching.

Regarding nitrogen application, subsurface slurry application reduces volatilisation by 80% compared to surface application. Conservation practices, such as minimum tillage and cultivation of cover crops, improve nitrogen retention and SOC, particularly when cover crops finish late.

The inclusion of a cover crop in only one year of the three-year rotation significantly reduces nitrogen losses in the growing months alone, regardless of soil type and climatic conditions.

This suggests that the systematic cultivation of cover crops in place of bare soil has benefits in terms of reduced nitrogen losses and increased SOC, offering viable opportunities to utilise manure as a nitrogen fertiliser.

Abstract number–219 Climate change effect jeopardizes the effectiveness of the natural small water retention measures in mitigating nitrate losses in an agricultural catchment in Poland

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Natural Small Water Retention Measures (NSWRMs) are small and multi-functional measures for the retention/management of water and nutrients in the landscape, thus addressing drought/flood control, water quality problems, climate change adaptation, etc. While NSWRMs are meant to reduce nutrient losses from agricultural catchments, future climate change may act in an opposing direction, thus creating a challenge for achieving good ecological status of water bodies. This study aimed to assess the performance of selected NSWRMs in mitigating nitrate losses from diffuse sources under future climate conditions in a small agricultural lowland catchment in the Cuiavia region in central Poland, one of the driest parts of the country. The area features intensive farming practices, leading to excessively high nitrate concentrations in water bodies.

We applied the Soil & Water Assessment Tool Plus (SWAT+) model to (1) simulate daily discharge and nitrate concentrations for the baseline period; (2) project the effect of climate change on the flow regime, nitrate losses and in-stream nitrate concentrations and (3) simulate the effectiveness of selected NSWRMs under current and future climate. The SWAT+ modelling protocol and a scripted workflow established in the OPTAIN project were used to harmonise modelling across 14 European catchments.

The model performance in calibration was satisfactory, with the Kling-Gupta Efficiency exceeding 0.8 for discharge and 0.6 for nitrate concentrations. Climate change is projected to accelerate the water cycle in the catchment, with increased precipitation, evapotranspiration and streamflow under most scenarios and time horizons. Tile drainage, the primary flow pathway in the catchment, is projected to increase by more than 50% under RCPs 4.5 and 8.5 for the far future (2071-2100). High increases in nitrate losses, reaching 100% for the far future under RCP8.5, are projected under all emission scenarios for all future horizons. The considered NSWRMs, such as: micro-reservoirs located on drainage ditches, afforestation, low tillage and cover crops, lead to a modest reduction of nitrate losses under the current climate, typically not exceeding 20%. The combined climate change and NSWRM scenarios show that the climate change signal strongly reverses the positive signal from NSWRM implementation. Our study shows that predominantly “wet” climate change scenarios for Central Europe may negate the positive role of sustainable measures

in catchments with high diffuse pollution of nitrates. Thus, in the long run, reducing the intensity of farming practices may be the only solution to improve the water status in such catchments.

Abstract number–221 Effect of microalgal biostimulants used in agriculture: An ecotoxicological assessment

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The growing global population and rising food consumption have inevitably raised the demand for agricultural food products. The effects of these agricultural practices on environmental quality and climate change are of critical importance. It is essential to achieve a balance between efficient food production and sustainable agricultural methods. Developing such a scenario requires a multifaceted approach which includes optimized nutrient input and an increased crop tolerance to environmental stress. Microalgal biostimulants are an example of innovative bioresource-based technology that aims to increase crop productivity while reducing agriculture's environmental impact. The development and implementation of this technology is hindered by a lack of scientific knowledge. Microalgae are said to elevate nitrogen waste products (e.g., ammonia, nitrite, nitrate), which become toxic at elevated concentrations and may significantly degrade soil and surface water quality. Therefore, in this study we examine the potential ecotoxicological impact of microalgal biostimulants on non-target aquatic and terrestrial organisms. We performed toxicity tests to document and understand the potential ecotoxicological impact of microalgal biostimulants (*Spirulina platensis*, *Chlorella vulgaris*, *Nannochloropsis gaditana*, *Dunaliella salina*, *Isochrysis galbana*, *Porphyridium purpureum*) on representative organisms for both terrestrial and aquatic ecosystems. The tests were performed with extracts of microalgae at concentrations of 0.01 g/L, 0.05g/L, 0.1g/L, 0.25g/L, 0.5g/L, 1g/L. The experiments were performed using model organisms *Daphnia magna* (water flea) 48 hours mortality/immobilization test and 21 days reproduction test, *Eisenia fetida/andrei* (earthworm) 21 days mortality test, and *Danio rerio* (zebrafish) 120 hpf acute toxicity test. At the highest concentrations (1g/L and 0.5g/L) of *Spirulina platensis*, *Chlorella vulgaris*, *Isochrysis galbana* there was significant mortality in *Daphnia magna* 48 hours test which is indicative of an ecotoxicological effect. *Isochrysis galbana* and *Spirulina platensis* showed the highest mortality for *Danio rerio* at the highest concentrations (1g/L, 0.5g/L, 0.25g/L). During the tests, significant oxygen depletion was observed, particularly at higher concentrations of *Spirulina* (1 g/L, 0.5 g/L, and 0.25 g/L). So far optimal biostimulant concentrations appear to be reached at concentrations < 0.1 g/L. Microalgae exposure produced more neonates in the chronic *Daphnia magna* test than in the control group. Conversely, the presence of microalgae had no detrimental effect on the survival of *Eisenia fetida/andrei* indicating that this species was able to withstand the conditions. However, more bioassays would be

required to understand the effect of these microalgae on water, soil and non-target organisms at this and lower concentration.

Abstract number–222 Phosphorus pollution in Germany: actual state and developments

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About 90 % of all surface water bodies in Germany do not achieve a good status, whereby excessive nutrient inputs play an important role. Apart from nitrogen, diffuse and point source emissions of phosphorus (P) are a major obstacle. Although significant P reductions have been achieved in the 1980s and 90s, mainly by the installation of the third purification stage at larger wastewater treatment plants, P concentrations levels in many surface waters have stagnated over the last 20 years, thus hampering the achievement of a good status of surface waters according to WFD.

The MEPhos model developed at Research Centre Jülich FZJ considers both, P inputs into surface waters from diffuse sources (water erosion, wash-off, artificial drainage, groundwater, interflow and atmospheric deposition on waters) as well as P inputs from point sources and urban systems (municipal waste water treatment plants, industrial effluents, rainwater sewers, combined sewer overflows and cesspits). Model applications in Germany are carried out since more than 15 years on behalf of individual Federal states.

On Federal State level, area-differentiated model results on the source-specific level of P emissions are used to determine the role of urban water management and agriculture and to implement selected area-adapted measures for P reduction. The application of MEPhos therefore supports the updating of river basin management plans and programs of measures of the past and for the coming management cycle under the WFD.

On national level, MEPhos is integrated since 2022 in the impact monitoring system that has been developed in Germany in the course of the EU's infringement proceedings against Germany for failing to implement the Nitrates Directive.

The presentation will highlight some model results regarding P pollution of water bodies for selected Federal German states and the various challenges involved in achieving the WFD objectives. In addition, exemplary results of the nationwide modeling with high-resolution input data will be presented and discussed. Finally, an outlook is given on what P reductions can be expected from agricultural measures currently being discussed as well as from the revised EU urban wastewater treatment directive.

Abstract number–225 Leaching of mineralized soil nitrogen is highly influenced by vegetation type

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A significant part of the mineralization of soil nitrogen (N) takes place during autumn and winter, and autumn vegetation is crucial for how much of the mineralized N that is potentially lost by nitrate leaching on agricultural land. We have quantified the proportion of mineralized N lost by nitrate leaching in four cropping systems: 1) permanent grass, 2) spring barley with a cover crop, 3) spring barley without cover cropping, and 4) a system without vegetation. The study took place over 2 years in 1.5 m deep lysimeters where the topsoil N was labelled by using ¹⁵N-labelled fertilizers in a period 25-30 years before the test period (Sørensen et al. 2023). In the years before the test period all lysimeters were covered with set-aside grassland. The soil was a sandy loam with 11 % clay. The leaching and crop uptake of labelled N was measured during two leaching seasons with the same crops growing in each year. By relating ¹⁵N leaching from cropped soil to ¹⁵N leaching from vegetation-free soil, the proportion of leaching of mineralized N was estimated to 2-4% from permanent grass, 14-16% from spring barley with a cover crop (CC) and 33-40% from spring barley without CC. A comparison of the ¹⁵N enrichment in unfertilized plants and the topsoil, in the year before the establishment of the different cropping, indicated that the labelled soil N pool was still more labile than the total soil N pool, even though the labelled N was applied 25-30 years before the experiment. We can still assume that crop uptake and leaching of labelled N derived from N mineralization. The average proportion between leaching and crop uptake of labelled N was 0.1 with grassland, 0.25 with barley plus CC and 1.1 with barley without CC. In conclusion the experiment confirms the crucial role of autumn-winter vegetation for the leaching risk from mineralized soil N and gives quantitative information about effects of different vegetation types under humid North-European conditions.

Reference: Sørensen, P, Pedersen, BN, Thomsen, IK, Eriksen, J & Christensen, BT. 2023. Plant availability and leaching of ¹⁵N-labelled mineral fertilizer residues retained in agricultural soil for 25 years: A lysimeter study. *J Plant Nutrition and Soil Science* 186, 441-450.

Abstract number–226 Assessing Pesticide Trends in Groundwater: A Comparative Study of the Netherlands and Denmark

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The occurrence of pesticides and metabolites in groundwater are of concern, due to their risk for human health and the environment. These contaminants can reach groundwater through various pathways, including runoff from agricultural fields. Once in the groundwater, these chemicals can persist for long periods, depending on their chemical properties and the hydrogeological conditions of the aquifer. Understanding the contamination patterns in groundwater has been difficult due to the heterogeneous groundwater age and redox status over the depth range that is typically sampled.

Groundwater is a vital resource for drinking water, providing approximately two-thirds of the drinking water in the Netherlands and the entire supply in Denmark. Both countries monitor groundwater quality through dedicated networks, which report to the EU Water Framework Directive and the Groundwater Directive. In these monitoring networks, pesticides are routinely measured. Also, major parts of the groundwater monitoring network of Denmark and parts of the monitoring networks in the Netherlands have been age-dated, by tritium/helium for the Netherlands and by a combination of CFCs and tritium/helium for Denmark. By linking pesticide concentrations to recharge years derived from groundwater ages, trends in pesticide leaching over time can be detected, correlating the presence of these substances to specific periods of farmland application. The availability of pesticides sales in both countries, make it possible to use groundwater ages to correlate pesticide detections in Danish and Dutch groundwater with pesticide sales.

The similarities between the monitoring networks allows for a comprehensive comparison between the pesticide data that was gathered in both countries. For the Dutch data a framework was recently published which allows the interpretation of large groundwater datasets on pesticides, relating them across various redox conditions, groundwater ages and land use types. A similar analysis was performed for the Danish monitoring network, where the effects of pesticide regulation on groundwater quality has been assessed. The results show, for example, that BAM is frequently detected in older groundwater in both Denmark and the Netherlands. The comparison between the Dutch and Danish data improves the understanding on the trends and trend reversals of pesticides in relation to their emission histories.

Abstract number–232 Modelling nitrate transport at watershed outlets and identifying nitrate-vulnerable zones in agricultural areas using redoxcline and nitrate leaching data

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In Flanders, about a quarter of the monitoring locations in surface water still do not comply with the EU nitrate directive. Further improvement seems elusive notwithstanding increasingly strict policy measures imposed on farmers. A stronger focus on nitrate-vulnerable zones, i.e. zones that contribute most of the nitrate in surface waters, may be appropriate. We hypothesised that these are the zones from which the nitrate follows a

shallow flow path through the groundwater, never crossing the interface between oxidized and reduced zone and thus not undergoing denitrification in the aquifer. The depth of this interface, the redoxcline, was determined in 1361 locations across Flanders from hydrochemistry data of multilevel groundwater wells, and its spatial pattern was examined. Next, the nitrate concentration was predicted at 86 small agricultural catchment outlets as the product of (1) the ratio of the thickness of the oxidized zone in the aquifer to the total aquifer thickness and (2) the nitrate concentration in recharging groundwater. Predicted surface water concentrations were compared with observations. We examined scenarios that differed in how the input nitrate concentration in recharging groundwater was quantified and whether the actual aquifer thickness or the Hooghoudt equivalent depth was used as aquifer thickness. Nitrate concentration in surface water were very poorly predicted when the nitrate concentration in the recharge water of a catchment is estimated with the concentration measured in a groundwater monitoring well(s) that have their filter in the oxic zone of that catchment, or with the average concentration of all oxic filters of groundwater wells across Flanders. Only when estimating the nitrate concentration in the groundwater recharge with the Nutrient Emission Model (NEMO) of the Flemish Environment Agency, the variability in nitrate concentration in surface water could be explained reasonably well. Further improvements were obtained by utilizing Hooghoudt's equivalent depth as aquifer thickness. Applying this model to 86 catchments resulted in a Nash-Sutcliffe Model Efficiency of 0.3 and a bias of 3.47 mg NO₃/L, when comparing predicted to observed surface water nitrate concentrations. That is promising considering that this simple model did not involve any calibration. It confirms that the relative thickness of the oxic zone within the (Hooghoudt equivalent) aquifer thickness is a key parameter. It varied from 0.03 to 1.0, averaging 0.42. This implies that on average 42% of Flanders is vulnerable to fertilizer application, but the vulnerable fraction varies widely between catchments.

Abstract number–233 Leaching of unexpected cyazofamid degradation products into groundwater demonstrates gaps in current pesticide risk assessment

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In Denmark, essentially all drinking water comes from groundwater that undergoes minimal treatment, typically aeration and sand filtering. To ensure that the relatively intensive agriculture in Denmark does not cause unwanted leaching of pesticides into the groundwater, the Danish government launched the Pesticide Leaching Assessment Programme (PLAP) in 1998. PLAP is an intensive field monitoring program designed to evaluate pesticide leaching risks and serves as an early warning system by providing decision-makers with field data on the leaching of approved pesticides and their key

degradation products. The program focuses on pesticides used in arable farming, and tests selected compounds in various crops annually by monitoring the shallow groundwater beneath agricultural test fields.

As part of PLAP, the fungicide cyazofamid was applied to a potato crop to study the leaching potential of its degradation products: 4-chloro-5-(4-methylphenyl)-1H-imidazole-2-carbonitrile (CCIM), 4-chloro-5-(4-methylphenyl)-1H-imidazole-2-carboxylic acid (CTCA), N,N-dimethylsulfamide (DMS), and dimethylsulfamic acid (DMSA). Leaching was monitored in the variably saturated zone and groundwater for over two years following the cyazofamid application, with 424 samples analyzed. Additionally, a parallel controlled laboratory column study was also conducted under controlled conditions to assess the formation and leaching behavior of the four degradation products.

According to the EFSA conclusion on cyazofamid, CCIM and CTCA are identified as the main relevant environmental metabolites, while DMS is not mentioned, and DMSA is only mentioned in relation to acute oral toxicity and bacterial mutation assays. However, contrary to the findings reported in the EFSA conclusion, our studies showed no leaching of CCIM or CTCA. Instead, significant leaching of DMS and DMSA was observed in both field and laboratory studies, with concentrations exceeding 0.1 µg/L in the shallow groundwater continuously for over six months. Based on these findings, we recommend improvements to current pesticide risk assessment procedures. Notably, the use of cyazofamid was later banned in Denmark.

Abstract number–234 Dissolved Organic Nitrogen Leaching from Cropland: Factors and transformations in soil

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Nitrogen (N) in soil undergoes complex transformations that are essential for soil–plant systems but often lead to losses. One potentially important pathway of loss is through dissolved organic nitrogen (DON) leaching. The DON concentration in soil is governed by inputs from litter leachates, manure, microbial and root exudates, and soil organic nitrogen (SON). Farming practices affect the quantity and composition of dissolved organic matter which is a key transporter of organic nitrogen from soils to aquatic ecosystems. While the role of these in nitrate (NO₃[−]) leaching is well-documented, their impact on DON leaching has not been extensively investigated. Measuring DON alongside inorganic forms gives a complete overview of total nitrogen leaching out of the system. We hypothesized that different crops and its management practices that contribute to increased SON will also contribute to increased DON leaching. To test these hypotheses, we selected treatments from five long-term experiments covering a diversity in crop type, soil cultivation intensity,

fertilizer levels, main and cover crop management, soil type and climatic conditions. Water samples were collected monthly from suction cups installed at 1 m depth from October to April in the leaching season 2024-25. Measurement of DON from monitoring wells at different depths was also conducted as a part of Pesticide Leaching Assessment Programme (PLAP) and The Agricultural Catchment Monitoring Programme (LOOP) to study its fate and transformation along the soil profile to near surface groundwater. We aim at identifying factors that significantly contribute to OM and ON in soil water to provide a basis for further scientific discussions in mitigating leaching losses to the aquatic environment.

Abstract number–235 Implementation of a climate-adapted water management in grasslands in North-West Germany – first effects on nutrient discharge and water availability

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Inland drainage characterizes the North-West German coastal area and is a prerequisite for agricultural land use as grassland in the target region. Over the past decades intensive water management has enabled the current agriculture practices. Modelling projections for the region indicate an increase in winter rainfall, an increase in the frequency of heavy rain events, and a rise in drought conditions following climate change. In recent years, the grassland has experienced substantial drought damage, attributable to the occurrence of hot and dry periods during summer months. The impact of drought periods on grassland vegetation and productivity has become increasingly evident in the intensively used grassland of North-West Germany. To provide enough water for intensively used grasslands during dry summer periods, a climate adapted drainage system is urgently needed and will be tested in a project named “Future Proof Grassland”. In the project, the current conventional drainage practice will be adapted to deal with dry and wet weather conditions. Modification in the drainage system during droughts are intended to maintain high groundwater levels, thereby mitigating the impact of drought stress on grasslands vegetation and productivity. Conversely, during wet conditions, the climate-adapted drainage system aims to prevent waterlogging and facilitate water discharge. Additionally, the project considers changes in land use intensity as a possibility to reduce nutrient discharge to receiving waters. For this purpose, large-scale randomized so called exact experiments are conducted in the target region. We hypothesize that the change in water management triggers the solution of previously bound nutrients, initially causing an increase in nutrient flux. In the long term, we expect that the adapted water management will lead to a reduction of nutrient discharge out of agriculturally used grassland.

Abstract number–236 Impact of drought on nitrate concentrations in leaching water from agricultural areas in the Netherlands

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The leaching of nutrients to shallow groundwater and surface water has been monitored for over 30 years by the Dutch Minerals Policy Monitoring Programme (LMM). Since the introduction of the EU Nitrates Directive (91/676/EEC), nitrate concentrations in the water leaching from the root zone of agricultural soils in the Netherlands have gradually declined until 2012. From 2012 onward concentrations have stabilized. However, recent dry years (2018 and 2022), seem to have caused an increase in nitrate concentrations. Due to climate change, it is expected that the number of droughts will increase in the near future. The aim of this study was to investigate the influence of droughts on nitrate leaching and to better understand why certain regions experience a stronger impact of drought than others. By understanding the underlying mechanisms and consequences of droughts on nitrate leaching, we can provide essential information to inform mitigation policies.

We used the monthly spatial Standardized Precipitation Evaporation Index (SPEI-6) over the period 1990–2023 to identify the intensity, the time of occurrence, and the regional differentiation of hydrological droughts. SPEI-6 data was analyzed statistically, alongside LMM water quality data and land use factors such as drainage, groundwater levels, and surface water levels.

Our findings show that duration and intensity of droughts vary widely between 1990–2023. The 2018 drought was exceptionally long and intense in all regions of the Netherlands compared to other droughts in this period. Furthermore, our findings show that soil type and hydrological conditions significantly influence the timing and magnitude of nitrate concentration increase after a drought. Additionally, the soil type and hydrological conditions also determine the time required for nitrate concentrations to recover from a drought. In regions with similar soil types, variations in nitrate leaching due to drought are mainly driven by regional differences in precipitation and evaporation.

The soil type and hydrological conditions, combined with the geographical variation in precipitations and evaporation, are the most important factors explaining the impact of drought on nitrate concentrations in leaching water. Therefore, it is essential to consider climate trends and related water issues in the design of the LMM monitoring programme. This will enable effective monitoring of how extreme weather conditions influence nitrate leaching, providing essential information for implementing targeted regional mitigation policies.

Abstract number–237 Anthropogenic Groundwater Contamination: A Case Study from the Nitra Region, Slovakia

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The Water Research Institute (WRI), in collaboration with Public Health Authority of the Slovak Republic, studied a 131-square-kilometer area in the Nitra region of southwestern Slovakia, where persistently high nitrate concentrations in groundwater have been recorded. This region is characterised by intense agricultural activity; however, wastewater from municipalities may also play a role. This abstract follows the contribution titled “Estimating the Origin of Extremely High Nitrate Concentrations in Groundwater at a Pilot Site” going into more details.

The WRI monitoring network is specialized in assessing the impact of agriculture on groundwater quality. In addition, this study included private domestic wells to assess whether pollution extends beyond agricultural land. Groundwater quality analysis in 2023 covered fundamental in-situ physicochemical parameters (pH, temperature, conductivity, groundwater level), nitrogen compounds (nitrate, nitrite, ammonium), phosphate, sulphate, chloride, 69 pesticide substances, 26 pharmaceuticals as well as isotopes of nitrogen and oxygen in nitrate, isotopes of hydrogen and oxygen in water, boron isotopes and tritium activity. Isotopic analysis was employed to identify the primary source of contamination. Historical nitrate concentration trends were examined, and the frequency of groundwater sampling was increased to 10 times per year to capture seasonal fluctuations. We compared water quality between WRI monitoring boreholes and nearest domestic wells.

Our findings indicate that nitrate levels in most WRI boreholes remained stable throughout the year. Extremely high nitrate concentrations observed in this area likely result from a combination of intensive agricultural activity and unfavourable geological conditions that hinder nitrate attenuation or dilution, leading to its accumulation. Boron isotope analysis helped distinguish between agricultural and municipal wastewater sources of pollution. Moreover, nearly all WRI boreholes showed the presence of various pesticides, with agriculture being the predominant source of contamination. In boreholes where boron isotopes indicated municipal wastewater influence, pharmaceutical residues and caffeine were also detected, reinforcing this indication. When pesticides were detected in WRI boreholes, their concentrations in nearby domestic wells remained below drinking water limits. This study highlights the importance of multi-parameter and isotopic analysis in groundwater contamination assessment, providing essential knowledge for safeguarding water resources and shaping effective protection strategies.

Abstract number–239 Irish stakeholder collaboration in developing Ireland's Nitrates Action Programme and beyond

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Like all EU member states, Ireland is faced with the challenge of meeting its Water Framework Directive target of achieving at least good status in all waters by 2027. Only 54% of Irish surface waters are currently in good or high ecological status.

Agriculture is the dominant land use in Ireland and identified as the most frequent pressure source on water quality. Agricultural nutrient levels are too high in several waterbodies. In response, Ireland's agricultural sector has significantly stepped up its commitment to improving water quality. Since 2022, Irish farmers are embracing significant changes under the fifth Nitrates Action Programme (NAP).

Key to this response was the formation of an all of industry 'Agricultural Water Quality Working Group', in 2023. This group is made up of representatives from farm organisations, agri-food industry, knowledge transfer services, state bodies and government Ministries. The group's goals are to minimise agriculture's impact and drive improvements in water quality. Their objectives have been to raise awareness on existing measures and bring forward additional suggestions. Within its first year, drawing on science-based evidence, the group agreed a set of recommendations, that fed into the interim review of Ireland's fifth NAP. Recommendations from the group are contributing the development of Ireland's sixth NAP, due to commence in January 2026.

In 2024, a plan titled "Water and Agriculture - A collaborative approach" was published by the Irish government, outlining the on-going work to improve Ireland's water quality and support the case to justify renewal of Ireland's nitrates derogation post-2025. This plan also outlines the approach to drive further reductions in nutrient losses from agriculture sources. The objective is that this will be achieved through an optimum combination of regulatory measures, knowledge transfer, awareness raising, and incentivisation through industry schemes and targeted national and EU financial supports.

The Agricultural Water Quality Working Group and the associated Collaborative Approach plan have been key drivers in achieving the current unprecedented engagement and desire to improve Irish water quality.

Ireland's, Environmental Protection Agency (EPA) data for 2024 shows signs these changes may be starting to reduce nitrates concentration in Irish rivers.

However, as progress is being made, there is still significant work to be done. It is important that the current stakeholder engagement is maintained and built on to improve water quality.

Abstract number–240 High-frequency water quality monitoring to support a spatial targeting approach for nutrients in two agricultural catchments

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During the past thirty years, the water quality in Dutch agricultural areas has improved, but still not enough to meet the goals for the Nitrates Directive and the Water Framework Directive. The national government of The Netherlands currently makes a case for a spatial targeting approach for nutrients in problematic catchments. However, without a clear image of the hot-spots and hot-moments of nutrient losses within those catchments, it is not possible to take focused and effective measures. Region-specific mitigation also requires region-specific monitoring.

The aim of this research is to explore the possibilities for supporting a spatial targeting approach for nutrients with new monitoring strategies. We designed and implemented detailed monitoring networks within two headwater catchments with intensive agricultural land use. The Vuursteentocht is a 13 km² regulated polder catchment in the clay region. The Vinkenloop is a freely draining 7 km² stream in the sand region.

In this poster, we focus on the results from two mobile laboratory equipped with sensors and auto-analyzers for P_{tot}, TRP, NO₃, NH₄, EC, pH, and O₂. The high frequent measurements produced valuable insights into hot-moments of nutrient losses. We registered the water quality responses to precipitation events, ditch and culvert maintenance, irrigation, weir level adjustments, and some unknown direct inputs. In combination with other monitoring data (e.g. discharge, precipitation, groundwater levels, conventional water quality sampling), the continuous data enabled closing the water and solute balance and the calculation of contributions of seepage and agricultural drainage to the total nutrient loads to the stream. The collected monitoring information unraveled the within-catchment nutrient sources and transport routes. We consider this to be a good starting point for selecting the right mitigation options at the right locations in discussion with farmers, the water boards, and other stakeholders.

Abstract number–241 The rocky road towards water quality ambitions: experiences from the Netherlands

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Worldwide, countries face challenges to restore and preserve water resources in accordance with the ambitions set in the UN SDGs. These challenges can be recognised in Europe as well. Although significant progress has been made in the past decades due to extensive environmental policies like the Water Framework Directive (2000/60/EC) and the Nitrates Directive (91/676/EC), water quality improvement seems to have come to a halt. In the most

recent evaluation, less than half of the EU's water bodies are in good condition. Also for the Netherlands, achieving these water quality ambitions, is a multifaceted challenge. Several studies demonstrate that although water authorities have carried out extensive programmes of measures, WFD ambitions are unlikely to be met by 2027. Water authorities and provinces have committed themselves to provide these programmes with an extra incentive in order to speed up the implementation of measures towards 2027.

A good ecological and chemical water quality is a prerequisite for a river to be healthy and serve its many ecosystem services such as, drinking water resources, bathing water, cooling water, irrigation, energy supply and transport. As a low lying delta of four international river basins, densely populated and with high economic productivity, the Netherlands struggle to balance these ambitions and other interests. Furthermore, the Netherlands has one of the most intensive agricultural land usage in the world. This inevitably affects the environmental quality and the state of our natural resources, both regarding nitrogen emissions and deposition, and leaching of nitrates to surface water and groundwater. In rural areas, the quality of shallow groundwater and surface water (leaching water) is strongly influenced by agricultural land use. Effects of climate change such as long periods of drought and heavy rainfall, add to these impacts.

Challenges for the Netherlands regarding water quality are related to both the physical requirements for healthy waters (hydromorphology, toxic pressures and nutrient loads) and the governance of water quality improvement. Traditionally, water management in the Netherlands has had a strong focus on ensuring safety from flooding for its citizens and economic interests. The introduction of the WFD has led to an increased understanding of its aquatic ecosystems and collaboration with among water authorities and provinces in the river basin, but it remains difficult to address issues related to other sectors beyond the water domain, such as agriculture.

The introduction of the ND in the 90-ies, has resulted in a large decline in surpluses of nitrogen and phosphorus as well as nitrate concentrations in groundwater. Since 2012 however, nitrate concentrations in groundwater have stabilised due to stagnating nitrogen surpluses, and levels of eutrophication seem to have increased. In the presentation, we will go into the experiences with the implementation of the WFD and ND in the Netherlands and current challenges and debates. We will use 30 years of data collection and analysis of water quality and agricultural practice to support our observations. What can we learn from the effects of agricultural policy in the past?

Abstract number–242 Can we save our waterbodies from excessive dissolved phosphorus?

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Soils with high degree of phosphorus (P) saturation export high amounts of dissolved inorganic P (DIP) downstream when the water table rises due to heavy rain events or human intervention (i.e. rewetting) (Reddy, DeLaune, and Inglett 2022). The surface water that migrates, in our case from rewetted degraded riparian wetlands, feeds primary producers and results in general degradation of freshwater and marine life. Surface water with DIP is thus highly mobile and bioavailable and when it crosses land with high stocks of P, it tends to reach a chemical equilibrium with it through processes like molecular diffusion. That means that when upstream water contains TP and DIP at very low levels and feeds riparian wetlands with legacy P, DIP footprint in the waterbodies multiplies (Wiegman et al., 2024). In our research project we investigate how two nature-based materials (calcinated leca and filter sand) sorb orthophosphates from water, the main form of DIP, under controlled laboratory conditions. More specifically, the experiment includes two distinct phases of application of (a) artificial water spiked with orthophosphates (0.2mg P/L) and (b) outlet surface water from one rewetted fen in Jutland, Denmark (similar concentration) in batch and fixed-bed column set-ups with stable flow rate. The results from the first batch round indicate that both materials sorb P in a way that can be described by a modified Freundlich isotherm model. The corresponding fixed-bed P sorption results from the first phase (duration 43 days) provided two breakthrough curves and information for the subsequent P removal efficiency, which is 14.9 mg P kg⁻¹ DM for calcinated leca and 2.7 mg P kg⁻¹ DM for filter sand. After 43 days the mediums didn't reach their maximum potential of retaining P and fitting of the Clark model to calcinated leca data showed good results (R²=0.89) and a total P Removal =65.42% (55 mg P kg⁻¹ DM) until the exhaustion point (at least 20% retention of the inlet concentration) after 191 days of constant solution flow. The next phase of the fixed-bed column experiment will reveal whether the mediums can retain P effectively when treating natural water of low P concentration, presence of various compounds such as DOC, Fe, Al and Ca. Interactions among P and those compounds will be examined as well as the mechanisms behind P sorption on the filters surface to enhance our understanding of the processes apart from the scale-up assessment of those filters' application on the field.

Abstract number–243 PROTECT – Groundwater Protection in a Changing Landscape

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How do we secure healthy drinking water that meets quality requirements, and how should groundwater protection areas be designed to create co-benefits for society? Providing answers to these questions are becoming more urgent and challenging due to abundance of nitrate and newly discovered pesticides and PFAS compounds in groundwater, which the Danish drinking water supply is entirely dependent on. At the same time agriculture, forestry

and nature need to co-exist to safeguard drinking water, the aquatic environment and meet climate, biodiversity and human health goals. This is paramount for the Danish green transition.

A new Innovation Fund Denmark protect called PROTECT, with a total budget of approximately DKK 35 million, will develop methods over the next four years that better and more cost-effectively secure the necessary knowledge for groundwater protection in future land use planning.

PROTECT aims to deliver a multi-disciplinary decision support workflow for authorities and stakeholders including all steps from collecting subsurface data over geo-modelling of pollutants to evaluating the environmental-economic consequences of various land-use scenarios. A Transient ElectroMagnetics (TEM) drone technology will be developed from a minimum viable prototype to a proven mature prototype for large-scale subsurface geophysical data acquisition. A sensor and awareness system will be built to make the heavy-lift DroneTEM capable of safety flying Beyond Visual Line Of Sight (BVLOS). An environmental economic model will include groundwater protection areas, health costs of drinking water pollutants and engage stakeholders and experts in creating needed knowledge for the protection of water quality, biodiversity and human health, and mitigation of climate change.

PROTECT is a interdisciplinary project with nine partners including 1) The Geological Survey of Denmark and Greenland (GEUS), 2) Department of Food and Resource Economics, University of Copenhagen (KU-IFRO), 3) SDU Drone Center, Mærsk Mc-Kinney Møller Institute, University of Southern Denmark (SDU), 4) Groundwater Mapping, Danish Environmental Protection Agency, 5) Department of Public Health, Aarhus University (AU HEALTH), 6) Department of Geoscience, Aarhus University (AU GEO), 7) Samsø Municipality, 8) Central Denmark Region, and SkyTEM.

The following collaborators take part of PROTECT: Anne Guldbæk Arvidsen, Anne-Sophie Høyer, Thomas Mejer Hansen, Berit Hasler, Jeppe Ustrup Hermann, Jussi Hermansen, Anker Lajer Højberg, Flemming Jørgensen, Hyojin Kim, Robert Ladig, Ulrik Pagh Schultz Lundquist, Rasmus Bødker Madsen, Peder Lund Rasmussen, Jörg Schullehner, Torben Sigsgaard, Mette Termansen.

Abstract number–244 Finding solutions for a good ecological and chemical quality in freshwater and marine water bodies in the Baltic Sea, North Sea and Irish Sea regions.

Brian Kronvang¹, Gerard Velthof², Luuk van der Heijden³, Anouk Blauw³

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Special session S1. 'Finding solutions for a good ecological and chemical quality in freshwater and marine water bodies in the Baltic Sea, North Sea and Irish Sea regions'.

Brian Kronvang (University of Aarhus, corresponding author bkr@ecos.au.dk), Gerard Velthof (WUR), Luuk van der Heijden (Deltares), Anouk Blauw (Deltares)

This special session will share the main results from the NAPSEA, NEW HARMONICA and the NORDBALT-ECOSAFE project through short presentations focusing on main project outcomes and a plenary discussion on the shared outcomes of the three projects and key messages.

Presentations

Presentation of the main results from NAPSEA: Current challenges to reduce nutrient pollution, eutrophication and its negative impacts on inland and coastal waters are addressed by an integrated approach focusing on nutrient pollution from source to sea. Luuk van der Heijden and Anouk Blauw, Deltares, The Netherlands

Presentation of the main results from NEW-HARMONICA: Combining science and policy to maximize the uptake and effectiveness of best management practices to improve water quality in NW European river basins.

Gerard Velthof, Wageningen University and Research, The Netherlands

Presentation of the main results from NORDBALT-ECOSAFE: Nitrogen and phosphorus load reduction approach within safe ecological boundaries for the Nordic-Baltic region.

Brian Kronvang, Institute of Ecoscience, University of Aarhus, Denmark

A final discussion and debate about:

- Achieving safe ecological boundaries in waterbodies today and under climate change – lessons from catchments in NW Europe.
 - Are current emission policies enough to reduce the nutrient load for these waterbodies?
 - If not: What is required to reach these reduction targets and thus ecological goals?
 - What can we gain from the use of high frequency sensor measurements in monitoring?
 - Are we enough aware of the multi-functionality of nature-based solutions? And what's missing?
 - Are current catchment nutrient emission models fit for purpose? And what's missing?
 - How do we ensure Best Management Practices continue to deliver in a changing climate?
 - Are Best Management Practices scenarios capable of delivering the required Load Reduction Targets or are more drastic action needed? And to what extent is this acceptable to stakeholders)?
 - Recommendations for governance at EU, national and catchment level.
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Abstract number–245 Special Session on the Water Framework Directive: challenges and pathways towards 2027.

Susanne Wuijts¹, Charlotte Offringa²

¹*RIVM/Utrecht University*

²*Utrecht University*

Special session S2. 'Special Session on the Water Framework Directive: challenges and pathways towards 2027.'

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Reducing pressures from agriculture on water quality has proven to be a multifaceted challenge in the last decades. Next to technical challenges related to the identification of issues, development of measures, monitoring and modelling, this challenge also encompasses legal and social-economic aspects. With the due date of 2027 for meeting the Water Framework Directive (WFD) objectives, countries in the EU are facing a challenge to achieve this ambition in time.

A recent study regarding the Netherlands shows that an important problem is that stakeholders, also within organizations, have different views on ambitions, achievements and necessary follow up actions in case policy measures have too little effects on water quality. This is problematic because for realizing the water quality ambitions, cross-sectoral cooperation (e.g. from agriculture and spatial development) as well as strengthened interlinkages between these related policy fields is crucial. Moreover, there is a tendency to stick to the status quo. In order to increase effectiveness, a better understanding of the underlying mechanisms for this lock-in will be necessary. This will enable the development of practical tools and instruments to support cross-sectoral and multi-level collaboration. The sectoral implementation of the WFD in the Netherlands was chosen by many other member states, possibly resulting in similar cross-sectoral challenges. This special session aims to share experiences, both from a social-economic, legal and technical perspective, on how countries deal with these cross-sectoral challenges in order to develop strategies that lead to achieving WFD ambitions.

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