Proceedings from the 3rd BONUS Symposium, Gdansk 14-16 March 2018 (Report on the conclusions)

Editors of this deliverable: Berit Hasler (coordinator) and Markku Ollikainen (co-organiser of the BONUS symposium

The main material (Appendices A-D) was prepared jointly by the Organising Committee for the Symposium:

- Jens Christian Refsgaard, Geological Survey of Denmark and Greenland, Denmark (BONUS SOILS2SEA)
- Nico Stelljes, ECOLOGIC Institute, Germany (BONUS SOILS2SEA)
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- Kerstin Bly Joyce, Stockholm University, Sweden (BONUS BALTICAPP)
- Karin Tonderski, Linköping University, Sweden (BONUS MIRACLE)
- Andrzej Tonderski, POMINNO, Poland (BONUS MIRACLE)

Deliverable	**5.5 ER/PU**
Project acronym:	BONUS Go4Baltic
Project title:	Coherent policies and governance of the Baltic Sea ecosystems
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Content

1. Executive summary

Final conference as a BONUS GO4BALTIC deliverable
BONUS GO4BALTIC aimed, according to the Description of Work, to organise an End conference to present final project results to stakeholders. At the BONUS triple meeting held in Brussels 1-2 December 2015, which included a BONUS Forum of coordinators meeting, the coordinators of the four BONUS projects GO4BALTIC, SOILS2SEA, BALTICAPP and MIRACLE decided to plan and organise a common end-conference for the four projects. The reason was that all projects dealt with nutrient load management, and we aimed to attract the same stakeholders. This idea was supported by the BONUS Secretariat, and the joint conference became the 3rd BONUS Symposium.

The present report (Deliverable 5.5.) is the formal reporting of the conference as a BONUS GO4BALTIC deliverable. The common conclusions from the conference are described in Appendix A: Synopsis, and this synopsis is common for all 4 projects. This synopsis is also published at the conference homepage: http://bonus2018.eu/ which also includes the other information included in the appendices of this deliverable (programme and book of abstracts).

Organisation of the 3rd BONUS Symposium
The conference organizing committee was created in early 2016 and comprised two representatives for each of the four projects:

Berit Hasler – BONUS GO4BALTIC – Aarhus University, Denmark
Markku Ollikainen – BONUS GO4BALTIC – University of Helsinki, Finland
Jens Christian Refsgaard – BONUS SOILS2SEA – Geological Survey of Denmark and Greenland, Denmark
Nico Stelljes – BONUS SOILS2SEA – ECOLOGIC Institute, Germany
Kari Petri Hyytiäinen – BONUS BALTICAPP – University of Helsinki, Finland
Kerstin Bly Joyce – BONUS BALTICAPP – Stockholm University, Sweden
Karin Tonderski – BONUS MIRACLE – Linköping University, Sweden
Andrzej Tonderski – BONUS MIRACLE – POMINNO, Poland

The organising committee has held 4 physical meetings (Helsinki, Stockholm and Gdansk) as well as 22 skype meetings.

The scientific programme
The scientific programme of the symposium comprised six external keynote presentations, 48 oral and 24 poster presentations from the four BONUS projects, as well as 6 oral and 4 poster presentations from other projects in two side events. In addition, 2 moderated panel discussions was held with focus on new insights to the Baltic Sea Region produced by the project research and on the next challenges, respectively.

6 internationally recognised top scientists that have not been involved in the BONUS projects gave keynote presentations:

- Lotta Anderson, Swedish Meteorological and Hydrological Institute, Sweden
- Jim Smart, Griffith University, Australia (invited by BONUS GO4BALTIC)
- James Shortle, PennState College of Agricultural Science, USA (Invited by BONUS GO4BALTIC)
- Jonathan Winsten, Winrock International, USA
- Kasper Kok, Wageningen University, The Netherlands
- Wim de Vries, Wageningen University, The Netherlands

The conference also included 2 panel discussions moderated by Mette Termansen (Copenhagen University), invited by BONUS GO4BALTIC, and Gun Rudqvist from BalticEye, Stockholm University.

In addition to the program organised by the 4 BONUS projects 2 additional research projects organised side events, each with an oral session and a number of posters:

- TReNDS – Transport and Reduction of Nitrate in Danish Landscapes at various Scales. TReNDS is supported by Innovation Fund Denmark
- Gypsum treatment of agricultural fields – A novel and cost-efficient water protection measure. The gypsum pilot contributes to the NutriTrade project lead by John Nurminen Foundation and funded by the European Union Central Baltic Program.

Conference participants

There were in all 123 participants in the conference. The names and contact details of the participants are not included in this public deliverable.
Of these 123 participants 25 were partners from BONUS GO4BALTIC, or invited by GO4BALTIC.

A synopsis of the Symposium is provided in Appendix A. The program is enclosed as Appendix B and the book of abstracts for all presentations can be found in Appendix C.

2. Appendix A: Synopsis of conclusions of the conference

This synopsis is published at the conference homepage http://bonus2018.eu/, and is agreed among the organizers from all 4 projects.

Synopsis

The 3rd BONUS Symposium “Sustainable Ecosystem Governance under Changing Climate and Land Use in the Baltic Sea Region” was organised jointly by four projects BONUS BALTICAPP, BONUS GO4BALTIC, BONUS MIRACLE and BONUS SOILS2SEA. In total, 126 participants joined the Symposium coming from 12 countries. Most participants were from countries across the Baltic Sea Region. Scientists and policymakers from the USA, Netherlands, and Australia also participated.

The Symposium brought together scientists, policymakers, NGOs, representatives from the private sector and authorities from various levels, in the European Solidarity Centre in Gdańsk from 14-16 March, 2018. The Programme and Book of Abstracts can be viewed.The symposium introduced results from four BONUS projects ending in 2018, and comprised 47 oral and 24 poster presentations from these projects, as well as five oral and four poster presentations from other projects in two side events (Gypsum and TReNDS). Two moderated panel discussions and six well received keynote presentations by external, internationally leading scientists completed the programme.

The scope of the symposium was to present, disseminate and discuss results from novel Baltic Sea research on catchment nutrient flows and agro-environmental policies and governance towards sustainable ecosystem services in the Baltic Sea Region. The studies covered international, national and local scales in both short and long-term perspectives. Key messages from the presentations and discussions are highlighted below, organized according to the Symposium themes. These key messages were emphasized in the panel discussions, along with the need to consider mega-trends, like urbanization and increasing size of farms in the region, with accompanying challenges, e.g. storage and spreading of manure.

Scenarios for the future

• Climate change will lead to increased nutrient loads (nitrogen and phosphorus) to the Baltic Sea. Societal changes that drive land use, agricultural practices and investments in point source control technologies may lead to changes in the nutrient load to the Baltic Sea of the same, or higher, order of magnitude as the climate change impacts.

• Scenarios for nutrient loads in a future climate suggest large uncertainties and spatial differences in the region. When moving towards more adaptive policy frameworks, those uncertainties and differences should be acknowledged.

• Scenarios can help society shape and adapt to an uncertain future. Different kinds of scenario analyses and methods to visualize the results can be useful for an efficient communication between scientists, local and regional stakeholders and decision makers.

Policies and ecosystem services in water governance within the Baltic Sea Region

• The costs of nutrient abatement measures are often high, but the value of additional local benefits may outweigh these costs.

• Habitat values, recreation and enjoyment of landscapes are amongst the most important cultural ecosystem services of the Baltic Sea.

• The group of stakeholders involved in nutrient governance needs to be expanded to include new sectors, for example by identifying synergies with other issues (like flood protection, fishery, recreation) that are more relevant to local stakeholders in the Baltic Sea basin.

• The coordination and interconnections between different sectors and policy instruments (e.g. CAP, Rural Development Programs, Water Framework Directive, Floods Directive, climate policies) need to be strengthened. Using the ecosystem services framework can facilitate the design of measures with multiple objectives.

• A better coherence between local and regional stakeholders may be achieved by strengthening the mandate of local stakeholder groups currently involved in water and nutrient governance. Co-governance and participatory bottom-up approaches boost innovation, enable better usage of otherwise hidden information about the local conditions and increase involvement.

Novel approaches for managing nutrients in the Baltic Sea Region

• There is a need to improve the nitrogen use efficiency in the Baltic Sea Region in order to reduce the loads and at the same time maintain or even increase the agricultural crop yields.

• The gap between the current phosphorus load to the Baltic Sea and the target load is high, which calls for additional efforts to develop and adopt new approaches to reduce phosphorus losses from agriculture and other sources.

• Progress of agri-environmental policies is important in the Baltic Sea Region, as the public and private costs of nutrient abatement are high.

• Farmers are skilled problem solvers, but they need the right incentives and a governance framework that provide possibilities for flexible adjustments when including environmental management into farm business decision making.

• Implementation of spatially differentiated regulations and incentives can reduce nutrient loadings, but need new governance concepts to be implemented.

• One size does not fit all; the complex environmental conditions and diverse societies around the Baltic Sea Region require a variety of policy instruments. Water quality trading, spatially targeted regulations and performance based measures have a high potential to reduce the cost of nutrient load reductions. Policy barriers for their use should be removed.

• Demonstration examples of various cooperation schemes, such as hybrid payments with both public and private funding, should be implemented in the Baltic Sea Region.

Advanced modelling from field level to the entire Baltic Sea Region

• Adaptive and flexible policies require reliable models that have credibility among stakeholders. To gain the necessary credibility, model predictive uncertainties should be communicated. To assess the uncertainty when modelling impacts of climate change and future land use, it is recommended to use several models in an ensemble modelling approach rather than relying on just one model.

• Models can also be used to aid and inform policy implementation to choose the most appropriate and cost-effective decisions, and further develop the science-policy interface. Here, the most appropriate models are needed, not necessarily the most detailed.

In the panel discussions, it was emphasized that science and policy should go hand in hand. Further, it was pointed out, that the four BONUS projects are very good examples of natural and social scientists working together, and that this approach should be taken forward. It was advised, that scientists must also concentrate on how their results can affect change and create an impact. For example, outcomes of the projects are directly relevant for the further development of the Common Agricultural Policy of the EU. In a longer time perspective, successful policies lead to changes in the attitudes and behaviour of people living in the Baltic Sea Region. Finally, it was seen as very positive that the four projects joined forces to organize a final symposium together. Selected papers from the conference will be published as a special issue in the journal AMBIO in early 2019.

The 3rd BONUS Symposium

Sustainable Ecosystem Governance under Changing Climate and Land Use in the Baltic Sea Region

Gdańsk, 14-16 March, 2018

Preliminary Program

Consortium of BONUS projects: MIRACLE, SOILS2SEA, BALTICAPP & GO4BALTIC

http://bonus2018.eu

Day 1: 14/3/2018		Day 2: 15/3/2018		Day 3: 16/3/2018	
09:00 - 09:15	Welcome	09:00 - 09:50	KEYNOTE: Kasper Kok	09:00 - 09:50	KEYNOTE: James CR Smart
09:15 - 10:05	KEYNOTE: Lotta Andersson	09:50 - 10:00	BREAK	09:50 - 10:00	BREAK
10:05 - 10:45	Project Presentations: BONUS BALTICAPP BONUS SOILS2SEA	10:00 - 11:00	1. Impacts of changing climate, policy and society on nutrient loading to the Baltic Sea I 2. Approaches for stakeholder dialogues	10:00 - 11:00	9. Policy support for multiple ecosystem services 10. Stream remediation measures Side event. Project TReNDS
10:45 - 11:15	BREAK	11:00 - 11:25	BREAK	11:00 - 11:25	BREAK
11:15 - 12:05 12:05 - 12:45	KEYNOTE: James Shortle Project Presentations: BONUS GO4BALTIC BONUS MIRACLE	11:25 - 12:45	3. Modelling nutrient transport 4. Outlooks for marine environments	11:25 - 12:25	11. Social learning for innovative governance 12. Spatially differentiated regulation
12:45 - 13:30	LUNCH	12:45 - 13:45	LUNCH + Poster	12:25 - 13:25	LUNCH + Poster
13:30 - 14:45 14:45 - 15:35	Poster-Session KEYNOTE: Jon Winsten	13:45 - 14:35	KEYNOTE: Wim de Vries	13:25 - 14:25	13. Local and regional governance 14. Economic decision support
15:35 - 16:00	BREAK	14:35 - 14:45	BREAK	14:25 - 14:40	BREAK
16:00 - 17:30	New insights on the Baltic Sea Region Discussions on modelling, stakeholder views, social learning, ecosystem services and policies	14:45 - 15:45	5. Impacts of changing climate, policy and society on nutrient loading to Baltic Sea II 6. Evaluating agri-environmental policies Side event. Project Gypsum	14:40 - 15:40	Next challenges and next steps.
		15:45 - 16:15	BREAK		
		16:15 - 17:15	7. Governance and Innovation 8. Catchment nutrient loading-scenario analysis		
18:30 - 20:00	Conference DINNER				

Legend
Plenary session
Coffee break, lunch, dinner
Sessions in parallel tracks
Side Events

PROGRAM		
Day 1: 14/3/2018		
Chair: Andrzej Tonderski	Welcome. **Andris Andrusaitis** (**BONUS Secretariat EEIG, Finland**)	*09:00 – 09:15*
Keynote *Chair: Karin Tonderski*	**Lotta Andersson (Swedish Meteorological & Hydrological Institute, Sweden):** Making the intangible manageable - is there a formula to merge research findings with local governance focusing on climate change adaptation?	***09:15 – 10:05***
Project presentations *Chair: Berit Hasler*	BONUS BALTICAPP - Well-being from the Baltic Sea – applications combining natural science and economics **Hyytiäinen K**, Ahtiainen H, Artell J, Bauer B, Bertram C, Buczyński M, Budziński W, Czajkowski M, Joyce KB, Gustafsson B, Ehrnsten E, Lankia T, Meier M, Meyerhoff J, Norkko A, Pihlainen S, Pouta E, Rehdanz K, Saraiva S, Sihvonen M, Tomczak M, Zagórska K, Zandersen M.	***10:05 – 10:45***
	BONUS SOILS2SEA – Reducing nutrient loads from agricultural soils to the Baltic Sea via groundwater and streams **Refsgaard JC**, Olesen JE, Wachniew P, Wörman A, Bartosova A, Stelljes N, De Jonge H, Chubarenko B, Jakobsen R.	
	BREAK	***10:45 – 11:15***
Keynote *Chair: Markku Ollikainen*	**James Shortle (Penn State College of Agricultural Science, USA):** Innovating policy for effective and efficient control of nutrient pollution: challenges and paths forward	***11:15 – 12:05***
Project presentations *Chair: Jens Christian Refsgaard*	BONUS GO4BALTIC – Coherent policies and governance of the Baltic Sea ecosystems **Hasler B**, Ollikainen M, Elofsson K, Czajkowski M, Andersen HE, Peterson K, Nielsen HØ.	***12:05 – 12:45***
	BONUS MIRACLE - Mediating integrated actions for sustainable ecosystem services in a changing climate **Tonderski K**, Neset TS, Tonderski A, Walczykiewicz T, Lagzdins A, Zilans A, Schwarz G, Jomaa S, Pedersen SM, Capell R, Olsson O, Powell N.	
	LUNCH	***12:45 – 13:30***
	POSTER SESSION	***13:30 – 14:45***

Keynote *Chair: Karin Ton-derski*	**Jon R Winsten (Winrock International, USA):** Improving participation and the cost-effectiveness of agricultural pollution control programs through the use of Pay-for-Performance Conservation.	***14:45 – 15:35***
	BREAK	***15:35 – 16:00***
Discussion *Moderator: Mette Termansen*	New insights on the Baltic Sea Region - discussions on modelling, stakeholder views, social learning, ecosystem services and policies	***16:00 – 17:30***
	Conference DINNER	***18:30 – 20:00***

<table>
<tr><th colspan="3">Day 2: 15/3/2018</th></tr>
<tr><td>Keynote
Chair: Kari Petri Hyytiäinen</td><td>Kasper Kok & Pedde, S (Wageningen University, Netherlands): Scenarios for land use, socio-economic and climate change – A call for integration</td><td>09:00 – 09:50</td></tr>
<tr><td></td><td>BREAK</td><td>09:50 – 10:00</td></tr>
<tr><td rowspan="3">Session 1
Impacts of changing climate, policy and society on nutrient loading to the Baltic I
Chair: Katarina Elofsson</td><td>Using extended socio-economic scenarios to investigate drivers and pressures on the Baltic Sea up to 2100
Zandersen M, Hyytiäinen KP, Meier M, Tomzcak M, Bauer B, Haapasaari P, Olesen JE, Gustafsson B, Refsgaard JC, Fridell E, Pihlainen S, Letissier M, Kosenius AK, Van Vuuren D.</td><td rowspan="3">10:00 – 11:00</td></tr>
<tr><td>Land use and land cover projections in the Baltic Sea Basin under different SSPs and future climate change
Jabloun M, Olesen JE, Zandersen M, Hyytiäinen KP, Smedberg E.</td></tr>
<tr><td>Change in nutrient loads to the Baltic Sea Basin with changing climate, socioeconomic impacts, and land management practices
Bartosova A, Strömqvist J, Capell R, Olesen JE, Jabloun M, Arheimer B, Donnelly C, Hyytiäinen K, Pedersen SM, Zilans A, Tonderski K, Zandersen M.</td></tr>
<tr><td rowspan="3">Session 2
Approaches for stakeholder dialogues
Chair: Kerstin Bly Joyce</td><td>Visualization supported dialogues in the Baltic Sea Region
Neset TS, Navarra C, Wilk J, Capell R, Bartosova A.</td><td rowspan="3">10:00 – 11:00</td></tr>
<tr><td>Employing narratives and ethnographic studies to inform policy options for nutrient reductions
Martinez G.</td></tr>
<tr><td>Constructing an open citizen science tool to collect information on the Baltic Sea and recreation. Proof of concept and future possibilities
Artell J.</td></tr>
<tr><td></td><td>BREAK</td><td>11:00 – 11:25</td></tr>
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Session 3 **Modelling nutrient transport** *Chair: Tomasz Walczykiewicz*	Geochemical processes affecting reactive nitrogen in a clay till, hill slope field system **Jakobsen R,** Hansen AL, Hinsby K, Refsgaard JC.	*11:25 – 12:45*
	Modelling of nitrate contamination in fissured-porous karstic aquifer underlying Kocinka catchment using tracer-calibrated flow and transport model Kania J, **Michalczyk T**, Witczak S, Bar-Michalczyk D, Rozanski K, Dulinski M, Najmann J.	
	How to increase utilization of nitrogen in manure - the Danish case **Blicher-Mathiesen** G**,** Andersen HE, Rasmussen A, Rolighed J, Carstensen M.	
	Utilising data and studies within the Baltic Sea Basin to develop a map for nitrogen reduction in groundwater **Højberg AL,** Hansen AL, Wachniew P, Żurek AJ, Virtanen S, Arustiene J, Strömqvist J, Rankinen K, Refsgaard JC.	
Session 4 **Outlooks for the marine environments** *Chair: Mikołaj Czajkowski*	Impacts of “greening” on eutrophication in the Baltic Sea **Jansson T,** Andersen HE, Gustafsson B, Hasler B, Höglund L.	*11:25 – 12:45*
	Uncertainties in projections of the Baltic Sea ecosystem driven by an ensemble of global climate models Saraiva S, Meier HEM, Andersson H, Höglund A, Dieterich C, Hordoir R, **Eilola K.**	
	What are potential future states of the Baltic Sea food web? **Bauer B,** Gustafsson B, Hyytiäinen K, Meier HEM, Müller-Karulis B, Saraiva S, Tomczak MT	
	Contingent behavior and asymmetric preferences – Valuing recreational benefits of the Baltic Sea **Bertram C,** Ahtiainen H, Meyerhoff J, Pakalniete K, Pouta E, Rehdanz K.	
	LUNCH & Poster Session	*12:45 – 13:45*

Keynote *Chair: Jens Chris-tian Refsgaard*	**Wim de Vries** & Kros H. **(Wageningen University, the Neth-erlands):** Assessment of the needed increase in nitrogen use efficiency in European agricultural soils in view of water quality.	*13:45 – 14:35*
	BREAK	*14:35 – 14:45*
Session 5 **Impacts of changing cli-mate, policy and society on nutri-ent loading to the Baltic II** *Chair: Jørgen E. Olesen*	Long term impacts of societal and climatic changes on nutrient loading to the Baltic Sea Zandersen M, **Pihlainen S,** Hyytiäinen K, Andersen HE, Jabloun M, Smedberg E, Gustafsson B, Bartosova A, Thodsen H, Meier M, Saraiva S, Olesen JE, Swaney D, McCrackin M.	*14:45 – 15:45*
	Modelled source apportionment of nutrient loads to Baltic Sea basins under current and future conditions **Capell R,** Bartosova A, Strömqvist J, Arheimer B.	
	Scenario for structural development of livestock production around the Baltic Sea **Niskanen O,** Iho A, Kalliovirta L.	
Session 6 **Evaluating agri-environmental policies** *Chair: Gerald Schwarz*	Exploring farmers' preferences for implementing agri-environmental schemes - a cross country comparison of schemes as incentives for nutrient abatement in Baltic Sea catchments. **Czajkowski M,** Hasler B, Elofsson K, Hansen LB, Helin J, Häggmark T, Konrad M, Nielsen HØ, Niskanen O, Noman T, Pedersen AB, Petersen K, Zagorska K.	*14:45 – 15:45*
	Game-theoretic analysis of Baltic Sea eutrophication: policy instruments for burden sharing of reduced eutrophication in the Baltic Sea **Pavlova Y,** Ahlvik L.	
	Flexibility in the choice of N abatement measures: Implications for costs of implementation and environmental service provi-sion **Hansen LB,** Termansen M, Hasler B.	
	BREAK	*15:45 – 16:15*

Session 7 **Governance and Innovation** *Chair: Nico Stelljes*	The impact of water quality policies on innovation in nitrogen and phosphorus technology in Sweden **Häggmark Svensson T,** Elofsson K.	*16:15 – 17:15*
	Public policies for wetland implementation in Denmark and Sweden – historical lessons and emerging issues **Graversgaard M,** Dalgaard T, Hoffmann CC, Jacobsen BH, Powel N, Strand J, Feuerbach P, Tonderski K. .	
	Drivers of technology adoption at farm level in the Baltic region **Nielsen HØ,** Konrad M, Pedersen AB.	
Session 8 **Catchment nutrient loading-scenario analysis** *Chair: Hans E. Andersen*	Impact of future climate changes on hydrology, N-reduction and N-load in a Danish groundwater-dominated catchment **Hansen AL,** Børgesen CD, Olesen JE, Refsgaard JC	*16:15 – 17:15*
	Nitrogen leaching losses from two Baltic Sea catchments under scenarios of changes in land use, land management and climate **Olesen JE,** Bar-Michalczyk D, Bosshard T, Børgesen CD, Hansen AL, Jabloun M, Refsgaard JC, Wachniew P**.**	
	Scenario analyses of future nutrient export from the Pregolya River catchment area to the Baltic Sea considering changes in climate, land use and agricultural practices **Chubarenko B,** Gorbunova J, Domnin D.	

Day 3: 16/3/2018		
Keynote *Chair: Berit Hasler*	**Jim Smart (Griffith University, Brisbane, Australia):** Nitrogen trading – modelling principles from Australia's Great Barrier Reef: parallels and contrasts with the Baltic	*09:00 – 09:50*
	BREAK	*09:50 – 10:00*
Session 9 **Policy support for multiple ecosystem services** *Chair: Antti Iho*	Mainstreaming ecosystem services for improved agricultural and environmental policy integration: Lessons from a review **Schwarz G,** Zilans A, Veidemane K.	*10:00 – 11:00*
	Adapting policy settings to promote multiple ecosystem benefits: Lessons learnt from case studies in the Baltic Sea Region **Zilans A,** Schwarz G, Veidemane K, Osbeck M, Tonderski A, Olsson O.	
	Cultural ecosystem services provided by the Baltic Sea marine environment **Pouta E,** Ahtiainen H, Bertram C, Liski E, Soini K, Meyerhoff J, Pakalniete K, Rehdanz K.	
Session 10 **Stream remediation measures** *Chair: Bo Gustafsson*	Interactions between climate change impacts and nutrient mitigation measures: Comparison of the Selke (Germany) and Berze (Latvia) catchments **Jomaa S,** Veinbergs A, Yang X, Lagzdins A, Abramenko K, Rode M.	*10:00 – 11:00*
	Design of stream remediation measures for nutrient retention and attenuation in the hyporheic zone Morén I, Wörman A, **Riml J.**	
	Scenario analysis for stream restoration actions aimed at reducing nutrient loads to the Baltic Sea **Wörman A**, Riml J, Capell R, Morén I.	
	BREAK	*11:00 – 11:25*

Session 11 **Social learning for innovative governance** *Chair: Eija Pouta*	A social learning perspective on water governance - experiences from Helge å, Sweden. **Olsson O,** Osbeck M, Do T, Powell N.	*11:25 – 12:25*
	Identifying mitigation measures for multiple benefits in the Reda basin **Tonderski A**, Okrągła E, Machnikowski M, Burakowska H, Tonderski K.	
	Two dimensions of nitrate pollution management in an agricultural catchment **Wachniew P,** Martinez G, Bar-Michalczyk D, Kania J, Malina G, Michalczyk T, Różański K, Witczak S, Zieba D, Żurek AJ, Berrini A.	
Session 12 **Spatially differentiated regulation** *Chair: Andis Zilans*	Dairy farm management when nutrient runoff and greenhouse gas emissions count **Lötjönen S,** Temmes E, Ollikainen M.	*11:25 – 12:25*
	Spatially differentiated regulation measures – can it save the Baltic Sea from excessive nutrient loads, and is it possible? **Refsgaard JC,** Hansen AL, Højberg AL, Olesen JE, Hashemi F, Wachniew P, Wörman A, Bartosova A, Stelljes N, Jonge H, Chubarenko B.	
	Spatially differentiated regulation of nutrients – stakeholder perceptions in three different case study sites **Stelljes N,** McGlade K, Martinez G.	
	LUNCH & Poster Session	*12:25 – 13:25*

Session 13 **Local and regional governance** *Chair: Przemysław Wachniew*	Reconcling Stakeholder demands by enacting a post normal approach within nutrient governance **Powell N,** Do T, Olsson O, Osbeck M, Schwarz G, Tonderski A, Zilans A, Veidemane K, Tonderski K.	*13:25 – 14:25*
	Possible land use scenario for the Reda catchment case study and its impact on water management and marine water Walczykiewicz T, Jakusik E, Opial-Gałuszka U, **Przygrodzki P**, Skonieczna M, Woźniak Ł.	
	The revealed preferences of Baltic Sea governments: Goals, policy instruments, and implementation of nutrient abatement measures **Elofsson K**, von Brömssen C.	
Session 14 **Economic decision support** *Chair: Neil Powell*	A bottom-up approach to environmental Cost-Benefit Analysis **Carolus JF,** Hanley N, Olsen SB, Pedersen SM**.**	*13:25 – 14:25*
	Developing improved methods for identifying the cost-efficient abatement set in the Baltic Sea region **Helin J.**	
	Improving the cost-effectiveness of water quality improvements through spatial scale changes to target-setting **Czajkowski M,** Andersen HE, Blicher-Mathiesen G, Elofsson K, Hagemejer J, Hasler B, Humborg C, Smart J, Smedberg E, Stålnacke P, Thodsen H, Wąs A, Wilamowski M, Żylicz T, Hanley N.	
	BREAK	*14:25 – 14:40*
Discussion *Moderator: Gun Rudquist*	**Next challenges and next steps.**	*14:40 – 15:40*

Side event 15/3 **Gypsum treatment of agricultural fields – A novel and cost-efficient water protection measure** *Chair: Markku Ollikainen*	Gypsum reduces agricultural phosphorus load: preliminary results from a large-scale pilot **Ekholm P**, Ollikainen M, Punttila E.	*15/3* *14:45 – 15:45*
	Gypsum treatment of fields: a cost-efficient measure for the Baltic Sea **Ollikainen M**, Ekholm P, Punttila E.	
Side event 16/3 **Transport and reduction of nitrate in Danish landscapes at various scales – TReNDS** *Chair: Anker L Højberg*	Accounting for natural reduction of nitrogen **Højberg AL**, Iversen BV,Jessen S, Engesgaard P, Refsgaard JC, Hansen AL, Gertz F, Kjaergaard C.	*16/3* *10.00 – 11.00*
	Analysing drain flow modelling: How can representation of nitrate drainage transport be improved in catchment scale models? **Karlsson IB**, Højberg AL, Iversen BV.	
	Advancing local engagement in nitrate regulation **Gertz F.**	

POSTER SESSION	
Title of poster	***Authors***
Modelling impact of agricultural land use changes on nitrogen export from the Kocinka catchment	**Bar-Michalczyk D**, Michalczyk T, Kania J, Børgensen CD.
Patterns and trends in riverine water quality in the Baltic Sea basin: modeling nutrients with HYPE	**Bartosova A**, Strömqvist J, Capell R, Simonsson L, Arheimer B.
Shaping environmental policy choices – A logistic regression analysis on Swedish municipal councils	**Brockwell E**.
Cost-effectiveness analysis of nutrient mitigating measures: A cross-country comparison under the impact of climate and land-use change	**Carolus JF**, Bartosova A, Pedersen SM, Olsen SB.
Spatially-explicit model of the Baltic Sea-based recreation demand – new estimates of recreational value, its distribution along the coast, and the influence of environmental conditions	**Czajkowski** M, Zandersen M, Aslam U, Angelidis I, Becker T, Budziński W, Zagórska K.
Scenario analysis of the Pregolya River discharge as response to changing climate conditions	**Domnin D**, Chubarenko B, Voropaev R.
Benthic-pelagic coupling in coastal seas – modeling macrofaunal biomass production in response to organic matter input	**Ehrnsten E**, Bauer B, Norkko A, Gustafsson, B.
Assessment of nutrient concentrations and export for the Pregolya River (South-Eastern Baltic) by monitoring data 2014 – 2016	**Gorbunova J**, Domnin D, Chubarenko B.
Understanding shallow groundwater dynamics and the effect of tile drainage on flow paths around the redox interface in a Danish till area	**Hansen AL**, Jakobsen R, Refsgaard JC, Højberg AL, Iversen BV, Kjærgaard C.
Methods of spatially targeting agricultural mitigation measures for reducing uncertainty of estimated nitrogen load reductions to aquatic systems	**Hashemi F**, Olesen JE, Jabloun M, Hansen AL.
Go4baltic farm survey	**Hasler B,** Czajkowski M, Elofsson K, Hansen LB, Helin J, Häggmark T, Konrad M, Nielsen HØ, Niskanen O, Noman T, Pedersen AB, Petersen K, Zagorska K.
Groundwater and stream threshold values as a tool for compliance testing of groundwater and surface water chemical status and protection of the Baltic Sea – general principles and examples	**Hinsby K**, Refsgaard JC, Jakobsen R, Hansen AL, Olesen JE, Wachniew P
What was the nitrogen concentration in runoff water from Danish catchments to coastal waters around year 1900?	**Jensen PN**, Olesen JE, Kronvang B, Windolf J, Eriksen J.

Potential significance of riparian lowlands on nitrogen fluxes from agricultural drainage in Danish watersheds	**Kjaergaard C**, Forsmann D, Hørfarter R.
Drivers of participation in gypsum treatment of fields as an innovation for water protection	**Kosenius AK**, Ollikainen M.
Economic benefits from reaching a good status of the Baltic Sea	**Lankia T,** Ahtiainen H, Meyerhoff J, Pouta E, Bertram C, Pakalniete K, Rehdanz K.
GHG marginal abatement cost curves for Finnish agriculture in the case of multiple pollutants and interrelations	**Lötjönen S**, Temmes E, Ollikainen M.
The making of the documentary film Soils2Sea: How narrative films complement scientific investigation	**Martinez G**, Berrini A.
Interactive visualization for data exploration – The MIRACLE Visualization Tool	**Neset T-S**, Navarra C, Wilk J, Capell R, Bartosova A.
Transport and transformation of nitrate in a Danish riparian lowland	**Petersen RJ,** Prinds C, Iversen BV, Kjærgaard C, Jessen S, Engesgaard P
Mapping groundwater flow paths in riparian lowlands with geophysics - how deep do we need to go?	**Prinds C.,** Petersen RJ, Greve MH, Iversen BV.
A study of the nitrate management discourse in Poland and a comparison with Denmark	**Ptak EN**, Busck AG, Refsgaard JC.
Nutrient retention in a remediated stream – evaluation of a tracer experiment with ^{15}N, ^{32}P and ^{3}H	**Riml J,** Morén I, Wörman A, Zięba D, Wachniew P.
Optimal Abatement of nitrogen and phosphorus loading from spring crop cultivation	**Sihvonen** M, Valkama E, Hyytiäinen K.
Increased nutrient recycling in agriculture around the Baltic Sea: implications for eutrophication	**Svanbäck A,** McCrackin ML.
Method for logging subsurface redox signature with a novel Redox Probe	**Vela I,** Ejlskov P, Højberg AL, Ernsten V.
Questions for modelling on the local scale – case study area of Reda catchment	**Walczykiewicz T**, Jakusik E, Opial-Gałuszka U, Skonieczna M, Woźniak Ł
Lagtime of pollutant transport through catchments: reducing nutrient loadings to the Baltic Sea	**Żurek AJ**, Różański K, Witczak S.

4. Appendix D: Book of abstracts

The 3rd BONUS Symposium

Sustainable Ecosystem Governance under Changing Climate and Land Use in the Baltic Sea Region

Gdańsk, 14-16 March, 2018

Book of Abstracts

Consortium of BONUS projects: MIRACLE, SOILS2SEA, BALTICAPP & GO4BALTIC

http://bonus2018.eu

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Preface

The 3rd BONUS Symposium

The 3rd BONUS Symposium “Sustainable Ecosystem Governance under Changing Climate and Land Use in the Baltic Sea Region” held in Gdansk, 14-16 March, 2018, is organised jointly by four projects BONUS BALTICAPP, BONUS GO4BALTIC, BONUS MIRACLE and BONUS SOILS2SEA. The four projects are supported by BONUS (Art. 185) funded jointly by the EU and national funding institutions: Innovation Fund Denmark, Estonian Research Council, FiRD Coop - Academy of Finland, Forschungszentrum Jülich GmbH, Latvian Ministry of Education and Science, Polish National Centre for Research and Development, Swedish Environmental Protection Agency (Naturvårdsverket), Swedish Research Council for Environment, Agricultural Sciences and Spatial Planning (FORMAS), and Russian Foundation for Basic Research (RFBR).
The scope of the conference is to present, disseminate and discuss results from novel Baltic Sea research on regulation of the environment in the Baltic Sea Region, at international, national and local scales in a long-term perspective. The conference will introduce results of four BONUS projects ending in 2018. Novel approaches for managing nutrients, as well as governance approaches for the Baltic Sea region will be presented for discussion. Analyses of scenarios for future development will be based on advanced, well-integrated modelling, from field level to the entire Baltic Sea region. The results and their use will be reflected on relevant policies and their implementation in the Baltic Sea region.

Scopes of the four projects BONUS BALTICAPP, BONUS GO4BALTIC, BONUS MIRACLE and BONUS SOILS2SEA

The common nominator of the four projects are their foci on policies, policy implementation, novel approaches for managing nutrients in the Baltic Sea Region, advanced modelling from field level to the entire Baltic Sea Region, ecosystem services approaches as well as scenarios for the future. The projects address governance issues related to emissions from agriculture as well as other nutrient emitting sectors, climate change impacts on water flow and nutrient loads, GHG emissions as well as the state of the marine environment and the values people place on healthy marine environments.
Policies and governance strategies to regulate the environment in the Baltic Sea Region work together, but can also be conflicting, creating win-win solutions or barriers between e.g. water management policies, climate policies and agricultural and fisheries policies. In the four projects, ecosystem services approaches are explored to integrate agricultural and environmental governance strategies for multiple ecosystem benefits both in the Baltic Sea Basin and the sea itself.
Hydrological, economic and interdisciplinary assessment methods and models are developed and applied at local to international scales. These models are capable of delivering information to various stakeholders and policy makers on the environmental effects, cost efficiency and cost-benefits of existing and potential policy objectives, and on how policies work together. Synergies and contradictions between current governance regimes aiming at eutrophication control, flood control and biodiversity enhancement are investigated in cooperation with diverse stakeholder groups. One aim is to initiate an integrated social learning process to improve policy innovation and effectiveness in water resource and nutrient management.
Existing state-of-the-art models as well as new models linking global drivers (climate and socioeconomic trends), anthropogenic pressures, marine ecosystem and human well-being are combined at different spatial scales to inform policy makers and other stakeholder groups. Model results are also visualized in interactive learning processes to advance stakeholder´s understanding and assist identification of win-win solutions to achieve common goals. Further, they are used to assess how the future provision of marine ecosystem services can be secured under changing climate and anticipated socio-economic developments. Future climate conditions will change the loads of nutrients to the sea and to air, and ecosystems and ecosystem services change accordingly.

Innovative policies include incentives for the development of technologies and management methods. Such technologies have been developed and dispersed in the Baltic Sea countries and has led to better and efficient utilisation of nutrients - caused by e.g. development and use of manure utilisation technologies and market mechanisms such as nutrient trading. How incentives work and can be improved is an important field of research that can inform the improvement of policy implementation; both climate policy, agri-environmental policy and different policies in the water sector.
Spatial differences in natural conditions, production and pressures as well as ecosystem services, are important for the effectiveness and costs of environmental regulation. One example is that differences in natural geological/hydrological conditions nutrients (Nitrogen, N and Phosphorus, P) are reduced/retained to various extents on their travel paths from soils in the agricultural fields to the sea, and other examples are that the agricultural production and the waste water pressure varies greatly between Baltic Sea catchments. This spatial heterogeneity in both natural and man-made conditions can be exploited for a more cost-efficient location of mitigation measures, tentatively based on the ecosystem services approach. Furthermore, stakeholders´ problem perceptions, as well as governance regimes also vary considerably in the Baltic Sea Region, which means that we can expect different win-win solutions in different parts of the basin. An important question is how much can be gained in practice by spatially differentiated governance regimes.
Climate change is likely to result in increased loadings of nutrient from both agricultural and urban areas in the Baltic Sea Basin, due to e.g. increased flooding, warmer and wetter winters and longer periods without crop cover. The loadings will also be affected by changes in land use and agricultural practices. The question is what we can expect in terms of changes in nutrient loads in the future, how robust such estimated changes are and how climate change mitigation is influenced by agricultural development and regulation.
Inclusion of diverse groups of stakeholders in social learning processes to identify desired ecosystem services, consumption patterns, hotspot areas of recreation and other cultural ecosystem services is a critical component of the research. Apart from visualization, also attempts are made to develop other tools, such as mobile phone apps, to facilitate stakeholder interactions and their engagement in identifying and developing innovative nutrient and water governance and climate change adaptation (flood risks) approaches in the Baltic Sea Region.

The scientific programme

The scientific programme of the symposium comprises six external keynote presentations, 48 oral and 24 poster presentations from the four BONUS projects, as well as six oral and four poster presentation from other projects in two side events. In addition, two moderated panel discussions will be held with focus on new insights to the Baltic Sea Region produced by the project research and on the next challenges, respectively.
Six internationally recognised top scientists that have not been involved in the BONUS projects will give keynote presentations:

- Lotta Anderson, Swedish Meteorological and Hydrological Institute, Sweden
- Jim Smart, Griffith University, Australia
- James Shortle, PennState College of Agricultural Science, USA
- Jonathan Winsten, Winrock International, USA
- Kasper Kok, Wageningen University, The Netherlands
- Wim de Vries, Wageningen University, The Netherlands

Two research projects have organised side events, each with an oral session and a number of posters

- TReNDS – Transport and Reduction of Nitrate in Danish Landscapes at various Scales. TReNDS is supported by Innovation Fund Denmark
- Gypsum treatment of agricultural fields – A novel and cost-efficient water protection measure. The gypsum pilot contributes to the NutriTrade project lead by John Nurminen Foundation and funded by the European Union Central Baltic Program.

Organizing Committee

The conference organizing committee is formed by the following project representatives:

- **Jens Christian Refsgaard** – BONUS SOILS2SEA – Geological Survey of Denmark and Greenland, Denmark
- **Nico Stelljes** – BONUS SOILS2SEA – ECOLOGIC Institute, Germany
- **Berit Hasler** – BONUS GO4BALTIC – Aarhus University, Denmark
- **Markku Ollikainen** – BONUS GO4BALTIC – University of Helsinki, Finland
- **Kari Petri Hyytiäinen** – BONUS BALTICAPP – University of Helsinki, Finland
- **Kerstin Bly Joyce** – BONUS BALTICAPP – Stockholm University, Sweden
- **Karin Tonderski** – BONUS MIRACLE – Linköping University, Sweden
- **Andrzej Tonderski** – BONUS MIRACLE – POMINNO, Poland

Address from the BONUS Secretariat

BONUS, the joint Baltic Sea research and development programme aims to enhance the region's research capacity and underpin the development and implementation of 'fit-for-purpose' regulations and management practices. This is done in order to respond effectively to the major environmental and key societal challenges which the region faces, and will face, in the coming years. Also, another aim of BONUS is to improve the effectiveness of the Baltic Sea region's environmental research programming and approach by integrating the research activities in the Baltic Sea system into a durable, cooperative, interdisciplinary well-integrated and focused multi-national programme.

So far, BONUS has launched four calls (2012, 2014, 2015 and 2017) and selected 40 projects for funding. Thirteen innovation projects and five research projects have finished; 22 research or innovation projects are ongoing, many of which are ending soon. Today, all 19 themes of the BONUS strategic research agenda are satisfactorily covered.

In recent times, a major emphasis has been placed on production of synthesising outcomes of BONUS research. The BONUS plan of projects' clustering and collaboration activities in 2017 included two first BONUS symposia: The first symposium titled '*Science delivery for sustainable use of the Baltic Sea living resources*' was held on 17-19 October 2017 in Tallinn and co-organised by BONUS INSPIRE and BIO-C3 projects; the second symposium titled '*Shipping and environment: From regional to global perspectives'* was held 24-25 October 2017 in Gothenburg and was co-organised by BONUS SHEBA together with 'SOLAS – International Surface Ocean - Lower Atmosphere Study'. These symposia have already now witnessed initiation of production of larger knowledge synthesis publications involving a great number of BONUS projects. Furthermore, the last call announced i.e. '*BONUS call 2017: Synthesis*' aims at further synthesising the research outputs that address the challenges for sustainable use of the Baltic Sea ecosystem services. The successful consortia are currently negotiating their grant agreements and are envisaged to start their desktop studies in autumn 2018. These projects are set to deliver robust, unbiased review of our multidisciplinary knowledge in chosen topics – all critically important for sustainable use of the Baltic Sea ecosystem services.

The synthesising work continues in 2018 as now on 14-16 March 2018 in Gdansk, the third BONUS symposium titled '*Sustainable ecosystem governance under changing climate and land use in the Baltic Sea region'* will take place. This symposium presents the key results from four BONUS projects ending in 2018: BONUS BALTICAPP, GO4BALTIC, MIRACLE and SOILS2SEA projects. Learning of how changes in climate and land use are likely to affect future nutrient loads and ecosystem services, including compliance with HELCOM goals; or how can research results feed into advise and suggestions for more efficient and cost-efficient nutrient and climate policies, are among the many topics of interest to policy makers, stakeholders and scientists alike. And again, the importance of knowledge synthesis will provide a valuable undercurrent on which to pin the deliberations of this 3-day symposium.

Helsinki, 22 February 2018,
The BONUS Secretariat

Content

Keynote lectures

Project presentations

Panel discussions

Session 1: Impacts of changing climate policy and society on nutrient loading to the Baltic I

Session 2: Approaches for stakeholder dialogues

Session 3: Modelling nutrient transport

Session 4: Outlooks for the marine environments

Session 10: Stream remediation measures

Session 11: Social learning for innovative governance

Session 12: Spatially differentiated regulation

Session 13: Local and regional governance

Session 14: Economic decision support

Side event: Transport and reduction of nitrate in Danish landscapes at various scales - TReNDS

Side event: Gypsum treatment of agricultural fields – A novel and cost-efficient water protection measure

Poster session

Making the intangible manageable - is there a formula to merge research findings with local governance focusing on climate change adaptation?

Lotta Andersson

The Swedish National Knowledge Centre for Climate Change Adaptation, Swedish Meteorological and Hydrological Institute, S-601 76 Norrköping, Sweden

The need to adapt to climate variability is not a new challenge. However, with a changing climate, there is a need of transformation from planning based on the climate that we have observed to making decisions based on the climate that we can foresee, although with a range of uncertainty.
Adaptation to cope with climate change is still seen by many policy makers as a rather intangible issue to deal with, and many challenges hold back actions at the local level.
Consequently, at the same time as policy makers and responsible staff in municipalities gradually transform into a mind-set where climate adaptation is seen as an issue that need to be dealt with, implementation of actual actions are often relatively modest. This has been suggested to be due to that laws and regulations not are adapted, that roles and responsibilities are unclear or due to lack of strategies and goals on all administrative levels. Accessible knowledge- and decision support, as well as warning systems have been asked for, as well as outlines of how the costs for adaptation should be distributed among actors and how resources for prioritized measures can be guaranteed.
However, although many decision-support systems have been developed within research projects, the actual use of these systems is very limited; and mainly linked to cases when a municipality has participated as "stakeholder" in a research project. When the project is finished, the use of the tools is usually terminated due to lack of perceived relevance or resources.
Also when it comes to the political decisions related to, e.g., laws and regulation or cost-sharing models, the merging of research findings as guidance to decisions is limited. Again, factors as perceived relevance, clarity and the lack of involvement of policy makers in the research process are often stated as the reason for this.
With focus on tools for awareness rising and decision-support, this talk will assess the possibilities and challenges for research to actually facilitate local governance related to adaptation to climate change. However, the difficulties of merging research finding with local governance (as well as governance on all levels that eventually have an impact on the local level) are not unique for adaptation to climate change.
The barriers between research and policy-making can partly be attributed to how researchers are professionally rewarded. Another obstacle is linked to the fact that many researchers have the perception that if scientifically sound decision-support systems or other sources of information are made available, they will be implemented as a basis for well-informed decisions.
To ensure merging between research and local governance, there is a need for researchers to shift from looking at potential users of results as not so well-defined groups of "stakeholders" that are to be provided with information or tools, to a true co-production together with people that have an interest in using project outputs in the long term.
The sphere of action for municipal politicians and officers on the local level is constrained by time and other resources. Relevance will be linked to level of complexity, correspondence with available resources (time, expertise and funding) and possibility to integrate decision-support tools or other research outcomes with existing local procedures.
Finally, the possibilities for researchers to make climate adaptation tangible and perceived as relevant among citizens by serious gaming and citizen science will be addressed.

Innovating Policy for Effective and Efficient Control of Nutrient Pollution: Challenges and Paths Forward

James Shortle

PennState College of Agricultural Science, USA

Water pollution control has been a top environmental policy priority in developed countries for decades, an area of significant regulation, and the focus of enormous public and private spending. Yet significant water quality problems remain in these countries, often related to inadequate control of nutrient pollution from agricultural nonpoint sources. Inadequate control of agricultural nonpoint pollution is typically the result of poor policy choices rather than an absence of policy initiatives. In consequence, policy reforms and innovations to improve the effectiveness of agricultural controls are essential to progress.

This presentation will examine the agricultural nonpoint water pollution policy problem in the context of the United States. In the US as in many other developed countries, water pollution remains a pervasive problem. For example, a recent U.S. Environmental Protection Agency assessment finds that 46% of U.S. rivers and streams are in poor biological condition, 25% are in fair condition, and only 28% are in good condition. This situation is in large degree due to fundamental flaws in the nation's water quality policy architecture. Point sources are regulated heavily and effectively, though at very high cost. Total discharges and especially discharges per capita of conventional pollutants from point sources have been substantially reduced. In contrast, agricultural nonpoint sources are generally lightly regulated and now rank as major, and often leading, cause of ongoing water quality problems. The same architecture has resulted in pollution controls that are unnecessarily expensive, to the point that the incremental costs of additional water quality protection exceed the benefits. Innovations in water quality policy are essential to improve the effectiveness and economic efficiency of water quality protection.

Decades of research on relationships between farming systems and water quality and technologies to reduce agricultural nonpoint pollution provide the sector with a substantial technological toolkit for water quality protection. The policy challenge is to induce the implementation of the right practices in the right places (within fields and watersheds) to achieve water quality goals at least cost. The existing policy architecture relies excessively on voluntary implementation of controls by farmers, focuses on effort rather than outcomes, and allocates scarce resources inefficiently across places and sectors. The presentation describes policy reforms that can improve water quality and reduce the total social costs of water pollution control.

Improving participation and the cost-effectiveness of agricultural pollution control programs through the use of Pay-for-Performance Conservation

Jonathan R. Winsten

Winrock International Institute for Agricultural Development

Farmers not only produce our food and fiber needs, they are important stewards of our water resources. Farmers are highly effective at responding to price signals for the efficient production of food and fiber; now it is incumbant upon us to develop appropriate price signals for the protection of water resources. Furthermore, inherent variation in topography, soils, farming systems, and farmer preferences dictates that a ”one-size-fits-all”, practice-based approach to agricultural pollution control is not likely to yield efficient nor cost-effective solutions. Recent advances in modeling nutrient losses from agricultural land have allowed for the development of performance-based conservation programs. This presentation explores the solution of using pay-for-performance (PFP) conservation as an approach that can reduce nutrient and sediment loss from agricultural land in a cost-effective manner. The ability of any given conservation practice to reduce nutrient loss varies very greatly from farm-to-farm and even from field-to-field. With PFP, crucial field-specific data are utilized in a science-based model to provide estimates of nutrient loss from very specific conservation actions that are of potential interest to a given farmer. The farmer receives an annual performance-based incentive payment based on the estimated units of phosphorus (P), nitrogen (N), or sediment (depending on the specific water quality needs of the given watershed) that are reduced relative to the farm’s baseline level of losses. In a PFP program, participating farmers are motivated to find and implement the most cost-effective actions for their specific fields. According to economic theory, farmers will start with the most cost-effective actions and continue to implement conservation up to the point where the margincal cost of the last unit of nutrient loss reduction equals the payment per unit in order to maximize farm profits. Program administrators can set the payment level to optimize nutrient loss reductions given budget constraints. Adding a secondary (i.e. BONUS) payment when in-stream nutrient thresholds have been met based on water quality monitoring at the mouth of the watershed has several important properties for program success. First, farmers, like all people, want to see that their actions are having a tangible impact toward a solution. Measuring load reductions allows farmers to see when they have ”moved the needle” toward improved water quality. Clearly defined and achievable goals are essential for human motivation. Second, to increase the probability that any participating farmer will collect the bonus payment, farmers are more likely to recruit participation of other farmers in the watershed, which is extremely valuable outreach for the program. Third, measuring load reductions at the mouth of the watershed is where ”the rubber meets the road” and is essential for understanding when improvements in ambient water quality have been achieved.

The U.S. federal government already spends in excess of $5 billion per year in an attempt to reduce nutrient loss from agriculture using practice-based programs. Using price signals through PFP conservation will embed environmental quality considerations into farmers’ business decision-making processes. This will benefit farmers, water quality, and tax payers.

Scenarios for land use, socio-economic and climate change – A call for integration

Kasper Kok, Simona Pedde

Soil Geography and Landscape Group, Wageningen University & Research, Wageningen, the Netherlands

Scenarios have been recognised as a useful tool for planning in the face of irreducible complexity and uncertainty. This particularly holds for climate change related research, where changes in socio-economic behaviour and related greenhouse gas emissions are highly uncertain and take decades to translate into temperature and precipitation change. As a result, the number of scenarios in climate change research and beyond has increased strongly. Often, scenarios are divided into parts of the system to improve the unravelling the complexity. This had led to a plethora of different types of scenarios, including qualitative stories and quantitative models; exploratory and normative scenarios; participatory and desk-top scenarios; and socio-economic and climate change futures. An important recent example are new global climate scenarios. For a number of practical reasons, climate change (RCPs – Representative Concentration Pathways), socio-economic change (SSPs – Shared Socioeconomic Pathways), and actions/ policies/strategies (SPAs - Shared Policy Assumptions) have been developed separately, leading to three largely disconnected sets of scenarios that are now being used around the globe. This method of developing partial scenarios has spawned methodological innovation on these parts, but has left the question of how to integrate across scale, sector/topic, and methodological differences. This presentation will showcase some of the state-of-the-art of partial scenario development, but will focus on specific integrative tools that have been developed to bridge the scale gap, as well as the gap between socio-economic narratives and climate model output. It focuses on land use scenarios as a type of scenarios that call for integration of drivers from different subdomains. It discusses current weak points and possible ways forward to improve our integrated understanding of future changes.

Assessment of the needed increase in nitrogen use efficiency in European agricultural soils in view of water quality

Wim de Vries[1,2] and Hans Kros[2]

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Background: The intensification of European agriculture, including large inputs of nitrogen (N) to soil by fertilizers and manure, has led to an increase in crop growth but also to adverse effects on the environment. In several regions in Europe, high N inputs have led to: (i) eutrophication of surface waters due to increased N runoff, (ii) increased nitrate (NO_3) levels in drinking water reservoirs due to elevated NO_3 leaching and (iii) (i) loss of terrestrial biodiversity due to increased emission and deposition of ammonia (NH_3). Inversely, in other regions there is still room for increasing N inputs without exceeding critical thresholds for N losses. When current N inputs exceed critical N inputs, environmental objectives can only be reached at lower N input, which likely would cause a loss in crop production, unless the nutrient use efficiency (NUE) is increased. When the NUE is increased, the current N input can be lowered, since the same crop yield can be reached with less N fertilizer, due to an enhanced N uptake fraction, while the critical N input increases since a lower fraction of N is lost to the environment. The NUE increase that is required to attain the current crop production while protecting surface water was assessed in a European wide study. The approach is relevant in view of discussion on the use of planetary N boundaries and the need for downscaling those boundaries at the regional level and country level
Methods: We calculated critical N inputs and their exceedances (current N inputs minus critical N inputs) for agricultural soils in the EU-27 region in view of N runoff to surface water and related effects on aquatic ecosystems. In addition, critical N inputs were calculated in view of critical NO_3 leaching to ground water and critical NH_3 emissions to air, respectively. The derivation of critical N inputs in view of adverse environmental impacts, consisted of three consecutive steps, i.e.: (i) identification of critical values for defined N indicators, (ii) back-calculation of critical N losses to surface water or air that correspond to critical values for N indicators and (iii) back-calculation of critical N inputs from critical N losses. The INTEGRATOR model was used to calculate current and critical N inputs at EU27 level. The calculated spatially explicit critical N inputs in view of losses to air and water were compared with current N inputs (the year 2010). For areas where critical N inputs were below current N inputs, we calculated the needed increase in NUE to attain environmental objectives at current crop yields.
Results: The calculations at EU-27 level showed that the critical N inputs were approximately 20% lower than current (year 2010) N inputs, using either critical N concentration in surface water or critical N deposition as criterion. The calculated NUE values that are needed to attain the current crop yield while not exceeding critical environmental thresholds nearly always ranged between 50 and 90%. In several regions, the current N input is much higher than the critical N input and vice versa. There is thus a clear need for a spatial reallocation of the N inputs to N deficient regions and an increase in NUE in highly productive regions to avoid environmental impacts, such as eutrophication of surface waters, while maintaining crop production.

Nitrogen Trading – modelling principles from Australia's Great Barrier Reef: parallels and contrasts with the Baltic

James C.R. Smart[1,2] & Syezlin Hasan[2]

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Dissolved inorganic nitrogen (DIN) runoff from agriculture, particularly sugar cane, is widely recognised to be causing significant adverse impacts on water quality in Australia's Great Barrier Reef (GBR). Catchment-generated anthropogenic DIN loads will have to be reduced by at least 50% if the end-of-catchment load targets set in the Reef 2050 Long-Term Sustainability Plan are to be achieved. Recent estimates suggest that the costs of meeting the 2025 DIN load targets will be very substantial. Modelling indicates that water quality credit trading, operating within proposed catchment DIN load limits, offers potential for delivering cost-effective improvements in Reef water quality.
This presentation describes a 'smart market' approach that has been used to model water quality trading for DIN in catchments along Queensland's Wet Tropics coast which drain into the GBR Lagoon, and considers parallels and contrasts with potential smart market DIN trading in an agricultural catchment in northern Denmark. Trading frameworks consider both changes in agricultural management practice (e.g. reduced fertiliser applications) and changes in land use (e.g. wetland construction). Extensions to the original model to incorporate point-sources, multi-year perspectives and non-emitting entities will be discussed.

BONUS BALTICAPP - Well-being from the Baltic Sea – applications combining natural science and economics

Kari Hyytiäinen[1], Heini Ahtiainen[4], Janne Artell[4], Barbara Bauer[5], Christine Bertram[3], Mateusz Buczyński[7], Wiktor Budziński[7], Mikolaj Czajkowski[7], Kerstin Bly Joyce[5], Bo Gustafsson[5], Eva Ehrnsten[1,5], Tuija Lankia[4], Markus Meier[8,6], Jürgen Meyerhoff[3], Alf Norkko[1], Sampo Pihlainen[1], Eija Pouta[2], Katrin Rehdanz[3], Sofia Saraiva[9], Matti Sihvonen[1], Maciej Tomczak[5], Katarzyna Zagórska[7], Marianne Zandersen[2]

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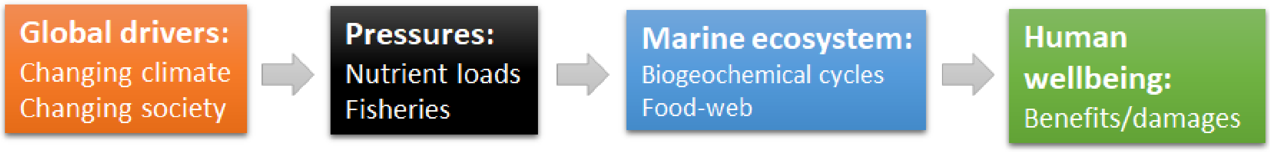
Despite its ecological vulnerability, the Baltic Sea produces and has the potential to sustain a rich array of ecosystem services essential for our wellbeing. In order to design policies to sustain the provision of these services, we need to understand and to quantify the causal chain of interactions that drive the polluting and extractive uses of the sea. BONUS BALTICAPP explores the consequences of alternative global socioeconomic futures (Shared Socioeconomic Pathways, SSPs) and climate futures (Representative Concentration Pathways, RCPs) on extractive and consumptive uses of the Baltic Sea, and subsequently, on biogeochemical processes, food web structure and the provision of marine ecosystem services.



Global climate change alters our environment and the types and levels of pollution in a fundamental manner. Increased precipitation and shortened winters will make it more difficult to reach and to maintain the mutually agreed environmental targets (HELCOM Baltic Sea Action Plan, BSAP). In addition, changes in the global and regional socioeconomic drivers such as population size, urbanization, education and life styles tend to have substantial impacts on the mitigation challenge. Some of these drivers, such as technological development, tend to reduce the challenges to mitigate nutrient loading, while some others, such as increased demand for food, tends to increase the challenge. Long-term projections prepared for the combinations of global climate and socioeconomic futures imply that reaching the Good Environmental Status (GES) will remain in the hands and in the capacities of the Baltic Sea countries. However, the level of mitigation effort will be largely determined by the long-term trends of global and regional socioeconomic drivers. Under certain global conditions (e.g. global sustainability scenario SSP1 combined with moderate climate change RCP4.5) the BSAP targets are reached by simply implementing current water policies. The phosphorus reduction target will remain more challenging to reach, and requires additional mitigation effort under all explored global socioeconomic and climate futures. Under an extreme societal future (fossil fueled global scenario, SSP5 combined with high-end climate future RCP8.5), expanding agriculture would create substantial challenges for water protection. Under this scenario, the targeted nutrient load level can be reached only through substantial structural changes and regulation of the agricultural sector, or alternatively, yet unforeseen technology leap in manure handling. The benefits of reaching GES are substantial. The respondents value highly improvements in ecosystem health and species diversity.

BONUS SOILS2SEA – Reducing nutrient loads from agricultural soils to the Baltic Sea via groundwater and streams

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BONUS SOILS2SEA assesses the nutrient load to the Baltic Sea under changed climate and land use in 2050. Furthermore, BONUS SOILS2SEA develops and tests the concept of spatially differentiated regulation of agriculture as a smart way of reducing nutrient loads by exploiting the fact that the retention (removal by biogeochemical processes or sedimentation) of nutrients in groundwater and surface water systems shows a significant spatial variation, depending on the local hydrogeological and riverine regime. Data and knowledge from field study catchments in Denmark, Sweden, Poland and Russia have been used to improve the HYPE model simulating water flows and nutrient transport for the entire Baltic Sea drainage basin. This has in particular focused on improving HYPE's capability to predict the effect of spatially differentiated regulatory measures. To support this, BONUS SOILS2SEA has produced a new map of N-retention in groundwater throughout the Baltic Sea drainage basin.
Preliminary results suggest that the nutrient loads to the Baltic Sea are likely to increase between 4% and 10% for N and between 6% and 20% for P as a response to climate change, while the ranges are substantially larger for individual catchments. Similarly, preliminary results suggest that land use change, depending on socio-economic developments, may lead to either a decrease (19% and 6% for N and P, respectively) or an increase (11% and 9% for N and P, respectively) in nutrient loads.
Analyses of differentiated regulation with spatially targeted measures for the agricultural cultivation areas and in streams/wetlands indicate that the N and P loads can be decreased substantially without significantly affecting the agricultural production. Preliminary results suggest that the potential gain in terms of decrease in nutrient loads vary considerably between individual catchments from a few percentage up to 25 % depending on spatial variation in groundwater retention and land use. Analyses also show that it will be difficult to exploit the full potential in practice due to constraints in agricultural land use and management as well as the uncertainties associated with groundwater retention at finer spatial scales.
The differentiated regulation with spatial targeting of measures within catchments implies that farmers are affected differently. Except for economic compensation, a precondition for this to be acceptable by stakeholders, if enforced by central authorities through traditional top-down regulations, is that the local scale information on the spatial variability of nutrient removal is reasonably accurate. As this will require more local data than is typically available today, new governance concepts are required to exploit the full potential gain from differentiated regulation. Results from a series of stakeholder workshops in the three study areas followed by regional stakeholder workshops suggest that the governance regime should be tailored to the local socio-economic and cultural context. Furthermore, in some countries with a strong tradition for local cooperation and a high level of societal trust, a co-governance system with delegation of some decision power to local stakeholders may be better capable of handling the large uncertainties in local scale data and hence better exploit the potential gain from spatially differentiated regulation.

BONUS GO4BALTIC – Coherent policies and governance of the Baltic Sea ecosystems

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The aim of BONUS GO4BALTIC is to provide policy relevant advice and recommendations for reductions of the eutrophication in the Baltic Sea in coherence with climate and agricultural policies, and examines environmental and agricultural policies across the Baltic countries, cost-effective solutions and potentials for coherence and conflicts between the policies. The project has a focus on technological development, including incentives, technological change, changes in management and innovation of new technologies, that could potentially reduce abatement costs. This presentation lays out the key findings of the Bonus GO4BALTIC and discusses implications for policy.
The project has studied the **developments of the agricultural sector**, especially the structural changes in livestock production, and the results indicate a heavy structural change resulting in fewer and larger livestock farms. This increases the risk of spatial over-application of manure nutrients, particularly phosphorus. The analysis shows that although the development seems to proceed in the same direction in all countries, new member states have more polarized structures than old ones. The effects of structural change should be taken into account in agri-environmental policies in Baltic Sea countries. Another highlight is the linkage of **CAPRI (Common Agricultural Policy Regionalised Impact Modelling system) model results to an agricultural nitrogen loss** model and a marine model for assessments of the effects of agricultural and environmental policy changes on the eutrophication of the Baltic Sea. The results show the differences in effects between countries and Baltic Sea regions and demonstrates a large potential for nutrient loss reduction in improving the management of manure. Yet another strand of results include responses from a **Farm Survey**, which has been answered by 2500 farmers in Sweden, Finland, Poland, Estonia and Denmark. The survey provides new knowledge of fertiliser handling practices, incentives for investments as well as choices between agri-environmental schemes.
Analytical models and simulations using Finnish data have been used to investigate how effective crop rotations are at providing profits and at the same time reducing nutrient loads and GHG emissions. By a series of models alternative preferences farmers' may exhibit for the use of gypsum are analysed. Danish data are used to analyse **incentives for farmers to trade** nutrient abatement requirements between them. The scarce empirical information on the **implementation of different policies** and measures to reduce nutrient loads from the surrounding countries has been examined, showing higher implementation levels for measures that are subsidized than measures that are regulated in relation to the goals. Our results suggest, among others, that better environmental performance and lower costs could be achieved through nutrient permit markets that permit credit stacking, i.e. compensation for both nitrogen and phosphorus reductions by a given measure. Nutrient policies for wastewater seem more successful than policies for the agricultural sector in terms of the incentives for technological development provided. In the coming months these and additional results will be translated into recommendations for a Baltic Sea socioeconomic action plan.

BONUS MIRACLE - Mediating integrated actions for sustainable ecosystem services in a changing climate

Karin Tonderski[1], René Capell[2], Seifeddine Jomaa[3], Ainis Lagzdins[4],Tina-Simone Neset[1], Olle Olsson[5], Søren M Pedersen[6], Neil Powell[7], Gerald Schwarz[8], Andrzej Tonderski[9], Tomasz Walczykiewicz[10], Andis Zilans[11]

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Water and nutrient governance in the Baltic Sea Region face several challenges. The future is highly uncertain due to climate change and on-going land-use changes, and different sectors works towards partly contradicting objectives, which makes it difficult to bring about integrated governance. In BONUS MIRACLE, a **social learning process** has been enacted to identify new configurations for water governance based on the hypothesis that more effective approaches to ’nutrient governance’ need to bring on-board new constellations of actors with stakes in local issues that are interconnected with nutrient enrichment. A series of learning events between stakeholder groups and researchers in four case areas have been orchestrated. To support the process of reconciling stakeholder interests, researchers were asked to provide ´on-demand´ results regarding effects, cost-efficiency and benefits of suggested measures on water flow, nutrient transport (using the HYPE model) and other ecosystem services benefits under different climate change and land-use scenarios. Results were visualized in the **MIRACLE Visualization Tool**. Lessons learnt and results of policy analyses were used to discuss governance approaches on the BSR level that could support more integrated actions.

An important project insight is that case level stakeholders, in general, are not interested in learning how different measures perform in reducing nutrient enrichment at a larger Baltic Sea basin level. Rather, they are interested in the impact measures have in terms of addressing multiple demands in the local settings. Regarding **stakeholder positions**, insights have emerged pertaining the important role position holders play in hindering or enabling change processes. In the ´pathways to change´, application of mineral fertilizers was one of the more **cost-efficient measures** suggested, along with creation of increased water retention, floodplains and wetlands. The latter also provide other **ecosystem service benefits**, and an approach was developed to interactively assess those, despite considerable knowledge gaps regarding effects and values. On the BSR level, the Visualization Tool provided useful learning support by visualizing E-HYPE model results regarding water flow and nutrient transport, as on this level the **stakeholder´s system of interest** is on governance innovations that address the nutrient issue. **E-HYPE scenario modeling** showed that while the mean water flow is expected to decrease in some southern BSR catchments, a substantial increase is predicted for most others. Similarly, the load of nitrogen may increase up to 25 % in some parts of the northern BSR, whereas a slight decrease is predicted for the south/southwestern parts. Governance innovations are needed that can accommodate those differences. However, current **policies are insufficiently coordinated and integrated between sectors**, due to imbalanced power relations and opposing agendas. This remains a constraint for the effectiveness of existing policy strategies, regulations and directives in addressing multiple ecosystem benefits. The involvement of local stakeholders needs to be strengthened and **new models for cooperative and collective measures with intermediaries** tested, to stimulate the use of local knowledge in improving the effectiveness and efficiency of management measures and reducing transaction costs. The synthesized BONUS MIRACLE results will be translated into a “Roadmap for improving water resource management in the Baltic Sea Region”, with suggestions for adaptation of policies, institutional settings and governance arrangements.

Panel discussion DAY 1 - New insight on the Baltic Sea Region

Moderated by Mette Termansen, University of Copenhagen

On the background of the presentations of key findings from the four projects representing highlights new insights on the Baltic Sea region will be debated.

The results from the four BONUS projects BALTICAPP, GO4BALTIC, MIRACLE and SOILS2SEA provide new insights based on evaluations and assessments, modelling frameworks and tools. The four projects have produced results that can improve state-of-the art within both social –and natural scientific research related to the Baltic Sea, and the research outputs can improve policy implementation and coordination around the Baltic Sea. The highlights from the four projects cover assessments from farm level scale to international agreement level, including:

- Scenarios for the future climate, land use and agriculture and their impacts on nutrient loads.
- Policy and governance – evaluations of the past, insights for the future
- Assessments of ecosystem services at land and sea
- Models developed at different scales, covering marine models, hydrological models at field and Baltic Sea Basin scales as well as integrated economic and ecological models

Panel discussion DAY 3 – Next challenges and next steps

Moderated by Gun Rudquist, Stockholm University

The conference has provided new knowledge and insights from the four BONUS projects BALTICAP, GO4BALTIC, MIRACLE and SOILS2SEA, as well as from the side-events of the conference. The members of the panel will provide a 2-3 minutes reflection of new insights in the light of current and new challenges, and how these insights might inform next steps of policy development, implementation and integration. The panel will also reflect upon research needs and challenges.

Using extended socio-economic scenarios to investigate drivers and pressures on the Baltic Sea up to 2100

Marianne Zandersen[1], Kari Hyytiäinen[2], Markus Meier[4,5], Maciej Tomczak[3], Barbara Bauer[3], Päivi Haapasaari[8,2], Jørgen E. Olesen[1], Bo Gustafsson[3], Jens Christian Refsgaard[9], Erik Fridell[5], Sampo Pihlainen[2], Martin Le Tissier[6] Anna-Kaisa Kosenius[2], Detlef Van Vuuren[7]

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The Baltic Sea is strongly influenced by human activities and the climatic system:

i) diffuse and point nutrient loads from agriculture, industry and waste water treatment plants have particularly over the past 60 years caused strong eutrophication and large areas of dead sea bottoms in the Baltic Sea, threatening a range of important ecosystem services; and

ii) perhaps increasing runoff integrated over the entire Baltic Sea catchment area in future climate, which in turn accelerates nutrient loads to the sea, while the resilience of the marine ecosystem is weakened due to higher surface water temperatures.

Scenarios that combine socio-economic and climate pathways can be powerful tools to help evaluate the challenges and uncertainties in ecosystem management and the scale of human contributions to regional environmental change under different plausible futures. Such scenarios can be used as input to integrated assessments to investigate how changes in nutrient emissions and subsequent responses in the ecosystem, combined with uncertainty about both future climate impacts and societal developments, may develop and what actions would be needed to obtain good environmental conditions.

Global climate futures, i.e. Representative concentration pathways (RCPs) and socioeconomic futures, i.e. Shared Socioeconomic Pathways (SSPs) were initially developed to address global challenges to mitigate and adapt to climate change. These can also be directly applied as tools when analyzing solutions to regional environmental problems, which would necessitate extending the pathways to regional sectors.

We present a collaborative and interdisciplinary effort to translate global climate and socioeconomic futures into regional drivers and pressures that drive pollution in the Baltic Sea. We propose sectoral narratives of the sustainability pathway (SSP1), the Middle of the Road (SSP2), Regional Rivalry (SSP3) and Fossil Fueled Development (SSP5) along with quantifications of the drivers impacting nutrient loads and the different levels of pressures in terms of total nitrogen and phosphorus loading up to 2100. We combine the SSP/RCP matrix structure with the analytical frame of DPSIR (Drivers, Pressures, State, Impacts and Responses).

Results indicate a plausible range of different responses needed under the different SSPs in order to ensure a good environmental status of the Baltic Sea up to 2100. The approach exemplifies the potential for applying scenario analysis stemming from climate research to regional environmental challenges, which are impacted by climate change.

Land use and land cover projections in the Baltic Sea Basin under different SSPs and future climate change

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[5]Baltic Nest Institute Sweden, Baltic Sea Centre, Stockholm University, Stockholm, Sweden

The Baltic Sea has suffered from severe effects of eutrophication for many decades and achieving greater sustainability and ecological restoration is becoming urgent. Therefore, a scenario-based modeling framework is needed to support the analysis of possible impacts of land-use change, and to delineate potential mitigation strategies on nutrient loading under an uncertain future climate. Whilst a wide range of climate change scenarios have been available to the community for several years, the development of land-use change scenarios can be considered relatively recent and a small range of models are available. Thus, to effectively prepare for change, policymakers would need as a first step information about how socioeconomic scenarios and different future climate projections may influence future land use and land cover (LULC) in the Baltic Sea Basin.
In this study, we developed a scenario-based modeling framework to analyze potential future land-use change in the Baltic Sea Basin. Expert knowledge was used to develop quantitative demand for future LULC change for three shared socio-economic pathways i.e. the sustainability pathway (SSP1), the Middle of the Road (SSP2) and Fossil Fueled Development (SSP5). The changes related to urban/built up areas were determined separately and the projected future population in 2050 under the different SSPs was used to determine the urban expansion as compared to current situation. For the other LULC classes (i.e. forest, grassland, cropland, and bare/spare vegetation) a LULC model was developed using the Random Forest (RF) classification tree. Data on historical LULC in 2010 and selected biophysical and historical climate indices were used as drivers. The RF LULC model was used to generate the probability maps of each of the LULC classes for four different climate projections for the relatively near-future time frame period 2041-2060 under RCP8.5 scenario. These probability maps were used to allocate the different land use demand for the different SSP story lines and spatially explicit future land-use maps were produced for the different climate projections.

Change in nutrient loads to the Baltic Sea Basin with changing climate, socioeconomic impacts, and land management practices

Alena Bartosova[1], Johan Strömqvist[1], René Capell[1], Jørgen E. Olesen[2], Mohamed Jabloun[2,3], Berit Arheimer[1], Chantal Donnelly[1], Kari Hyytiäinen[4], Søren M. Pedersen[5], Andis Zilans[6], Karin Tonderski[7], and Marianne Zandersen[2]

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An integrated dynamic model E-HYPE v.3.1.4 developed by SMHI allows us to investigate impacts of changing climate, socioeconomic development, and implementation of mitigation measures on nutrient loading to the Baltic Sea Basin on a large scale. The new scenarios framework developed by the climate change research community over the recent years consists of two sets of pathways: Representative Concentration Pathways (RCPs) that describe the extent of climate change and Shared Socioeconomic Pathways (SSPs) that depict plausible socioeconomic conditions during the 21st century.
We have investigated the following for the Baltic Sea Basin:

- What nutrient loads can we expect to be delivered to the Baltic Sea by 2050s given the potential future socioeconomic development and climate changes?
- How do combinations of changes in climatic conditions with targeted changes in land use and land management affect nutrient loading to the Baltic Sea in different basins?
- How effective are spatially differentiated, single-objective, and multi-objective measures at reducing nutrient loads to the Baltic Sea under the current and future conditions?

We selected RCP 8.5 together with three SSPs: SSP1 (Sustainability), SSP2 (Middle of the road), and SSP5 (Fossil-fueled development). SSPs were interpreted within the context of the RCP 8.5 to project land use and agriculture practices as well as changes in waste water discharges to 2050s. Four climate models were selected for simulation. Compared to the current situation, the nutrient loads are expected to increase by 8% (between 2% and 13%) for N and by 14% (between 6% and 20%) for P as a response to climate change. However, when socioeconomic changes are considered together with changing climate the nutrient load to Baltic Sea is affected even more significantly. The load can decrease by 13% and 6% (SSP1) or increase by 11% and 10% (SSP5) for nitrogen and phosphorus, respectively, compared to the current situation.
Spatially differentiated measures take advantage of the fact that the retention (removal by biogeochemical processes or sedimentation) of nutrients in groundwater and surface water systems shows a significant spatial variation. The strategic placement of anthropogenic activities can be used to help achieve the goals for nutrient load reduction set out in the Baltic Sea Action Plan. The traditional uniform regulations can be much less cost-effective than spatially differentiated regulations with measures targeted towards areas where the natural retention is low. The effect of multi-objective measures on nutrient load is not as pronounced but the efficiency needs to be weighted also with respect to providing other benefits such as reduction in flooding or increase in biodiversity.

Visualization supported dialogues in the Baltic Sea Region

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Drawing on recent research and development in geographical and information visualization, the BONUS MIRACLE project developed an interactive visualization tool to enable stakeholders around the Baltic Sea to explore data generated by hydrological and hydrochemical modelling as well as visual representations of cost-benefit assessments and illustrations of pathways that were developed in the project. The BONUS MIRACLE Tool is a web-based tool that has been designed to allow exploration of data for four case study catchments as well as the whole Baltic Sea Region. The MIRACLE Tool supports the selection of multiple variables as well as land-use and climate change scenarios. Linked multiple views enable users to select and compare results of the HYPE model, an integrated rainfall-runoff and nutrient transfer model developed at the Swedish Meteorological and Hydrological Institute (SMHI). The tool is designed to be employed in stakeholder interactions, both in workshops in the MIRACLE pilot areas, for cross case comparisons as well as for deliberations on Baltic Sea Region scale. Introducing new formats to traditional stakeholder interactions, such as focus groups, workshops and consultations, presents however a challenge both in terms of design and analysis. This paper exemplifies a typology of visualization-supported dialogues and discusses challenges, opportunities and trade-offs.

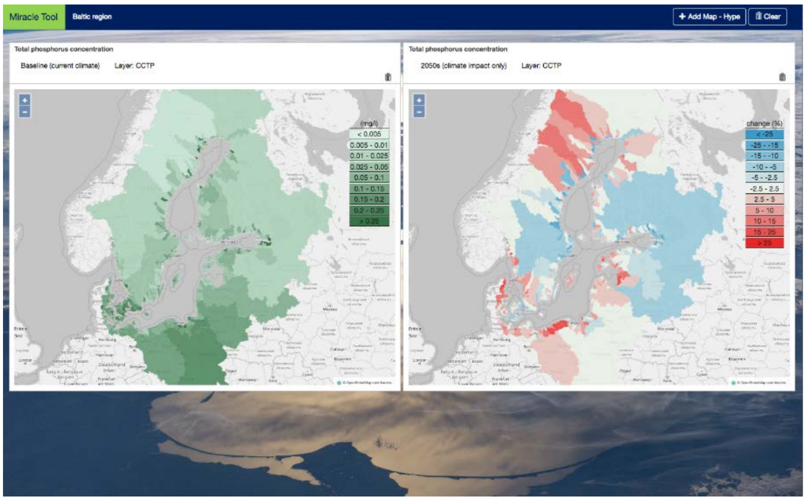


Figure 1: The Baltic Sea Region Module of the MIRACLE VISUALIZATION TOOL with the 'total phosphorus concentration' indicator for the baseline (current climate) to the left and its relative change for the future climate in the 2050s to the right. The two maps allow simultaneous exploration of scenarios and indicators.

Typologies of visualization supported dialogues cover a wide range of application areas including (i) the use of inspirational imagery, such as images representing e.g. measures that might be taken in a catchment to reduce nutrient emissions, (ii) map representations of supporting information, e.g. flood risk maps, (iii) interactive map displays for data exploration, or (iv) information visualization tools such as Sankey diagrams to display e.g. cost benefit data.
While these typologies have different aims in stakeholder dialogues, the use of interactive tools and visual representations demands new approaches to the design of these interactions. In particular the integration of various types of visual information in stakeholder dialogues creates a need to revisit and rethink participatory research methods to provide opportunities for the available information to be optimally used by stakeholders to guide, support and inform their discussions. This paper presents aspects that need to be addressed when designing interactive tools for participatory processes as well as to develop a methodological framework for the application of visualization supported tools in stakeholder dialogues.

Employing narratives and ethnographic studies to inform policy options for nutrient reductions

Grit Martinez

Ecologic Institute, Berlin, Germany

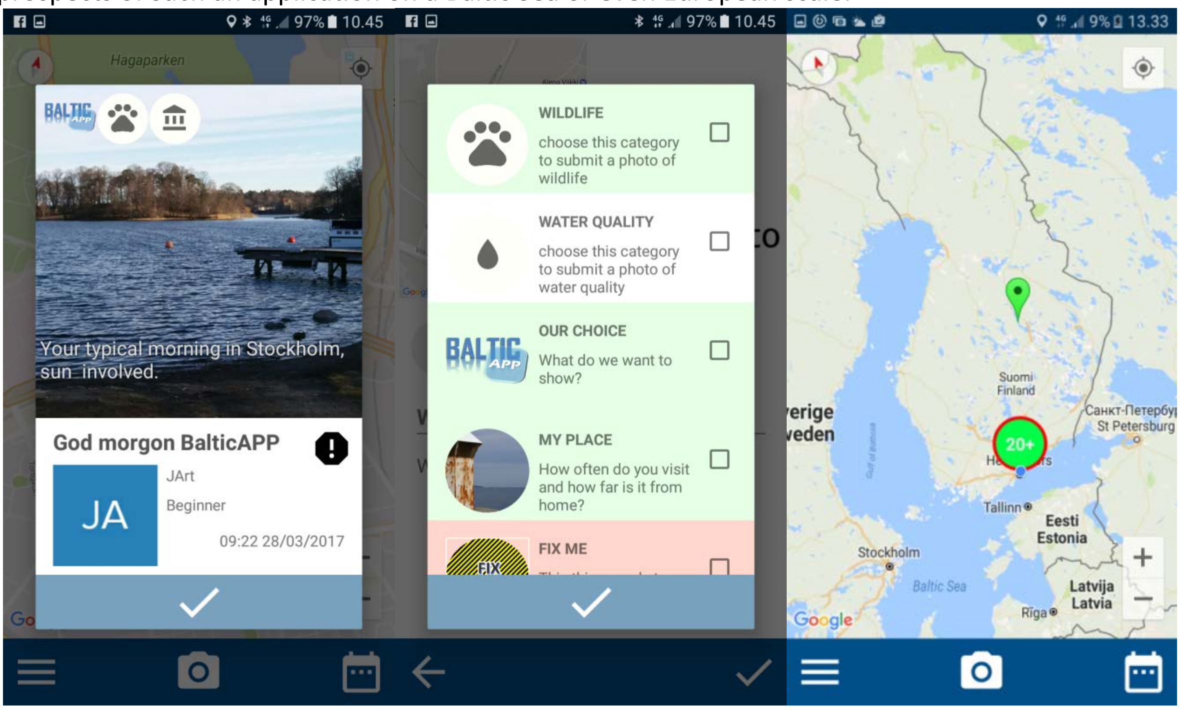
Ethnographic studies were an ongoing activity feeding into the development of governance concepts and policy options in the BONUS Soils2Sea project. The studies – which consisted of interviews and oberservations - provided insights into the history and socio-economic culture of institutional and non-institutional stakeholders in the three Soils2Sea case study sites in Denmark, Poland and Sweden. This insights are the subject of the presentation.
It was found that the perceptions, values, beliefs, thoughts about nature, the environment and hence needs, acceptance and uptake of measures and regulations are in many ways opposed which in turn demands different policy approaches.
In general it can be stated that - in the same way as the geo-morphological soil conditions differ across the three case study areas - the socio-cultural-political and economic contexts of the people living and working on the different soils are very different and hence lead to diverse decision making with respect to farming practices, nutrient inputs and outputs, collaboration amongst farmers, monitoring and reactions towards measures, regulations and policy options.
The information gained was used in BONUS SOILS2SEA project to assist the co-development of measures and provide reality checks regarding acceptability and socio-cultural fit of the policy options.

Constructing an open citizen science tool to collect information on the Baltic Sea and recreation. Proof of concept and future possibilities

Janne Artell

Natural Resources Institute Finland (Luke), Helsinki, Finland

While the physical attributes and ecological quality of the Baltic Sea are continuously monitored in an organized fashion, the views and uses of the Baltic Sea by the public are not. Further, there are few instances for the public to obtain scientific information in layman's terms about the sea, let alone possibilities to bring about their contributions to ongoing research efforts through simple means.
From a management perspective there is a lack of simple updating channels to disseminate up-to-date information on a Baltic Sea scale on issues such as beach closures or algae blooms. Enabling citizens to contribute to a monitoring network through guided observations could provide cost savings and a monitoring network not otherwise possible.
Further, economists and management are also interested in where the public goes for recreation, how often, and what factors describe perceptions of Baltic Sea quality in real time. We lack recreation monitoring on a Baltic Sea scale – recreation information is available from single points in time through survey results, which may be difficult to compare.
The BalticAPP open source citizen science mobile application was designed to serve as a proof of concept of a platform that would allow Baltic Sea users to share their views of the Baltic Sea in photos, feelings and text amongst themselves, scientists and management, providing information on recreation behavior and water quality to scientists and management authorities. The application could also allow authorities an information dissemination channel that reaching users of the Baltic Sea on the move. This presentation describes the rationale behind the application design providing insights and warning about pitfalls for others aspiring to construct mobile apps for research purposes while looking for the future prospects of such an application on a Baltic Sea or even European scale.



Geochemical processes affecting reactive nitrogen in a clay till, hill slope field system

Rasmus Jakobsen, Anne Lausten Hansen, Klaus Hinsby and Jens Christian Refsgaard

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

The geochemical processes, with focus on reactive nitrogen, occurring in the clay till of a hill slope used for wheat production for for >5 yr was assessed through water samples from 25 cm screens inserted by hand augering. Thirty samplers were distributed randomly in an ~0.5 ha area and sampled 4 times during a year. Another set of 21 samplers made up a 135 m long, 2D transect in the direction of the general groundwater head gradient established from piezometers in the vicinity. This set was sampled 3 times during a year. Both sets were supplemented by a set of 12 suction cups inserted at 0.5, 1, 1.5 and 2.0 meters below surface (mbs), providing water samples from the unsaturated zone and the uppermost groundwater. The level of the water table fluctuates from 0.5-1 mbs during the wet season to 3 mbs during dry summers. Samples were analyzed for main cations and anions as well as ammonium, nitrite and water isotopes.

Data from the suction cups indicate that the water infiltrating to the groundwater has a fairly constant nitrate concentration around 1 mM at 2 mbs. This is in spite of a clear seasonal variation above 2 mbs related to uptake. Here concentrations go from 10 µM at the end of the growing season to slightly above 1 mM in February, indicating that reactive nitrogen must be transported to 2 mbs via macropores. Low concentrations (~1 µmol/l) of ammonium in the upper 2 m indicate that this zone contains enough oxygen for efficient nitrification. Dissolved organic carbon goes from ~0.6 mM at 0.5 mbs to ~0.1 mM at 2 mbs.

In the till system, deeper samples are generally more reduced, but the depth at which nitrate disappears varies from 3-5 mbs. Plotting data for sulfate and total inorganic carbon as a function of decreasing nitrate concentrations indicates a zone rather than a sharp front, where nitrate reduction occurs via pyrite oxidation. Nitrate reduction by organic matter does not show due to interfering carbonate dissolution. Below 2 mbs an increase in the ammonium concentration indicates release from oxidation of organic matter, given that there are no clear signs of cation exchange. Assuming that the oxidizing organic matter is derived from wheat roots and a typical C/N ratio for wheat roots, it appears that approximately 20% of the nitrate could be reduced by organic matter. Inverse modelling using PHREEQC on samples constructed from averages samples at 0.5 mbs, 2 mbs and 5-6 mbs also indicate that organic matter could be responsible for around 20% of the denitrification between 2 and 5 mbs. In addition, the inverse modelling indicated that potassium in the infiltrating water is removed by the formation of illite and that primary silicates are dissolving by weathering processes.

Data from the 2D cross-section show variations in the nitrate and ammonium distribution as well as the position of the redox interface that appear to correlate with the content of stable water isotopes. It seems that the nitrification goes slower in a zone where the stable isotopes indicate that infiltration is focused, apparently related to a flat central part in the 2D transect. Perhaps locally increased infiltration limits the access of oxygen, limiting nitrification. It could imply that the depth to the reducing zone where nitrate disappears relates to small-scale variations in the topography. A quantification of the described processes in the saturated zone of the 2D transect is underway using the reactive transport code PHAST in which PHREEQC is used to handle the biogeochemical reactions in the system.

Modelling of nitrate contamination in fissured-porous karstic aquifer underlying Kocinka catchment using tracer-calibrated flow and transport model

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The fissured-porous karstic aquifer located in southern Poland is the main source of potable water for ca. 300000 inhabitants of the Częstochowa city and the surrounding villages. The aquifer belongs to the category of Major Groundwater Basins in Poland (GZWP 326). Annually, approximately $7.8 \cdot 10^6$ m^3 of water is pumped annually from the aquifer. In the mid 1980s nitrate levels exceeding 50 $mgNO_3/L$ began to appear in wells located in the southern part of the aquifer. By the early 2000's all major exploitation wells were affected by high nitrate levels. In 2006, a denitrification plant reducing nitrate levels in water to ca. 10-15 $mgNO_3/L$ has been build and put in operation, thus allowing local Waterworks Company to keep nitrate levels in potable water supplied to the clients below 50 mg NO_3/L. Since the mid 2000's the nitrate levels in major groundwater intakes remain roughly constant in the range between ca. 30 and 70 $mgNO_3/L$ (Michalczyk et al., 2016).
The presentation summarizes results of comprehensive modelling efforts aimed at reproducing time series of nitrate concentration in major exploitation wells of GZWP 326, available for the period since 1985. The approach consists of two major steps: (i) assessing input function of nitrate to groundwater using historical data on nitrate sources at the ground surface and modelling of nitrate percolation through the soil column with the aid of NLES 4 model (Højberg et al., 2015) combined with assessing time lag of nitrate transport through unsaturated zone using water balance approach (Wachniew et al., 2016), (ii) modelling of nitrate transport in the aquifer using 3D flow and transport model, calibrated with time series of environmental tritium. The degree of nitrate reduction in the aquifer was assessed through measurements of gaseous nitrogen excess in groundwater.
The modelling framework outlined above allows to quantify time lags associated with transport of nitrate through the unsaturated and saturated zones. It also allows to identify zones on the surface which contribute most to the nitrate load observed in the aquifer.

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How to increase utility of nitrogen in manure - the Danish case

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In Denmark, the first Action Plan for the Aquatic Environment was adopted in 1987 with target of a 50 pct. reduction in the nitrogen load to the aquatic environment. The measures in the plan were directed towards the individual farmer and included a.o. an obligation to establish slurry tanks with nine months storage capacity and a ban on slurry spreading from harvest to November 1. on fields destined for spring crops. At that time, farmers applied chemical fertilizers in amounts that almost solely covered the crops demand for fertilizer. The farmers did not fully acknowledge the fertilizer value of manure. Therefore, the manure nitrogen was applied in excess and caused a significant nitrogen leaching to the aquatic environment.

The rationale of the first Action Plan was that increased manure storage capacity would allow farmers to apply manure at the most favorable time from a nitrogen utilization point of view and thus reduce the application of chemical fertilizer.

However, this voluntary reduction in the application of chemical fertilizers did not materialize to the degree anticipated. Therefore, the governments implemented restrictions on the actual consumption of chemical fertilizer and manure from 1994 onwards.

In order to transfer the Danish experience to other countries it is necessary to have knowledge on the interplay between manure storage capacity, timing of manure application, application technology and the effects on nitrogen utilization and on nitrogen leaching.. In this study, we present how the Danish farmers in the Agricultural Monitoring Program step-wise increased spring application of manure and adjusted the applied amount of chemical fertilizers to increase utilization of nitrogen in manure. How some farmers did not use excess nitrogen and some did. Using data on nitrogen leaching obtained by suction cups below the root zone we analyze the effects of application of both chemical fertilizer and manure and of the timing of manure application.

Utilising data and studies within the Baltic Sea Basin to develop a map for nitrogen reduction in groundwater

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Riverine load of nitrogen to the Baltic Sea has been reduced in recent years, but further amendments are required to meet the goal of the EU Water Framework Directive. The largest contributor from anthropogenic activities is agriculture and reduction in the load from farming praxis is inevitable. Regulation of nitrogen has typically relied on uniform regulation, i.e. imposing the same restrictions on farming all over. During transport from the field to the sea nitrogen undergoes natural reduction, but with large spatial variations, due to variation in the hydrogeological and hydro-geochemical conditions. Mapping this variation would allow more optimal regulation strategies, where most restrictions are imposed in areas with low natural reduction. Most assessments on nitrogen transport and reduction take a catchment scale approach in which the total removal of nitrogen for the catchment is estimated, not differentiating between surface water and groundwater. Discriminating between the two domains is nevertheless important in order to identify the correct type of mitigation measure to implement. In the project BONUS Soils2Sea (www.soils2sea.eu) a map for nitrate reduction in groundwater was developed by groundwater experts from five countries in the Baltic Sea Basin based on a review of national data and previous studies. The review revealed large variations in the hydro-geochemical conditions important for transport and degradation of nitrogen in groundwater. This includes the hydrogeology, the reducing conditions of the subsurface, and the fraction of water transported by drainage systems bypassing the reducing subsurface environments. Significant variations in groundwater reduction between the countries and within most of the countries were thus found, indicating that strategies for nitrogen regulation and mitigation measures may be optimized, if variation in the natural reduction of nitrate is considered.

Impacts of “greening” on eutrophication in the Baltic Sea

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Continued actions are needed to reduce eutrophication in the Baltic Sea, especially nutrient reductions from the agricultural sector, as agriculture continues to be the most important source of diffuse nutrient loads into the Baltic Sea. The excessive nutrient loads into the Baltic Sea can, to a large extent, be explained by agricultural loads constituting 60-70% of the loads, and coherence between agricultural and environmental developments is necessary to combat eutrophication. There is a large number of EU- and other regulations that set out to reduce nutrient loads: BSAP (the Baltic Sea Action Plan), WFD (the water Framework Directive) and the Nitrates Directive. The most important policy for the development of agriculture in this region is the EU Common Agricultural Policy (the CAP). The latest CAP reform from 2013 aims to link farmers’ financial support with the provision of public goods and externalities by introducing the so-called ‘greening’ requirements.
However, the environmental effects of the greening requirements and corresponding support are small, suggesting there is room for more efficient ways of achieving the targets. One method is to decrease nutrient losses by increasing the utilization of the fertilizer and manure application, and this might reduce emissions to both air and water. In this study, undertaken as part of the BONUS Go4Baltic project, we investigate the c and environmental effects of alternatives to the greening requirements, which could be superior in terms of achieving nutrient load reductions.
Applying a chain of three numerical models, the study comprises simulations of the farm sector and environmental effects of incremental reforms involving the following elements:

- removing the greening requirements, to get a measure of the effect of it
- improving manure storage capacity, allowing for better timing of application
- improving manure application technologies
- increasing the share of liquid manure, which can be applied more efficiently.

The manure handling measures impact on the availability of crop nutrients in manure. The CAPRI model is used for modelling the farm economic adjustments and consequences on land use and nutrient consumption. Those results are used as inputs in a nutrient transportation model computing riverine loads of nutrients to the Baltic Sea. In the final step, those loads are fed into a marine ecosystem model of the Baltic Sea, BALTSEM (Long-term large scale eutrophication model), computing the impacts on selected environmental indicators.The environmental effects considered are the nutrient loads to the Baltic Sea, the effects on eutrophication of the Baltic Sea basins as well as the emissions of greenhouse gases.
The analysis finds that the effects on the environment of removing the greening would be small, which is in line with previous studies. We also estimate the saved costs of removing the greening requirement to be significant, since approx. 30% of the national farm envelopes are tied to this requirement. Therefore, there is scope for considerable economic and environmental gains from removing the greening requirements and replace them with the other measures that bring more substantial environmental benefits.

Uncertainties in projections of the Baltic Sea ecosystem driven by an ensemble of global climate models

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Many coastal seas worldwide are affected by human impact like eutrophication causing, *inter alia,* oxygen depletion and extensive areas of hypoxia. Depending on the region, global warming may reinforce these environmental changes by reduced air-sea oxygen fluxes, intensified internal nutrient cycling and increased riverborne nutrient loads. The development of appropriate management plans to protect more effectively the marine environment, requires projections of future marine ecosystem state. However, projections with regional climate models commonly suffer from shortcomings in the driving global General Circulation Models (GCMs). The differing sensitivities of GCMs to increased greenhouse gas emissions may considerably impact regional projections. In this study, we focused on one of the most threatened coastal seas, the Baltic Sea, and estimated uncertainties in projections due to GCM deficiencies relative to uncertainties caused by unknown future greenhouse gas emissions and nutrient load scenarios and by natural variability. To address the latter, transient simulations for the period 1975- 2098 were performed using the initial conditions from an earlier performed reconstruction with the same Baltic Sea model (starting in 1850). To estimate the impacts of GCM deficiencies, dynamical downscaling experiments with four driving global models were carried out for two greenhouse gas emission scenarios, RCP 4.5 and 8.5, and for three nutrient load scenarios covering the plausible range between low and high loads. Results of primary production, nitrogen fixation, and hypoxic area show that differences caused by the various nutrient load scenarios are larger than the uncertainties due to global model deficiencies, unknown future greenhouse gas emissions and natural variability. In all scenario simulations, a proposed nutrient load abatement strategy, the Baltic Sea Action Plan, will lead to a significant improvement in the overall environmental state. However, projections cannot provide detailed information on the timing and the reductions in future hypoxic area due to uncertainties in salinity projections caused by uncertainties in projections of the regional water cycle and of the global mean sea level rise.

What are potential future states of the Baltic Sea food web?

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The Baltic Sea ecosystem is subject to multiple interacting human pressures, with substantial impacts on the state of the marine ecosystem. Our goal here was to investigate the relative importance of selected pressures under various pathways of changing climate and society around the Baltic Sea and identify the ones with the largest impact on the marine ecosystem. To achieve this goal, we compiled quantitative simulations of plausible future states of the marine ecosystem under five scenarios. The scenarios are based on consistent storylines for plausible developments of climatic factors and socio-economic drivers in the Baltic Sea region.

Socio-economic drivers were translated as pressures concerning evolution of the type of fisheries and nutrient pollution. The latter, together with regionally downscaled global trends in climate were the basis of computing abiotic habitat quality for benthic and demersal marine fauna both at lower and higher trophic levels. We achieved this by using outputs from a coupled physical-biogeochemical model as forcing in a spatially resolved ecosystem model of the offshore Baltic Sea, together with fisheries forcing, which we defined based on scenario narratives. The ecosystem model provided spatially explicit projections of the development of marine fauna, including benthos, fish populations, seals, offshore feeding birds and commercial fish catches. We analyzed each scenario in terms of pressures on the ecosystem and the ecosystem's response to those, especially concerning state of habitats, fish populations and biodiversity. The scenario assuming a sustainable society (low greenhouse gas emissions, the implementation of the Baltic Sea action Plan and fisheries aimed at maintaining ecosystem integrity) resulted in an increased capacity of the Baltic Sea to maintain diverse communities. In contrast, the scenario envisioning increasing inequality, high greenhouse gas emissions and continuing nutrient pollution due to weak environmental regulations resulted in decreased habitat quality, very high fishing pressure and diminished biodiversity. We hope that our exploratory study provides inspiration and a broader context for strategic level discussions with stakeholders about the future of the Baltic Sea food web and society.

Contingent behavior and asymmetric preferences – Valuing recreational benefits of the Baltic Sea

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In this study, we combine information on actual and contingent recreational behavior at the Baltic Sea coast under different management scenarios to gather information about welfare implications of improvements and deteriorations in the coastal environment. We thus augment the traditional travel cost (TC) approach in which people are asked about past visits to recreation sites by asking respondents how their future recreational behavior would change if environmental conditions changed in a certain way. With this approach, termed the contingent behavior (CB) method, changes in water quality outside the range of currently observed conditions and their impact on human welfare can be examined.

Data were collected with identical surveys in Finland, Germany, and Latvia from November 2016 to February 2017. The surveys were implemented as internet surveys and computer-assisted personal interviews. In total, there were 4800 respondents, with response rates of 15-35% depending on the country. The environmental attributes considered in the hypothetical contingent behavior scenarios include water clarity, blue-green algal blooms, amounts of algae onshore, biodiversity, and facilities at the recreation site. In the survey, we additionally gathered spatially explicit information on the recreation sites which respondents had visited in the past including perceived environmental conditions. We estimate current recreational benefits and changes in recreational demand allowing for asymmetric effects of improvements and deteriorations. To evaluate future changes in environmental conditions due to climate change and eutrophication, we calculate changes in the recreational value of the Baltic Sea coast for different scenarios of environmental conditions, including a best case and a worst case scenario.

The results show substantial impacts of environmental changes on annual consumer surpluses (CS) generated in the three countries. In the best case scenario, average annual CS per visitor would increase by 23.0% in Finland, 48.8% in Germany, and 14.6% in Latvia. In the worst case scenario, in contrast, average annual CS per visitor would decrease by 45.0% in Finland, 48.8% in Germany, and 52.1% in Latvia. This reveals substantial loss aversion for the respondents in Finland and Latvia: While the sizes of perceived environmental changes are relatively similar in these countries, losses have a much larger impact on welfare than gains. However, this result does not hold for German respondents, for whom welfare changes in the best case and worst case scenario are of the same magnitude.

Long term impacts of societal and climatic changes on nutrient loading to the Baltic Sea

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The Baltic Sea is a vulnerable ecosystem that is greatly influenced by human activities and the climatic system due to a combination of natural conditions and multiple, interacting anthropogenic pressures. Excessive nutrient loading is one of the main pressures altering the state of the Baltic Sea. Policy-makers and stakeholders around the riparian countries can benefit from a systematic exploration of how alternative global developments in climate and socio-economic factors are likely to affect the amount of nutrient loading to the Baltic Sea in the long term. Such load projections can be used for estimating the additional nutrient abatement efforts needed to reach the goals of marine protection, such as under HELCOM BSAP.

We develop long-term quantitative scenarios of nutrient loading under different combinations of RCPs and SSPs over the period 2010-2100. The SSPs include the pathways *Sustainability* (SSP1), *Middle of the Road* (SSP2), *Fragmentation* (SSP3), and *Fossil-fuelled development* (SSP5); RCPs cover *intermediate scenario* (RCP4.5) and *very high GHG emissions* (RCP8.5). The analysis accounts for all major sources of nitrogen and phosphorus from non-point source loading (i.e. agricultural load, loads from forest and background loading), point source loading (i.e. load from wastewater treatment plants) and the atmospheric deposition. The impacts of inventory uncertainty and structural uncertainty are addressed for scenarios.

Quantitative assumptions of drivers of nutrient emissions are developed based on an extension of the SSP narratives to the Baltic Sea and applied in a spatially explicit model framework combining agricultural management and land use, wastewater treatment levels and scale, and atmospheric deposition based on sectoral developments. Climate impacts are integrated via the HYPE riverine flow model, altering nutrient loads from land compared to no climate change.

Results show that nutrient loads overall are on a declining trend for SSP1, SSP2, SSP3 but increase for SSP5 with respect to both nitrogen and phosphorus loads. With sustainable development and moderate climate change (SSP1/RCP4.5), N loads could be halved and P loads decrease to around 60% of the current level by the end of the century. In a fossil-fuelled world (SSP5) and extreme climate change (RCP8.5) the nutrient loads would increase by around 25% from the current level, necessitating substantial policy efforts in nutrient abatement.

Non-point sources are the biggest contributor to the external nutrient loading of the Baltic Sea. Furthermore, their share of the total load will increase over time for all climate and socioeconomic scenarios considered. Point source loading of both N and P will decrease, but for different reasons for different SSPs. Main determinants include technological development and urbanization (SSP1 and SSP2), investments in treatment technology (SSP1, SSP2 and SSP5), and decreasing population (SSP3).

Modelled source apportionment of nutrient loads to Baltic Sea basins under current and future conditions

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Riverine nitrogen and phosphorus loads to the Baltic Sea originate from multiple sources such as diffuse leakage from agricultural areas and point emissions from industrial and waste water treatment plants. Besides variation in overall load amounts from different land areas around the Baltic Sea, there is also spatial variation in relative load contributions from individual source types.

A source apportionment of nitrogen and phosphorus loads at sea outlets allows us to differentiate between net contributions of different sources and to compare their relative importance for riverine nutrient emissions into the Baltic Sea. Because nutrient emissions undergo different retention-removal processes during transport from source to sea outlets, the importance of load contributions from individual source types can differ between gross emissions into surface waters and net contributions at sea outlets. We can estimate surface water retention and removal by comparing gross nutrient emission into surface water and net transports at sea outlets. Such an analysis of nutrient load source apportionment can be used to support the design of effective programs of measures to target load reductions into the Baltic.

Here, we conduct a comparative analysis of nutrient load source apportionment under current and future conditions. We use E-HYPE v.3.1.4, a pan-European integrated rainfall-runoff and nutrient transport model developed by SMHI, to conduct a source apportionment analysis for nutrient loads into the Baltic Sea as a whole and into individual Baltic Sea sub-basins as defined by HELCOM based on available data for hydrological and nutrient model calibration, gross emission estimates, and reduction-removal processes. In particular, we include the following aspects in our analysis of E-HYPE modelled nutrient loads:

- Long-term source apportionment into Baltic Sea sub-basins under current (1981 to 2010) and future (2036 to 2065) conditions using climate forcing data from four climate models under IPCC Representative Concentration Pathway (RCP) 8.5
- Inter-annual variation of source apportionment
- Comparison of future source apportionment under three IPCC Shared Socioeconomic Pathways (SSPs): SSP1 (Sustainability), SSP2 (Middle of the road), and SSP5 (Fossil-fueled development)

Long-term source apportionment under current and future climate conditions give a holistic overview over the relative importance of different nutrient sources around the Baltic today, and provide insight into expectable changes due to climate change impacts. By comparing model results from four different climate models, we can complement projected changes with climate model uncertainty estimates, while inter-annual variation in loads provide an insight into the impact of hydrological conditions on load amounts. Finally, a comparison of loads under different SSPs allows comparing the impact of socioeconomic developments on nutrient loads from different sources.

Scenario for structural development of livestock production around the Baltic Sea

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The ongoing structural change in livestock production in the EU is having wide-ranging impacts on agriculture, the environment and rural areas. The transition to larger production units increases the agronomic segregation of livestock and crop production areas. On the one hand, such specialization may strengthen the competitiveness of livestock production and promote innovations in hot spot areas; on the other, it may hasten a transition towards monoculture and impede the supply of organic matter in the form of manure to crop production regions. Structural change may also alter the pressure that manure nutrients place on nutrient runoff and water quality by increasing the agglomeration of animals and altering the distribution of production animal species and farm sizes.

Countries with a significant proportion (or all) of their land acreage in the Baltic Sea drainage basin (Denmark, Estonia, Finland, Latvia, Lithuania, Poland, Germany and Sweden) apply a total of some 218 thousand tons of phosphorus and about five times as much nitrogen in the form of manure in their agricultural production. Comparing this to the total annual anthropogenic phosphorus loading to the sea, currently around 30 thousand tons, it is apparent that any changes in animal agriculture that affect the handling, storage and application of manure may have sizeable impacts on nutrient loading to the Baltic Sea.

The aim of the present paper is to search for methods to link manure nutrient production to structural change. In order to discuss the future baseline of structural development, ex-post macrodata of livestock farm structure is analysed from eight Northern European countries surrounding the Baltic Sea. A Markov chain model is developed to estimate probabilities of changes in farm size. Ex-ante development until 2030 is estimated with the model and adjusted by results for production volume obtained using the agricultural sector model CAPRI. The total quantity of nutrients (nitrogen and phosphorus) is disaggregated by farm size category.

Observed data shows that between 2003 and 2013 more than half (1.1 million) of the farms in these countries exited livestock production. According to estimate, some 670 000 more livestock farms will further exit production between 2014 and 2030. Roughly 7.6 million livestock units (LSUs) in total would shift to farms in higher size classes by the year 2030. This would entail investments in annual animal housing for 380 000 LSUs; that is, roughly 2 % of production animals would change farm size class annually. Farms with over 500 LSUs would produce 63% of all manure phosphorus in 2030; as in 2010 they produced 32%. According to CAPRI baseline, the total number of animals however shows only a slight change.

It is possible that development induces pressure on the areas where livestock continue to concentrate and most manure is spread. If we assume a 170 kg limit for manure nitrogen, the average such area on livestock farms would grow from 6.4 hectares to 22.4 hectares per farm. In total, growing farms need to acquire or conclude contracts for 4.9 million hectares for spreading manure from exiting farms or open markets. This is 71 % of the total minimum spreading area in 2010 and 15 % of the total utilized agricultural area of the regions studied. Stagnant markets for arable land might precipitate a risk of the overuse of manure. Structural change thus creates risks of spatial nutrient accumulation, but also opportunities to address these threats if the utilization of manure nutrients is regulated properly and coherently across national borders.

Exploring farmers' preferences for implementing agri-environmental schemes - a cross country comparison of schemes as incentives for nutrient abatement in Baltic Sea catchments.

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We use data from a stated preference survey administered to farmers in Denmark, Estonia, Finland, Poland and Sweden to investigate their preferences for adopting agricultural practices aimed at reducing nutrient leaching. In particular, we consider set asides, catch crops and reduced fertilization contracts that also vary with respect to the area enrolled in a contract, its length, possibility of premature termination, availability of professional advice and subsidy levels. We find which contracts are preferred and we are able to estimate minimum willingness to accept levels for their adoption. These results vary substantially between countries. Surprisingly, we also find that farmers prefer shorter contracts and contracts that require enrolling lower areas of land. Overall, our results may be used together with the estimated efficiency of the measures to design optimal country-specific nutrient reduction policies.

Game-theoretic analysis of Baltic Sea eutrophication: policy instruments for burden sharing of reduced eutrophication in the Baltic Sea

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Protection of the Baltic Sea from eutrophication requires substantial reductions of nitrogen and phosphorus and calls for joined action by all countries in the region. In this paper architecture of a viable agreement on reducing eutrophication in the Baltic Sea is analyzed using various game-theoretic modelling. Financial instruments of the EU, in particular, the Cohesion and Structural Funds and the European Agricultural fund for Rural Development, are examined from the perspective of focusing on measures and activities of nutrient pollution flow into the Baltic Sea. Our findings are three-fold: First, we show that there is coherence between water treatment investments originated from the EU fund, social welfare generated in Baltic Sea by reduced eutrophication and the game-theoretic recommendations of coordinated actions. Secondly, we suggest that reduction of nitrogen is close to the equilibrium game-theoretic level, while further reduction of phosphorus loading in to the Baltic Sea is necessary. Finally, empirical game-theoretic findings and relevant EU financial instruments, compared against history of nutrient loading into the Baltic Sea, brings a conclusion that Helsinki Commission targets are only partially consistent with the 'polluter pays' principle.

Flexibility in the choice of N abatement measures: Implications for costs of implementation and environmental service provision.

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Farmers are required to introduce N abatement measures to reduce water quality pollution to fresh water and marine systems. It has been argued that due to the heterogeneity of farms and farming practices it is essential that farmers are given flexibility with respect to the choice of abatement measure. In this paper, we report on evidence from a national scale Danish farm survey assessing farmers rating of alternative measures. Using a factor analysis, we use the data to analyse the heterogeneity of how farmers perceive the suitability of alternative measures and analyse the extent to which this correlate with farm and attitudinal characteristics. The analysis shows that there is a significant diversity in ratings. The results indicate, that preferences over implementation measures represent a multitude of agricultural and amenity rationales. This imply that abatement implementation frameworks can be optimised as they provide both public and private benefits.

The Impact of Water Quality Policies on Innovation in Nitrogen and Phosphorus Technology in Sweden

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We examine the effects on innovation of environmental regulations aimed at reducing eutrophication. This study focusses on the wastewater treatment sector and the agricultural sector and utilises patent data from Sweden over a 50-year period as a measure of innovation. We estimate a negative binomial regression model in a reduced form and use a two-stage equation setting, controlling for environmental regulation as well as more general determinants of innovation. Our results suggest that increased regulation has induced innovation in the wastewater treatment sector, both in the long and short run. The short-run effect was approximated to 40-70% in the years immediately following the introduction of new environmental regulations. A corresponding effect could not be identified in the agricultural sector. The differences in findings between the sectors are likely explained by differences in policy design, where performance standards are usually applied in the wastewater sector, while design standards and measure-specific subsidies dominate in the agricultural sector.

Public policies for wetland implementation in Denmark and Sweden – historical lessons and emerging issues

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Natural wetlands used to cover a significant part of the rural landscape but these areas have been reduced significantly all over the world and so also in Denmark and Sweden. Since the 1980s' efforts have been made to re-establish these wetlands. Findings from other studies suggest that compensation levels, efficiency, implementation approach and flexibility are key factors in a successful implementation. The analysis of the implementation in Denmark have shown that the original efficiency per ha was overestimated and the costs were underestimated. The political targets have been too optimistic for the last 30 years and continue to be so. The experience gained from previous implementation and the layout of the subsidy scheme has not been fully utilised due partly to a shift from national financing schemes (lumpsum) to a partly EU financed Rural Development Program (yearly payment over 20 years). Sweden started earlier and the programs have in more cases a more multifunctional purpose as in Denmark were N reduction effect is the main policy goal. The main barriers in the implementation of wetlands in Sweden have *changed somewhat over time, and have included* economy, land availability and institutional and governance barriers.
Looking at the two countries they both show a change from a focused on the local approach to a broad Rural Development Program approach where the efficiency per ha went down.
However, a large potential for more wetland implementation still remains in both countries. Consequently, the objective of this paper is to provide a comprehensive overview of the historical implementation of wetlands and related governance processes. This is carried out in order to illustrate barriers of why more wetlands have not been created and restored, and to illustrate the opportunities for future wetlands implementation. Details about lessons, impacts and learning outcomes from the two neighbouring countries will be reviewed to gain an overview of the systemic transformations needed to facilitate a more sustainable development.

Drivers of technology adoption at farm level in the Baltic region

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Policies influence the incentives to adopt new technologies aimed at improved nutrient management and reduced emissions from manure handling. But policies interact with a number of other factors to influence farmers' decisions on technology adoption. This paper examines the drivers of diffusion of manure handling technologies among farmers around the Baltic.

According to classic economic literature on technology diffusion, new technologies are adopted when they offer private benefits. In the case of manure technology, such benefits could be improved utilisation of nitrogen in manure, hence greater crop yield, or, the technology may embody economic gains more generally compared with current practices. Policies may affect the economic calculation on technology adoption in several ways, e.g. through research programs that lead to cheaper technology, through subsidies for purchase of technologies or through regulation that limits the use of mineral fertilisers and therefore intensifies the value of utilizing the fertilizers in manure. However, studies of technology diffusion suggest that social relations may also guide technology adoption. Lynne (1995, 2006) found that farmers might invest in equipment for manure handling to live up to norms among their non-farming neighbours about reducing odour or reducing environmental impact. Likewise, shared norms among farmers about good manure practice may lead to investments in manure handling equipment (Lynne 1995. 2000). Finally, Genius et al. (2013) identified a neighbouring effect - the likelihood of technology adoption increased if nearby farmers had invested in similar technologies, because this lowered learning costs to the late-coming farmer. Still, other studies have shown that technology adoption may be driven by individual attitudes, including a general receptivity to new technologies or the reverse (Bishop et al. 2010; Lee 2004) or personal perceptions of the impact of fertiliser use on water and air quality. Altogether, this leads to a pattern of heterogeneous adoption and diffusion of technology with some quick to adopt while others follow (Bishop et al. 2010).

The paper therefore examines the effect of economic motivation, social norms, attitudes towards technology and environmental awareness among farmers on their previous decisions to adopt manure-handling technologies as well as on their intent to invest in such technologies in the future. It will map heterogeneity among farmers as to their technology adoption. We use data from a survey among farmers 5 countries around the Baltic Sea (approx. 2400 respondents), gathered under the Bonus project go4Baltic and analyse the data using multi-variate statistical models. We control for country variables as well as for farm characteristics including income, size, and farm type.

The insights provided offer policy relevant information as it will contribute knowledge about factors that affect technology adoption directly, but also the impact of policies on technology diffusion.

Impact of future climate changes on hydrology, N-reduction and N-load in a Danish groundwater-dominated catchment

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Denmark must further decrease the N-load to coastal waters from agriculture to comply with the Baltic Sea Action Plan and the EU Water Framework Directive. However, the expected future climate changes will affect groundwater and thereby also the transport and reduction of nitrate in a catchment, and the needed N abatements may therefore change with time.
In this study we have analysed how the expected climate changes for the period 2040-2060 will possibly affect the hydrology, N-reduction and N-load in the groundwater-dominated Norsminde catchment in Denmark. We have used an ensemble of four climate models (CM1-4) selected to encapsulate the uncertainty of climate model projections. The projected future climates were downscaled and bias-corrected, and then used as input to the N-leaching model NLES and the groundwater-surface water model MIKE SHE.
The results show that three of the climate models (CM1-3) give an increase in average yearly precipitation in Norsminde catchment of 5% (CM1), 19% (CM2) and 17% (CM3). One climate model (CM4) gives a slight decrease in yearly precipitation of -2%. The monthly distribution of precipitation over the year is found to differ between the four climate models, with CM2 having the largest precipiatation amounts in the late summer/early fall and again in late winter and CM1 in the fall. The future evapotranspiration changes only slightly in future for all four climate models (-1% to 5%). The drain flow component is found to increase for all three climates models (CM1-3) with increased precipitation. However, the drain flow is found to increase more than the increase in precipitation for CM2 and CM3. This could indicate that these two climate models result in more shallow flow paths.
All four climate models project an increase in both N-leaching from root zone and in total N-load at the catchment outlet. But the changes in N-load do not follow the changes in N-leaching in a linear way for all climate models. CM1 projects the highest increase in N-leaching of 61% and CM4 the lowest with 23%. The increase in N-load is 60% and 20% for the two climate models respectively, and thereby similar to the change in N-leaching. But for CM2 and CM3 the increase in N-leaching is 41% and 26% respectively, whereas the increase in N-load is 55% and 38% and thereby relatively higher than the increae in N-leaching. The reason for this difference in reponse in N-load must be found in the amount of N-reduction in groundwater (GW%). For CM1 and CM4 the change in N-reduction is small or unchanged (-7% and 0% respectively), whereas for CM2 and CM3 the N-reduction decreases with 13%. This lower N-recution in groundwater for CM2 and CM3 is probably caused by the higher drain flow.
Based on the findings from this study we conclude, that the N-load in Norsminde catchment is likely to increase in the future and that stricter abatement targets therefore will be needed. But there is a considerable uncertainty on how much the N-load will increase.

Nitrogen leaching losses from two Baltic Sea catchments under scenarios of changes in land use, land management and climate

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The Baltic Sea Action Plan and the EU Water Framework Directive requires further reductions in nitrogen (N) loadings to the sea, a large part of which originates from agricultural land. Also the geology in the catchments influences N flows and the N reduction processes affecting loading. Measures therefore need to be taken to reduce N loadings. However, future climate change and changes in socioeconomic developments will affect the baseline on top of which mitigation measures for reducing N loadings need to be taken.
We analysed the effect of a combination of land use and climate scenarios on N leaching from two catchments in the Baltic Sea: Norsminde in Denmark and Kocinka in Poland. The two catchments vary greatly in time lag of the groundwater flow and the related N retention and reduction processes. For each catchment the effects on N leaching were analysed with the NLES leaching model, which at Norsminde was linked to a physically-based distributed groundwater model (MIKE SHE). The land use changes were based on three selected future scenarios taken from the Shared Socioeconomic Pathways (SSP), i.e. SSP1 (sustainability), SSP2 (middle of the road) and SSP5 (fossil fuelled development). For each SSP quantitative effects were given for changes in land use and agricultural activities, including fertilisation. The agricultural land use was maintained in SSP2 compared to baseline, reduced by 10% in SSP1 and increased by 10% in SSP5. Livestock density was maintained in SSP2, reduced by 50% in SSP2 and increased by 50% in SSP5. The climate change scenarios cover a 20 year period for 2041-2060 compared with baseline period of 1991-2010, and four different climate model runs were used based on the RCP8.5 emission scenario. The N leaching estimation with the NLES model was recalibrated for the temperature changes in the climate change scenarios using representative model runs with the dynamic Daisy simulation model.
For Norsminde the mean N leaching from agricultural areas was 54-60 kg N/ha in the baseline land use and climate, which increased to 71-88 kg N/ha under projected climate change. Under baseline climate, SSP1 has a reduced N leaching of 9-10 kg N/ha and SSP5 has an increased leaching of 10-11 kg N/ha. These differences increase under projected climate change due to the higher leaching level. These effects are moderated at catchment scale by different land use in the different SSPs. The range of N leaching in the catchment compared with baseline therefore ranges from 5% decrease to 23% increase and for N-load from the catchment between 6% decrease and 26% increase for SSP1. For SSP2 N-leaching is predicted to increase 23%-60% and N-load 20%-59%. For SSP5 N-leaching increases 63%-113% and N-load 52%-106%.
For Kocinka the mean N leaching from agriculture land was 28-34 kg N/ha in SSP2 under baseline climate, and this increases to 38-52 kg N/ha under projected climate change. The leaching in SSP1 was reduced by 2-3 kg N/ha under baseline climate and 3-5 kg N/ha under future climate. In SSP5 N leaching was increased by 3 kg N/ha under baseline climate and 4-5 kg N/ha under projected future climate.
A scenario analysis was conducted for Norsminde to explore how large agricultural area would be needed for spatially targeted set-aside to meet an N-load reduction target of 20% compared to baseline. For SSP2 this set-aside area is about 850 ha under baseline climate increasing to 1400-2200 ha under future cliimate. For SSP1 and SPP5 this range is 650-1400 ha and 2150-3000 ha, respectively, for future climate.

Scenario analyses of future nutrient export from the Pregolya River catchment area to the Baltic Sea considering changes in climate, land use and agricultural practices

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The contribution (Soils2Sea BONUS Project, 2014-2016; FASO 0149-2018-0012, 2018) presents for the first time a hydrologic and nutrient export-retention study covering the whole transboundary Pregolya River catchment (Polish and Russian parts of it). This middle size river is also first time considered with their two brunches at the lower reach: Downsteram Pregolya and Deyma Branch flowing to the Vistula and Curonian lagoons respectively. Significant spatial variations in characteristics of retention was found, which gives room for formulation of spatially differentiated measures to reduce the export to the Baltic Sea.

The nutrient load on the Russian part of the catchment area is currently much smaller than on the Polish part, but it will increase progressively when agricultural activity recover to the level of 1970-1980th, while load in the Polish part of the catchment already achieve limits permitted in EU.

Source apportionment for nutrient load revealed that the main sources of nitrogen and phosphorus input in the individual catchment of the Pregolya River upstream the separation into two branches are arable lands (58 and 67%), livestock wastes (21 and 13%) and municipal wastewater (12 and 15%). For the individual catchment of the Downstream Pregolya main snutrient sources are livestock wastes (29 and 31%), municipal wastewater (18 and 28%) and arable lands (27 and 21%), and for the individual catchment of the Deyma River these are municipal wastewater (44 and 64%), arable lands (14 and 10%) and livestock wastes (12 and 10%). The nutrient load from the entire catchment basin of the Pregolya River calculated as an average for the baseline climate period (1991-2010), amounted to 5.3 thousand tons/year for total nitrogen and 657 tons/year for total phosphorus (assuming the nutrient inputs of 2014).

The situation for the baseline period (climate for 1991-2010, nutrient inputs of 2014) was compared with two groups of scenarios: 4 climate change scenario for 2041-2060 (using an ensemble of 4 regionally downscaled and bias-corrected climate models, nutrient inputs of 2014) and 3 scenarios of socio-economic development (Business as Usual with keeping current trends, implementation of documented strategic plans of regional authorities and good agricultural practice for Russian part of the catchment) assuming a baseline climate of 1991-2010.

The results of scenarios of climate variations showed the uncertainty for nutrient export ranged from decline by 10% up to increase by 27% for the TN, and decline by 10% up to increase by 29% for TP. Simulations assuming different socio-economic scenarios under the same basic climate showed that in the case of Business and Usual (BAU scenario) the nutrient export will increase only by 3% for total nitrogen (TN) and phosphorus (TP). In the case of implementation of the documented plans of socio-economic growth (DP scenario) the nutrient export will increase significantly, by 78% for TN and 55% for TP.

According to the evaluation, it is potentially possible to organize in the Kaliningrad Oblast a "closed cycle" for complete use (according to the HELCOM standards) of the organic fertilizers produced in the region.

Results provided clear evidence that the changes in local climate in the Baltic Sea region can lead to changes in the nutrient export from a catchment comparable to those that might be expected under socio-economic development of the territory that achieves modern agricultural standards. Even when considering stable nutrient inputs to the catchment, climate change itself leads to an increase in nutrient export. This should be considered when elaborating plans of socio-economic development (currently the climatic aspect is usually not taken into account in Russia), as the uncontrolled growth of the nutrient export will adversely affect the currently low water quality of the Baltic Sea.

Mainstreaming ecosystem services for improved agricultural and environmental policy integration: Lessons from a review

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The major source of eutrophication of the Baltic Sea is nutrient enrichment from the agricultural sector. It is thought that a more systematic use of the ecosystem services approach in agricultural and environmental policies can assist in facilitating greater integration and combination of different policy objectives and deliver an integrated policy framework to more effectively and efficiently address eutrophication and flooding in the Baltic Sea Region and provide multiple ecosystem benefits.
This paper aims to develop of a conceptual framework of the strengths and weaknesses of the ecosystem services approach to promote greater policy integration and innovation in relevant sectoral policies with an emphasis on agricultural and environmental policies. The development of the conceptual framework is informed by an examination of the extent to which current EU agricultural and environmental policies have considered aspects of the ecosystems services approach and what has hindered the implementation of a more integrated approach. A review is undertaken of the current discussion of the strengths and weaknesses of mainstreaming an ecosystem services approach in agricultural and environmental policies and related instruments to deliver greater integration or win-win situations between environmental and agricultural objectives and interests.
The undertaken literature review and policy document analysis seek to develop a better understanding of: 1) The extent to which current agricultural and environmental policies consider and apply an ecosystems services approach and what ecosystem services are targeted and indirectly promoted; 2) The main challenges in implementing a more integrated approach and how mainstreaming of an ecosystems services approach can improve the integration of sectoral policies and their objectives; 3) The main strengths and weaknesses and key policy instruments to mainstreaming the ecosystems services approach in agricultural and environmental policies currently discussed in the scientific literature.

Adapting policy settings to promote multiple ecosystem benefits: Lessons learnt from case studies in the Baltic Sea Region

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Greater mainstreaming of the ecosystem services approach in agricultural and environmental policies could support better policy integration, potentially refocusing agricultural policy objectives on win-win and trade-off considerations between agricultural and environmental interests. Scientific discussions of innovative policy instruments such as collaborative approaches and outcome-based payments for ecosystem services suggest potentials in addressing and involving new key stakeholders and creating new incentives for collective actions to produce multiple ecosystem benefits from reduced eutrophication and flood prevention.

This work examines how adaptations to the institutional settings and the governance of EU agricultural and environmental policies can increase the effectiveness of measures delivering multiple ecosystem benefits from reduced nutrient enrichment and flood management in the Baltic Sea Region. The work focusses on how specific institutional barriers and drivers affect the success of governance and policy innovations in four case areas in Selke (DE), Berze (LV), Reda (PL) and Helge (SE). Factors of success synthesized from existing examples of innovative agricultural and environmental policy instruments in the EU and further afield improve understanding of barriers and opportunities for the implementation of such policy innovations in different institutional settings across the Baltic Sea Region and inform the assessment of the required changes in existing governance.

Key factors of success include close and trusting cooperation in scheme development, utilization of intermediaries in trust building, an active role of civil society and private sector, spatial targeting and coordination of measures, exploring result-based and long-term approaches. The effectiveness of measures can be increased by adopting a less prescriptive approach to implementation, strengthening bottom-up participatory stakeholder learning processes, fostering cross-sectoral planning and funding initiatives, incentivizing local collaborative actions, developing cooperative nutrient management initiatives in the BSR, developing a more systematic and coordinated approach to pilot-testing of new concepts and measures.

Cultural ecosystem services provided by the Baltic Sea marine environment

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The concept of cultural ecosystem services (CES) brings out the importance of ecosystems in terms of their life-enriching and life-affirming contributions to human well-being. In contrast to provisioning and regulating services, cultural ecosystem services cover all the non-material, and normally non-consumptive, outputs of ecosystems that affect physical and mental states of people. We focus on the question about the relative importance of all CES in the marine environment, developing a measure that covers the entire CES range for the Baltic Sea and its coastal areas. The measure is based on the CICES ecosystem service classification and included eight ecosystem service categories: recreation, landscape, inspiration, learning and education, spiritual experiences and belonging, historically and culturally important places and existence of habitats. We use the measure in three Baltic Sea countries to identify the relative importance of various CES. In examining the whole range of various CES, we are also interested in defining the variables that explain the individually perceived composition of the importance of different CES. Furthermore, we identify categories of CES that are perceived to be separate and those that cluster with each other, as well as grouping individuals based on their perceptions on CES.

The results show that especially recreation, existence of habitats and landscape were considered important CES in the Baltic Sea. The importance of CES associated significantly with several variables describing the respondent's sociodemographic background, use of the Baltic Sea and spatial factors. Most important explanatory variables were country, gender and recreational use of the Baltic Sea, and these factors were also used to predict the importance of the services.

The importance of CES differs significantly between countries, with recreation being the most important service in Latvia, while habitat is more important in Finland and Germany. People who do not visit the Baltic Sea place more emphasis on those CES which are less tangible and not associated with the use of coastal and marine areas, including education, spiritual and habitat services. Clustering of CES elements shows that several subcategories clustered together: education, spiritual and sense of belonging as well historic and cultural experiences. Second cluster of subcategories were recreation and landscape. Importance of habitats seems separate from the other CES. In addition, several CES are seen as less important, including inspiration, education, spiritual and historic and cultural experiences.

Interactions between climate change impacts and nutrient mitigation measures: Comparison of the Selke (Germany) and Berze (Latvia) catchments

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There is an increasing concern about the environmental deterioration of streams due to the growing anthropogenic pressures as well as the impacts of land use and climate changes. Hydrological water quality modelling has been proven to be an appropriate decision supporting tool to improve the physical understanding of processes and then to test the effects of different nutrient mitigation measures and their interactions with climate change impacts. This study is a part of the MIRACLE-Bonus project, where the Hydrological Predictions for the Environment (HYPE) model was used to test the interactions between preventive nutrient mitigation measures, suggested by stakeholders, and climate change effects in two different catchments. Two agricultural-dominant land use catchments (≈ 50%), but distinct in terms of topography, soil type and climate conditions; the Selke (463 km^2 in Germany) and Berze (872 km^2 in Latvia) were used as implementation sites.
First, the HYPE model was successfully tested to mimic the baseline simulations (for the period 2005-2014) for discharge (Q), Nitrate-N (NO_3-N) and Total Phosphorus (TP), for both catchments. Multi-site and multi-objective calibration approach was considered. Second, the effects of different stakeholders-designed mitigation measures on nutrient loads were simulated. Mitigation measures include both agricultural targeting measures, e.g., buffer strips, reduced tillage and optimized fertilizer application rates, as well as point-sources controlling inputs such as increased number of households connected to wastewater treatment plants and improved wastewater treatment efficiency. The scenario modelling was delivered in close cooperation with cost-benefit assessments. Third, the interactions between climate change effects and mitigation measures were investigated in the horizon of 2016-2045. Particularly, modelling results of how much the suggested measures by stakeholders in each case study can mitigate the climate change effects were evaluated.
For the Selke case study, results showed that, the implementation of 10-m buffer strips close to the streams reduces the TP loads by 10% at the catchment outlet. Also, it was found that reduced tillage's is more efficient than the implementation of contour ploughing's measure, where the TP loads were reduced by about 12% and 6%, respectively. For NO_3-N loads, findings showed that 20% reduction of nitrogen fertilizer decreases the loads by about 6% compared to the baseline simulations. Results revealed that climate change will increase the TP loads due to the amplified storm events occurrence in the near future.
For the Berze case study, the implementation and maintenance of 10-m buffer strips along waterways and 2-m along open drainage ditches in agricultural lands could reduce the TP loads by 6%. Also, it was found that improvements in three existing municipal wastewater treatment plants according to the HELCOM recommendations for increased treatment efficiency would reduce the TP and TN loads at the outlet of the Berze River catchment by 2% and 0.1%, respectively. In addition, it was obtained that reduced application rate of mineral fertilizer by 20% would result in reduced TN loads by 13%.

Design of stream remediation measures for nutrient retention and attenuation in the hyporheic zone

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In agricultural areas, streams can serve as an important nutrient sinks, specifically through the interaction between surface water and ground water, so called hyporheic exchange. Biogeochemical processes are particular intense in the hyporheic zone and enhancing hyporheic flows through modification of stream geomorphology may therefore be an effective tool for retention and attenuation of excess nutrients. However, there is a lack of specific design guidelines for in-stream remediation measures. In this study an analytic model was developed that relates the stream-morphology to the distribution of hydraulic head gradients along the streambed and, further, to quantitative water quality objectives. This was done by linking a 2D spectral model for hyporheic exchange to a longitudinal solute transport model, accounting for first-order decay and equilibrium partitioning between dissolved and particulate phases. The spectral approach provides a way to predict and evaluate hyporheic exchange based on stream geomorphology and hydraulics, on all relevant scales. To evaluate the model, Rhodamine WT tracer tests were performed in Tullstorps Brook, which is a partly restored stream in Sweden. The model can be used for guidance when designing in stream remediation features for improved water quality. We show that in every stream reach there is a Damkhöler number, defined as the product between the hyporheic residence time and the denitrification rate along the hyporheic streamlines, which optimize the nitrate mass removal. However, one Damkhöler number can be associated with several different stream-morphology designs. Furthermore, we show how various stream morphologies utilize a different degree of the total hydraulic head fall over a stream reach and specifically compare the self-cleaning capacity of features that create a stepwise decent in the surface water profile with a degraded agricultural stream. The results shows that steps have the potential to increase the self-cleaning capacity of a degraded agricultural stream, but only if the hyporheic zone is not constrained to a shallow depth by upwelling groundwater or an impermeable geological layer.

Scenario analysis for stream restoration actions aimed at reducing nutrient loads to the Baltic Sea

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Main targets of the Baltic Sea Action Plan are to reduce nutrient loading to the Sea by land-based remediation actions. This work shows a scenario application for restoration actions in streams with specific water quality targets aimed at reducing nitrogen export to the Baltic Sea. Denitrification that reduces the export of nutrients to recipient waters can occur both in the flowing water, in riparian zones and in the hyporheic zone of streams in which denitrification and adsorption is often significantly more intense. The exchange with such transient storage zones can be enhanced in a predictable way by introducing remediation structures, like check dams, sequences of riffle-and-pools, boulders and stream meanders, which enhances the water exchange with the hyporheic zone. A developed quantitative design method is used to forecast the effects of a multitude of remediation actions in Tullstorps Brook, Sweden, and generalized to 1001 watersheds distributed over the entire area of Sweden. This generalization was based on an analytical solution relating the nitrate reduction in surface water systems to hydrologic residence times and denitrification rates. The rate estimations were grounded in a vast literature survey of denitrification rates in streams, wetlands and laboratory environments, while estimates of hydrological residence times were determined from more basic estimates of stream network distances and flow velocities. Account was also taken to variation in the denitrification rate with temperature over the year and statistical variation in the result by means of Monte Carlo simulations.

We found that the predominant part of the nitrogen removal through denitrification occurs in first-order streams, such as drainage ditches through agricultural land. The founding is explained both by the high nitrogen load to those local streams and their long residence times. This study has shown that remediation actions in streams greatly can reduce the total export of nitrogen from Swedish catchments to the recipient Sea. If remediation actions are well designed and implemented to full potential in all local streams, the maximum possible reduction of the total mass export from local streams to the downstream Swedish surface water system is estimated to be 60 % ± 24 % including the current reduction and the enhancement based on remediation actions. The reduction of the nitrogen load at the river basin effluence depends on the behavior of downstream aquatic system in terms of further denitrification, atmospheric deposition and other relevant nitrogen processes as well as contribution from other nitrogen sources.

A social learning perspective on water governance - experiences from Helge å, Sweden

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An important innovation of the EU Water Framework Directive is its emphasis on how drainage basins, not formal boundaries of jurisdictions, should be the central point of departure for governance of water governance. This is implemented through the development of River Basin Management Plans (RBMPs), which include a strategy and a set of measures deemed necessary to reach good ecological status in the basin.

In recent years, criticism has been raised against the process in which RBMPs are developed, with an important argument being that it has too much of a top-down character and that there is a need to get a broader set of stakeholders involved. The aim of the BONUS MIRACLE project is to investigate how more stakeholder-driven river management governance frameworks perform in terms of addressing water management issues.

One of the four case study areas in the project is the Helge river basin in Southern Sweden. Water management issues in the basin are multi-faceted and very much characterized by historical man-made alterations of the river and its surroundings. Channeling, hydropower installations and drainage to free up agricultural land are factors that have served important purposes historically but that now pose significant problems in terms of reaching good ecological status. In addition, the basin is characterized by intensive agriculture (in the south) and forestry (in the North) that also contribute to making management of the Helge river basin a wicked problem.

During the three-year BONUS MIRACLE project, a broad set of Helge river position-holders have repeatedly been consulted in a process aimed at developing and testing a bottom-up management strategy for the basin that can serve as a hypothetical alternative to the formal RBMPs. A key finding during the consultations is that whereas the RBMPs are highly focused on mitigating emissions of nitrogen and phosphorus, brownification is the systemic issue in Helge Å according to stakeholders. The consequence is that even if the RBMP are successfully implemented, it may do little to address actual stakeholder concerns.

When stakeholders were invited to help develop alternative pathways, they tended to suggest measures that were more systemic than those typically included in the RBMP. These stakeholder-proposed measures hold the potential of entailing multiple benefits in the basin, but many of the potential benefits are qualitative in nature. This is likely an important reason for the relative absence of systemic measures in the Helge Å RBMP, which is dominated by measures that can more easily be quantified in terms of societal benefits from reduced nutrient emissions. In order to further improve water management structures in the Helge basin and more generally in the EU, it is important that RBMPs incorporate a stronger component of stakeholder involvement away from an excessively reductionist focus on nitrogen and phosphorus.

Identifying mitigation measures for multiple benefits in the Reda basin

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A recent EC assessment of the implementation of River Basin Management Plans (RBMP) stated that measures to achieve 'Good status' are often based on what is feasible and in the pipeline, rather than on the most appropriate and cost-effective measures. In the BONUS MIRACLE project analysis was made if a social learning approach to water governance can lead to identification of pathways that better address water problems and priorities. In the Reda catchment (Poland), early stakeholder consultations revealed that the systemic issue in the basin is flooding and that the nutrient status is of low stakeholder priority, despite the river not meeting Good ecological status according to the WFD. Diverse stakeholder groups with varying interests were then invited to formulate development pathways as alternatives to the existing plans (Business-as-usual) for the catchment. They suggested measures that were addressing the priority problems and were of a more systemic character than those typically included in both the RBMP and the FRMP. For example, various water retention measures were proposed to reduce the flood risks, and it was estimated that they could lead to multiple benefits, including improved biodiversity and nutrient retention. Furthermore, when discussing the Flood Risk Management Plans (FRMP), a discrepancy was identified between the plan and areas at risk for flooding according to local knowledge, calling for an update of the assessments. Also, better planning and public education were addressed as an alternative to heavy infrastructure solutions.
Clearly, an improved water governance will require a stronger stakeholder involvement to identify the priority issues and better integrate different policy goals, such as water quality, flooding, agriculture, and rural & urban development.

Two dimensions of nitrate pollution management in an agricultural catchment

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The Kocinka River catchment underlain by the karstic-fissured upper Jurrasic Częstochowa aquifer in Southern Poland is the site of an interdisciplinary research aimed at finding solutions to pollution of water resources with nutrients. These efforts are conducted in the framework of the BONUS Soils2Sea project that deals with the development of differentiated environmental management measures based on utilization of the natural ability of soils, groundwater and surface water to remove surplus nutrients. Implementation of these or any other measures for the improvement of water quality depends primarily on the perceptions and attitudes of the major actors, which in turn are a product of the socio-economic, cultural-historical and political development spanning many generations. The problem of the deteriorating water quality is therefore twofold. Understanding the complex natural system consisting of the coupled groundwater and surface water component with a wide spectrum of time lags of pollution transport is only the beginning of the solution. The mitigation policies and measures based on this scientific knowledge have to recognize the equally complex nature of social factors and interactions. Implementation of the European and national policies and legislations has to take into account the regional perspective. Identification of the key stakeholders is in this regard a first step followed by an inquiry into their values, perceptions and motivations through interviews, workshops, etc. Understanding of the socio-cultural, historical, economic and political factors that shape stakeholder actions is a prerequisite for the development of the successful management and mitigation schemes. The process of gaining insights into the environmental and social aspects of nutrient pollution in the Kocinka catchment is partly presented by the documentary film "Soils2Sea: Reducing nutrient loadings into the Baltic Sea" (https://www.youtube.com/watch?v=LUouES4SeJk).

Dairy farm management when nutrient runoff and greenhouse gas emissions count

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Dairy production in agriculture receives currently a lot of attention in environmental policy. In many regions, such the Baltic Sea or Chesapeake Bay, nutrient loads from dairy production are considerable. Climate mitigation policy is entering dairy farming all over the world given the high methane emissions from animal husbandry. Negative environmental effects of dairy production are directly linked to management decisions, such as the choice of the herd and its diet, fertilization of field parcels, and technology choices for manure management.

In the earlier literature of dairy management, a comprehensive theoretical modelling of privately and socially optimal production with both nutrient runoff and GHG emissions, and with endogenized interdependent choices (especially diet) in the animal husbandry farm, is missing. Optimizing the diet is important, since its changes affect many aspects of dairy production (e.g. milk production, manure excretion and composition, fertilizer application, land allocation between crops, and methane emissions from enteric fermentation).

We provide a comprehensive theoretical analysis of private and social optimum in dairy production. The private farmer maximizes revenue from milk production by choosing herd size, its diet (share of silage and concentrate feed), manure storage and spreading technologies (with or without cover; broadcast or injection spreading), fertilization (manure or mineral fertilizer), and land allocation between crops (barley or silage). The social planner accounts also for nutrient runoff to waterways and GHG emissions to the atmosphere.

We show analytically that critical radius emerges for both the choice of crops and fertilizer type (mineral and manure) not only in the private but also in the social optimum. We also show that manure application rate decreases in distance to farm center and fertilizer intensity is higher in the manure fertilized fields than in the fields in which mineral fertilizer is used. In contrast to what has generally been thought, the socially optimal fertilizer application follows the same spatial pattern than the private fertilization but at a lower level of intensity. This implies that nutrient policies designed for crop production do not fit to dairy farming.

A simulation model applied to the Finnish agriculture is used to further examine the features of the model. Numerical simulations reproduce the results derived in the theoretical analysis. In addition, we examine how accounting for only climate or water damage affect the optimal choices. Our numerical analysis shows that reducing GHG emissions is surprisingly difficult unless the farm reduces the number of productive animals. Although adjusting diet reduces nutrient loading, a lower herd size is the most effective way to reduce both nutrient runoff and GHG emissions. The number of barley parcels is also reduced when society accounts for only runoff damage or both damages. Diet contains less concentrates in the socially optimal solutions. Optimal manure management technologies are identical in all cases (storage with a cover, broadcast spreading).

Spatially differentiated regulation measures – can it save the Baltic Sea from excessive nutrient loads, and is it possible?

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The Baltic Sea Action Plan and the EU Water Framework Directive both require substantial additional reductions of nutrient loads (N and P) to the marine environment. The remediation measures can be grouped into two main classes i) measures at the field surface affecting the leaching out of the root zone from the crops in individual fields (e.g. catch crops, fertilisation norms, set-aside); and ii) measures restructuring the flow pathway affecting the reduction/retention (e.g. wetlands, river restoration). Focussing on nitrate, we present a widely applicable concept for differentiated regulation, where the remediation measures are differentiated spatially between geographical locations and between root zone, groundwater, wetlands and streams. Hereby we can exploit the fact that the removal of nitrate in groundwater and surface water systems shows large spatial variations. Hereby we can exploit the fact that the removal of nitrate in groundwater and surface water systems shows large spatial variations. By targeting measures towards areas where the local capacity for removal is low, spatially differentiated regulation can be much more cost-effective than the traditional uniform regulation.
Differentiated locations of measures will affect stakeholders differently. Hence, it requires reasonably accurate predictions of capacity for natural removal of nitrate, not only in average for large areas, but specifically for local areas down to field scale. This requires substantially more data and knowledge on flow and transport processes at local scale than is usually available today. In order to assess the impacts of local scale measures for the entire Baltic Sea Basin, local data and modelling results have been upscaled from the three study catchments to the HYPE model that is operationally run for the whole Europe, including the Baltic Sea Basin.
The presentation will discuss the key challenges related to implementation of spatially differentiated regulation measures, including the need for better scientific knowledge, handling of uncertainties and practical constraints related to agricultural practise. Finally, a quantitative assessment is given of the potential effects of spatially differentiated measures as well as a discussion of how much can be achieved in practice and to which extent this could matter for the Baltic Sea environment.

Spatially differentiated regulation of nutrients – stakeholder perceptions in three different case study sites

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One of the goals of the BONUS SOILS2SEA project is to find new and innovative approaches to further reduce nutrient loads to the Baltic Sea. It is common practice to use nationally applied, one-size-fits-all regulations to manage nutrient loads. However, this uniform approach does not account for the significant spatial variation in the retention (removal by biogeochemical processes or sedimentation) of nutrients in groundwater and surface water systems. By using local data on nutrient transport and retention, measures can be spatially differentiated to target 'hotspot' areas where the natural retention is low. The Soils2Sea project considers the potential of spatially differentiated approaches for achieving further reductions in nutrient loads to the Baltic in three case study areas: the Norsminde Fjord catchment in Denmark; Tullstorp Brook in Sweden and the Kocinka catchment area in Poland.
Apart from technical obstacles to implementing a spatially differentiated approach (e.g. defining the target area, uncertainties in scientific assessments), an appropriate governance framework is of equal importance to the implementation of these measures. Existing patterns of government-society interaction, the requirements of relevant EU-level policies as well as influencing factors such as culture, history and society were analysed within the project on the basis of stakeholder consultations, ethnographic studies and desk-based research. The presentation will focus on the outcome of the analysis and determine the potential of spatially differentiated approaches for each case study area.

Reconcling Stakeholder demands by enacting a post normal approach within nutrient governance

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Understanding how to govern nutrient emissions from the 634 sub basins[1] that make up the Baltic Sea Region (BSR) has baffled policy and scientific communities for decades. Nutrient governance is characterised by high degrees of uncertainty, controversy and power brokering, conditions which tend to be amplified with climate change. These conditions are referred to as post-normal situtions in which facts are uncertain, complexity is the norm, values are in dispute, stakes are high and decisions are urgent. In spite of this, they are still considered to be objectively knowable by both the policy and the scientific community. As a response, a post-normal scientific approach has been enacted to reconcile stakeholder demands and support innovative governance reconfigurations in the BSR, by drawing on insights emerging from the four case studies in the BONUS-MIRACLE project, including Berze (Latvia), Helge (Sweden), Reda (Poland) and Selke (Germany). In all the case studies, a systemic issue was identified and deployed as a key vehicle to orchestrate the social learning process and create a platform for co-learning and deliberation among a diverse set of stakeholders. In so doing, it can arguably infuse both a systemic and intersubjective cognizance of existing governance configurations and those under development.

[1] According to Hannerz (2006), there are 634 sub basins larger that 6 km2.

Possible land use scenario for the Reda catchment case study and its impact on water management and marine water

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Due to the fact that water management responds to changing natural and socio-economic conditions its future perspective, depending on multiple and variable factors, is difficult to predict future using traditional prognostic methods. The scenario development process is a useful method for long-term strategic planning in the water management sector. The paper analyzes the possible scenario of land use development in Reda catchment area and its impact on water management and marine water. Scenario building uses mainly analysis of land use trends and analysis of planning documents of different sectors for this area. Reda river is situated in the northern part of Poland in Pomeranian Province next to Tricity (Gdansk, Gdynia, Sopot) metropolitan area. Area of Reda catchment is approximately 486 km2. Currently land use is dominated by agriculture areas (arable land, heterogeneous agricultural areas and pastures) and forest. The shares of agriculture and forest in the Reda catchment are 51% and 44%, respectively. Agricultural areas are dominated in the upper reaches of river and its estuary. Area of artificial surfaces is 4 %. Other types of land use like wetlands and water bodies are insignificant.

Currently one of the main problems in the catchment Reda is a danger of flooding. The river is characterized by high water levels in the winter and early spring. With an average state of the river water reaches an average width of 10-12 meters. In the past Reda river was used for floatable transport, today it is used almost exclusively by kayakers in the sport and tourist. The intensive housing development is continuously implemented. The cause of the increasing flood risk in the catchment Reda is mainly spatial planning. Polish planning system is not hierarchical. National Spatial Development Plan (NSDP) and zoning plans provinces are indicative only for public administration respectively at governmental level and regional level. In practice, the NSDP translates, however, for the management of space at the regional level, less at the level of local (municipal), while zoning plans provinces have some impact on land use in the municipalities, at least in the field of directions, priorities and concepts, to a lesser extent on specific decisions and solutions. They contain objectives and principles formulated in general and hence poorly translate into actions having a direct impact on changes in space and their consequences.

The elaborated scenario assumes that the development of residential buildings outside the Tricity will continue. The inhabitants of Tricity will choose as a place to live outside of the center. This will affect the intensification of surface runoff and, consequently, the threat of flood and marine pollution. Therefore, the importance of rainwater management will increase. Thus, development of the water management sector should, in the future, concentrate more on specific local catchment areas where application of the IWRM principles and adaptation to climate changes will be easier and possible to merge with local spatial planning. Activities for adaption to climate changes should, above all, be undertaken by parties which will directly experience the change effects, i.e. by citizens, large and small enterprises and service providers.

The revealed preferences of Baltic Sea governments: Goals, policy instruments, and implementation of nutrient abatement measures

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Eutrophication of the Baltic Sea has been recognized as a major problem since the 1960s. Excessive nutrient loads are considered a major explanation. Internationally agreed upon nutrient reduction targets for the Baltic Sea were first defined in the Ministerial Declarations of 1988 and 1990. These declarations stipulated that by 1995, emissions of nitrogen and phosphorus to the Baltic Sea should be reduced by 50 percent of the emissions level 1985. These targets were not met, however. The Baltic Sea Action Program (BSAP), launched in 2007, defined new load reduction targets and required a decrease in nitrogen and phosphorus loads by 16 and 70 percent, respectively, compared to the reference period of 1997-2003. A subsequent follow-up suggests that substantial progress has been made towards the nitrogen target, where almost ¾ of the intended reduction was achieved, whereas for phosphorus, only ¼ of the targeted reduction was achieved. Most of the reductions made since the1980s are due to abatement at municipal and industrial point sources, but it has proven to be much more difficult to curb emissions from agriculture, forestry and scattered settlements. Consequently, agriculture remains the main source of nutrient inputs into the Baltic Sea. It is argued that the failure to reach overall load reduction targets can be explained by inefficient policy instruments and insufficient enforcement as well as rapidly increasing costs of abatement and political difficulties to distribute these costs among countries, sectors, and stakeholders. Together, this suggests that the reasons for not meeting targets can be found throughout the whole chain of policy choice, design, and enforcement.

The purpose of this study is to investigate the determinants of how nutrient abatement measures are implemented by countries in the agricultural sector in the Baltic Sea region. We investigate how goal setting, policy instrument choice, and the level of implementation of a measure are determined by characteristics of the abatement measure as well as the socio-economic characteristics of the country where it is implemented. To this end, we use cross-sectional data on 25 different measures in ten countries in the Baltic Sea catchment, compiled within the framework of the BONUS-funded BALTIC COMPASS project, in combination with data on institutional and economic conditions in the countries in question. The results suggest that income, institutional capacity, and economies of scope in abatement and enforcement are important determinants of policies developed and their implementation.

A bottom-up approach to environmental Cost-Benefit Analysis

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Cost-Benefit Analysis is a method to assess the effects of policies and projects on social welfare. CBAs are usually applied in a top-down approach, in the sense that a decision-making body first decides on which policies or projects are to be considered, and then applies a set of uniform criteria to identifying and valuing relevant cost and benefit flows. By suggesting an alternative approach, this paper investigates the possible advantages, prerequisites and limitations of applying CBA in what may rather be considered a bottom-up approach. Instead of starting out with a pre-defined policy option, the suggested approach departs from the underlying environmental problem, and thus assesses costs and benefits of various strategies and solutions suggested by local and directly affected stakeholders. For empirical case studies concerning two river catchments in Sweden and Latvia, the bottom-up CBA approach utilises local knowledge, assesses strategies and solutions which are not only developed for local conditions but are also likely to be more acceptable by the local society, and sheds additional light on possible distributional effects. By not only benefitting from, but also encouraging and supporting participative environmental planning, bottom-up CBA is in line with the growing trend of embedding stakeholder participation into environmental policy and decision-making.

Developing improved methods for identifying cost-efficient abatement set in the Baltic Sea Region

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Economic nutrient abatement models analysing the Baltic Sea protection policies commonly operate on a large scale, grouping river systems to large catchment areas. However, operating at the level of large catch- ment areas has consequences for policy recommendations. In particular, averaging the in-stream capacity of river systems to retain nitrogen from reaching the sea, removes the opportunity of targeting measures to the most vulnerable regions within the catchment, while overestimating the capacity of abatement measures in the upstream areas. In this study we build a model to show what kind of bias in the optimal abatement set is caused by the assumption of spatial homogeneity. We classify catchment area to zones with increasing distance from the coast and solve the model with and without the zones. We find that while assuming homogeneity prevents from using abatement measures where they would be the most effective (typically close to coast), it also leads to ignoring spatial limitations that are more relevant to a subset of abatement measures, such as the wetlands and buffer zones. Therefore, the bias for setting economic instruments optimally is not only derived from overestimating the costs due to underestimated efficiencies, but also from overestimating the abatement measure capacities relative to the average efficiency. We illustrate this outcome with numerical Swedish data on reaching the good ecological status for the South-West coastal waters.

Improving the cost-effectiveness of water quality improvements through spatial scale changes to target-setting

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In this paper, we investigate the potential gains in cost-effectiveness from changing the spatial targeting of nutrient reduction targets in the Baltic Sea, focusing on nutrient loadings associated with agriculture. A new, fully disaggregated model, which represents losses in agricultural profits, changes in root zone N concentrations and transport to the Baltic Sea is proposed, and is then used to estimate the gains in cost-effectiveness from changing the spatial scale of nutrient reduction targets. The model includes 14 Baltic Sea marine basins, 14 countries, 117 watersheds and 19,023 10x10 km grid cells. Costs of achieving loadings reductions are compared across five levels of spatial scale, namely the entire Baltic Sea; at the marine basin level; at the country level; at the watershed level; and at the grid square level. Cost-effectiveness turns out to be highest when targets are set at the largest area of spatial aggregation and lowest when targets are set at the smallest level. We argue that our results have important implications for both domestic and international policy over achieving water quality improvements where non-point pollution is a key stressor of water quality, and discuss the range of policy options, which are available to get close to the cost-effective reductions in N loadings identified by the constrained optimization model.

Accounting for natural reduction of nitrogen

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Nutrient loads to groundwater, estuaries and inland freshwater systems poses a serious risk to the water quality and ecological state of these systems. In Denmark, nitrogen comprises the largest problem in many fjords and estuaries, where it is estimated that approximately 90% of the load is from diffuse sources, primarily agriculture. Regulation to reduce nitrogen excess, has historically been based on a uniform approach imposing the same restrictions for all areas independent on physical and hydro-geochemical conditions. However, during transport from the root zone to the marine environments, nitrate may be naturally reduced or subject to retention by sorption or sedimentation in surface water systems, but the amount of nitrate being reduced or retarded varies significantly in space. A spatially differentiated regulation, targeting areas with small natural reduction/retention, thus has the potential to be much more cost-effective compared to the uniform approach, and is currently under development in Denmark.

To utilise natural variation in nitrogen reduction and retention in regulation, detailed knowledge on the controlling processes and their spatial variability is required. The aim of the research project "TReNDS – Transport and Reduction of Nitrate in Danish Landscapes at various Scales" (www.nitrat.dk) is to advance the understanding of these processes and quantify their impact on nitrate transport and transformation. The project combines detailed field studies and model simulations and develops new methodologies and tools. Combining GPR and Dual EM it has been possible to detect the location of drain networks, but the method is sensitive to clay and moisture content. Intensive monitoring in two lowland areas have provided detailed insight in the complex interaction between water flow paths and reducing compounds, and its importance on the hydro-biogeochemical transformation of nitrate in riparian lowlands. During transport in the subsurface nitrate is reduced in anoxic environments and mapping the interface between the oxic and anoxic parts (the redox interface) is thus of great importance. A new redox-probe has been developed in the project that can provide us with many new measurements of the redox interface in a more cost-effective way. Furthermore, a new method is developed to construct a national map of depth to the redox interface that can be easily updated at local scale when new measurements are available. Learning from the detailed field studies, new methods to upscale and implement the local-scale processes in catchment scale models are currently under development. Finally, to utilise local conditions optimally and learn what is practically feasible, the project also have a large involvement of local stakeholders

Combining the project results, the current estimate on the spatially variation in nitrate reduction at national scale can be improved, and are expected to provide input to the implementation of a new targeted regulation strategy that will take effect in Denmark from 2019.

Analysing drain flow modelling: How can representation of nitrate drainage transport be improved in catchment scale models?

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Nitrate pollution from agriculture of surface water bodies are an increasing problem in countries all over the world. As nitrate leaches from the root zone it is exposed to degradation processes in the soil and saturated zone, however in areas with tile drainages the percolating nitrate may get transported to the drains; often bypassing reduction; ending as non-reduced nitrate components in water bodies. Therefore the correct partitioning of drain and groundwater flow is essential for modelling of nitrate transport in tile drained areas.
Unfortunately most catchment scale models have proven incapable of capturing local scale drain flow due to lack of information on the appropriate scale to guide the calibration and limitations in the model concept.
This work presents the development and testing of different drain concepts capable of being incorporated into a catchment scale model in the MIKESHE modelling framework; with the objective of improving drain flow modelling; and thereby nitrate transport modelling. The concepts are built on differentiation between different drainage types (tile, natural and urban drain) and hypothesises of tile drain typologies.
The concepts are tested in the agricultural dominated and extensively tile drained 101 km^2 Norsminde catchment in Denmark (Hansen et al., 2014; He et al., 2015). The effect of the concepts on drain flow dynamics and magnitude is evaluated using drain flow measurements from eight small drain catchments (Kjærgaard et al., 2011-2015) within Norsminde.

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Advancing local engagement in nitrate regulation

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For the last 30 years nitrate regulation of agriculture in Denmark has been governed through general "top down" regulations and legislation which has reduced nitrogen emissions to coastal waters by approx. 50%. This has obviously been a success, but has happened without engagement of stakeholders and has often taken place with reluctance and significant costs for the individual farmer.
Implementation of the Water Framework Directive has led to further reduction needs, and it was decided that previous practices of general regulation were no longer sufficient since the measures in the general regulation became too expensive. The Government therefore, in 2015, decided to introduce more targeted regulation. This in terms of restoration of wetlands, constructed wetlands, targeted catch crops and a division of Denmark into areas with different nitrate retention zones (1500 ha) with the perspective to differentiate nitrate restrictions more cost effective.
A change from general regulation to more site-specific and targeted regulation requires a new water governance based on more local engagement. In 2017, the government introduced a new concept of 28 Catchment officers with the purpose of finding suitable sites for constructed wetland and wetlands through direct contact with farmers. However, this new initiative by the government is only one step forward going from “top down control” to more cooperative and engagement in governance.
In the TReNDS pilot area - the catchment for Norsminde Fjord - farmers face more than a 50% nitrate reduction target to the fjord by 2027. This has so far led to two tracks: 1) a willingness to make a positive difference by taking an active role in finding measures, but so far only with measures on a voluntary basis and with compensation 2) at the same time a critical attitude towards the significant reduction requirements. This demonstrates that an acceptance of the nitrate reduction targets, is crucial for willingness among farmers to engage further into the challenges with reducing nitrate.
The constructive attitude towards finding solutions, even though the reduction targets are a mayor challenge for the agro-economy, should probably be seen in the context of the collaboration in the pilot area between farmers, farmers union, advisers and researchers since 2007 including establishing a local water council in 2012.
In the TReNDS project, we use the “governance infrastructure” (water council, catchment officer, engaged farmers) to test and find solutions for water management strategies suitable for future demand for local engagement.

Gypsum reduces agricultural phosphorus load: preliminary results from a large-scale pilot

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Eutrophication is the major problem in open and coastal waters of the Baltic Sea. According to the HELCOM's Baltic Sea Action Plan, Finland has to reduce the load of phosphorus (P) into the Gulf of Finland by 364 t y^{-1}. Municipal and industrial wastewaters being efficiently purified for P, the abatement measures should focus on agricultural diffuse load. Yet, even if all the planned measures were fully implemented, the target would fall about 250 t y^{-1} short. New approaches for tackling agricultural P load are therefore urgently needed.

We are testing the performance of a novel agri-environmental measure, the surface application gypsum ($CaSO_4 \cdot 2H_2O$), in reducing P losses from clayey agricultural fields. In autumn 2016, gypsum was spread (4 t ha^{-1}) on 1550 hectares in the middle reaches of the river Savijoki, south-western Finland. The upper reaches of the river were left as a control area, where gypsum was not used. Runoff in both areas has been intensively monitored before, during and after the gypsum amendment.

In this presentation we will discuss the ability of the measure to decrease dissolved and particulate forms of P, based on data collected during 14 months after the gypsum amendment. In addition, we present the results of extensive ecotoxicological studies, which focussed on a potential side-effect, the impact of increased concentrations of sulfate on riverine fish, mussels and mosses. The results suggest that gypsum has a marked potential in reducing P losses from clayey fields with minimal adverse effects on riverine biota. Future studies will concentrate on evaluating the duration of the gypsum effect, which is related to the gradual leaching of gypsum from soil. The gypsum pilot contributes to the NutriTrade project lead by John Nurminen Foundation and funded by the European Union Central Baltic Program.

Gypsum treatment of fields: a cost-efficient measure for the Baltic Sea

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The Baltic Sea Action Plan aims to reduce the annual load of phosphorus and nitrogen entering the sea by 14 400 and 89 300 tons, respectively. This reduction should be achieved mostly by measures within wastewater treatment and agriculture. Wastewater treatment plants can still considerably reduce nitrogen loads at low costs when compared to those of agriculture. Possibilities to reduce phosphorus are, however, more limited in many countries increasing the need to reduce phosphorus in agriculture. Current measures to reduce phosphorus runoff from arable fields are quite ineffective and limited. Gypsum provides a new measure that has been found to effectively cut down phosphorus runoff from fields. Gypsum suits well to clay soils and the average gypsum dose per hectare is four tonnes. Once spread on fields, gypsum increases the ionic strength of soil. It creates larger aggregates of soil particles and affects phosphorus binding, which decreases the phosphorus losses to waterways. The soil structure improves, erosion decreases, and phosphorus remains available to plants. These beneficial effects occur immediately after the dissolution of gypsum, last for several years and are achieved without any loss of crop yields. Gypsum treatment can be easily combined to the ordinary farming practices, as shown by the recent gypsum pilot project in the Savijoki catchment.

Previous research suggests that gypsum treatment of fields reduces dissolved reactive phosphorus by about 30% and particulate phosphorus by 60%. In southwestern Finland, the average P runoff may rise up to 1.3 kg/ha/y entailing 0.4 kg dissolved phosphorus. Gypsum amendment reduces this runoff by 0.63 kg, that is, almost by a half. We estimate that gypsum may reduce P loading into the Archipelago Sea as much as by 100 tons. For comparison, increasing the phosphorus removal rate to 98% in all the Finnish wastewater treatment plants (larger than 10 000 PE) would result in only 30 tons reduction in loads.

Gypsum has yet another advantage: it is much cheaper than the measures currently included in the Finnish agri-environmental payment scheme (buffer strips, fertilization limits and wetlands). Previous work suggests that the marginal costs of reducing 30% of P runoff from fields with these measures are about 230 €/kg. Drawing on the cost data from the gypsum pilot we conclude that gypsum reduces loading by more than 40% with a cost of 70 €/kg.

Gypsum treatment can provide an exciting solution to agricultural phosphorus loading in the entire Baltic Sea. Gypsum treatment may suite e.g. for Sweden, Denmark and Poland. Clay soils are dominant in Sweden and Denmark, while soils in Poland more coarse. Together with Finland, the agricultural phosphorus runoff to the Baltic Sea from these four countries amounts to 8000 tonnes annually. By rough estimates gypsum treatment of fields could reduce the load by up to 1500 tonnes from these countries alone.

The gypsum pilot contributes to the NutriTrade project lead by John Nurminen Foundation and funded by the European Union Central Baltic Program.

Modelling impact of agricultural land use changes on nitrogen export from the Kocinka catchment

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The aim of the study is to compare the influence of different land use options on the export of nitrogen from the agricultural catchment with complicated hydrogeology setting. Water flow in the Kocinka river catchment is strongly dependent on groundwater inflows from fissured-porous karstic aquifer (Major Groundwater Basin GZWP326). Two modeling approaches were used to assess effects of the land use scenarios. One of the approaches is based on downscaling of the results of the E-HYPE3.1 model. The hydrological catchment model HYPE simulates fluxes of water and dissolved substances through catchments. Another approach couples the model of nitrate leaching from the root zone (N-LES4) with the numerical model of groundwater flow and nitrate transport (Visual MODFLOW). The input data for the nitrate leaching model are patterns of soil and crop types supplemented with information on agricultural practices, fertilization levels and soil properties. The N-LES4 framework allows to reflect the actual conditions of the arable land and to assess effects of land use scenarios. Results from N-LES4 are spatially oriented using ArcGIS desktop and implemented to the Visual Modflow model. Only the second approach takes into account the delays (lagtimes) of nitrate transport in groundwater. The first approach is more appropriate for catchments where the role of groundwater in pollutant spreading is less pronounced.

Patterns and trends in riverine water quality in the Baltic Sea basin: modeling nutrients with HYPE

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Nutrient transport models are important tools for large scale assessments of macro-nutrient fluxes (nitrogen, phosphorus) and thus can serve as support tool for environmental assessment and management. Results from model applications over large areas, i.e. from major river basin to continental scales can fill a gap where monitoring data is not available. Here, we present results from the pan-European rainfall-runoff and nutrient transfer model E-HYPE focusing on Baltic Sea Basin (BSB). E-HYPE 3.1 was updated within the SOILS2SEA and MIRACLE projects (1) to make the model comparable across other on-going BONUS projects, and (2) to improve the process description affecting nutrient transfer and retention in BSB. In addition to model performance evaluations based on comparing simulated and observed concentrations at observation points, the E-HYPE model performance was reviewed with respect to 3 process-based data for which maps could be provided: baseflow fraction, nitrogen leaching, and reduction of nitrogen in groundwater.

Monitoring data from several national data bases were examined along with the model to detect temporal trends across Baltic Sea Basin. In addition, we analyzed residuals between model results and observations. The residual trend analyses help to identify locations where observed concentrations may be affected by changes in weather patterns. Both positive and negative trends were found in nutrient concentrations in European rivers.

Analyses did not detect any significant trend at most of the 194 sites in BSB with IN observations during 2000-2009. Decrease of IN concentrations related to changes other than climate was detected at 22 sites. Five of these sites did not show a decreasing trend in the observed concentrations. Increase of IN concentrations related to changes other than climate was detected at 5 sites, with 1 of these sites not showing any trend in the observed concentrations. A similar proportion of trends was also detected for TN and PP with 11-15% and 0-3% sites showing a decrease or increase in the residual, respectively. For ON, the proportion of sites showing an increase in the residual was similar (2%) while the proportion of sites showing a decrease was higher (23%). SP and TP concentrations decreased in a smaller proportion of sites (4-6%), while again they increased in a similar proportion of sites (2-4%). Assumption and the study settings such as time period or trend significance can affect the detected trends and patterns.

The model results show spatial patterns in N concentration in rivers across Europe which can be used to further our understanding of nutrient issues across the European continent. Residual analyses illustrate how the E-HYPE model can be used to evaluate nutrient trends and their drivers and provide information beyond that contained in the observed data.

Shaping environmental policy choices – A logistic regression analysis on Swedish municipal councils

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The objective of this study is to examine the decisions by Swedish municipalities to adopt environmental targets and action plans and to allocate a responsible authority. To this end, we assess how socioeconomic, environmental and political factors, as well as the availability of environmental expertise, affect these municipal decisions. Questionnaire data from the Swedish Association of Local Authorities and Regions (SKL) in combination with environmental monitoring data and official statistics on socioeconomic and political characteristics of municipalities are used for this analysis. We employ logistic and multinomial logistic regressions to our cross-sectional data set. We find the main results to be that:

(i) an increase in average income and collaboration with local interest groups increase the likelihood for municipalities to adopt local environmental goals;

(ii) municipalities with good water quality or small surface water area are less inclined to adopt local targets and action plans;

(iii) municipalities with good water quality, small surface water area and a larger area of natural reserve land are more inclined to set responsibility of environmental target setting with other environmental forums than with the municipal council board; and

(iv) high representation of environmentally-oriented parties implies a greater likelihood of adopting local environmental goals and setting responsibility for environmental targets with the municipal council board.

Cost-effectiveness analysis of nutrient mitigating measures: A cross-country comparison under the impact of climate and land-use change

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The objective is to assess the cost-effectiveness of nutrient mitigating measures, which were suggested by local stakeholders in four Baltic Sea Region river catchment areas, namely Berze (Latvia), Reda (Poland), Helge (Sweden), and Selke (Germany). While the cost structures are estimated according to system design and life-time, the effects are based on case-specific hydrological modelling results. Differences due to the impact of climate and land-use change, as well as due to dissimilarities between case areas in terms of cost structures, physical conditions and modelling assumptions, will be highlighted.

Spatially-explicit model of the Baltic Sea-based recreation demand – new estimates of recreational value, its distribution along the coast, and the influence of environmental conditions

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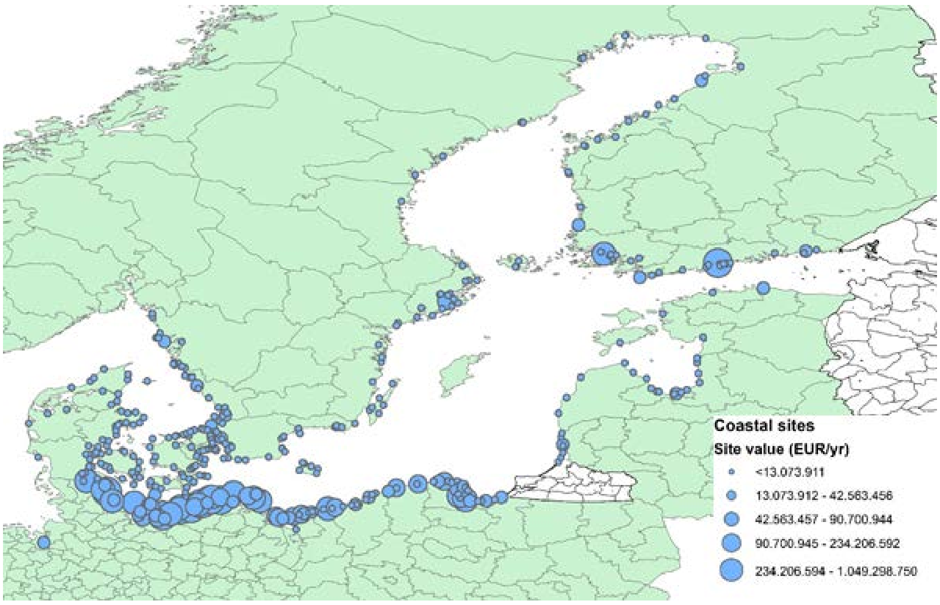
Recreation in coastal areas has been growing over the past decades, and it is a key factor in regional economic development and social welfare. At the same time, many coastal recreation possibilities are sensitive to environmental quality, but the link between recreational welfare and environmental quality is rarely made.

We provide new estimates of the recreational value of Baltic Sea coastal sites, based on the observed recreational trips of people in eight of the nine littoral countries and applying a spatially explicit random utility model-based Travel Cost Method. This approach accounts for substitution among recreational opportunities and makes it possible to value access and site specific quality changes, such as water quality.

Results indicate an estimated total value of recreational sites of 11.4 billion EUR between the available coastal locations, enabling us to identify recreational hotspots around the Baltic Sea (See map). In addition, by observing varying environmental conditions at different sites, namely meeting the "blue flag" status conditions, we are able to simulate the increase in the total recreational benefits of the Baltic Sea in the case water quality at all sites improved to this level. We find that it is nearly 9 billion EUR, illustrating the extent of the benefits resulting from improving water quality and infrastructure.



Scenario analysis of the Pregolya River discharge as response to changing climate conditions

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The Pregolya River catchment is a transboundary catchment located at the territory of the Kaliningrad Oblast (Russia) and Warminsko-Mazurskie and Podlaskie Voivodeships (Poland). The river is bifurcated in two branches in the town of Gvardeysk: the Downstream Pregolya flowing into the Vistula Lagoon and Deyma Branch flowing into Curonian Lagoon.

The response of the Pregolya River discharge to changes of climate conditions was analysed within BONUS Soils2Sea Project (2014-2016). The HYPE model simulations of the four scenarios of the future climate projections (2041-2060) for the South-Eastern Baltic Region were fulfilled. The set-up of the Pregolya catchment in the E-HYPE v3.1 hydrological model (Hundecha et al. 2016) was improved using local spatial data and calibrated for real atmospheric forcing and discharge data in Gvardeysk for 1979-2009. We refer to this model hereon as Pregolya-HYPE.

The basic model run series was made for the baseline climate (1991-2010). The climate projection data was bias-corrected to the WFDEI reference data using the DBS method (Yang et al. 2010). For this period the discharge of the Pregolya River before its dividing into the arms was estimated as 2.72 km^3 a year in average. Considering additional water gain from local catchments, the average water flows to the Vistula and Curonian lagoons were 1.96 km^3 (via the Downstream Pregolya) and 1.20 km^3 (via the Deyma Branch).

According to four climate projections (CM5A-MR_WRF, CanESM2_RCA4, MPI-ESM-LR_CCLM, CNRM-CM5_RCA4, 2041-2060) the increases in temperature over the catchment area of the Pregolya range from 1.2°C (CM5A-MR_WRF) to 2.1°C (CanESM2_RCA4), while precipitation increase ranges from 20 mm/year (MPI-ESM-LR_CCLM) to 200 mm/year (CNRM-CM5_RCA4) which corresponds to increases of 10-25% relative to the baseline period. The uncertainty of changes in meteorological and hydrological characteristics for climate period 2041-2060 (in comparison to baseline period 1991-2010) is described by the ranges: (a) the precipitation will increase in the range from +59 mm (+7%) to +216 mm (+27%); (b) the mean annual air temperature will increase by 1.3-2°C; (c) the projection for the mean annual discharge is not unambiguous, it may decreases by 7 m^3/s (-8%) or increases by 26 m^3/s (+31%); d) therefore, the mean annual specific run-off is not unambiguous, it may decrease by 23 mm (-10%) or increases by 62 mm (+28%).

As we can see the increase in precipitation does not always lead to an increase in the river runoff from the catchment area. This nonlinearity is associated primarily with an increase in temperature, which leads to increased evapotranspiration from the catchment area.

Evapotranspiration is a result of the coupling of temperature and precipitation, and thus is sensitive to climate model uncertainty. Two (out of the four) climate projections (CM5A-MR_WRF, CNRM-CM5_RCA4) project the increases of discharge while the other two (CanESM2_RCA4, MPI-ESM-LR_CCLM) project decreases. This suggests that the natural conditions in the Pregolya River catchment don't allow to project with certainty the trend caused by climate changes: increase and decrease of the river discharge. It complicate the process of developing of adaptation measures as the action plans should be developed for these both possible projections.

Benthic-pelagic coupling in coastal seas – modeling macrofaunal biomass production in response to organic matter input

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Benthic macrofauna is an important component linking pelagic and benthic ecosystems, especially in the productive coastal zones. Through their metabolism and behavior, benthic animals affect fluxes of carbon, nutrients and oxygen between the sediment and water column, which in turn has implications for the frequency of plankton blooms and water clarity. Benthic fauna is also an important food source for commercially exploited fish, such as cod and flatfish. Because of its functional significance, benthic fauna is used an indicator of environmental status in the Baltic Sea.
In this study, we develop a process-based dynamic model of benthic fauna to investigate the relationship between organic matter input and benthic macrofaunal biomass in the coastal zone. The model simulates the carbon dynamics of three functional groups of benthic macrofauna and their sediment food sources, and is linked to a hydrodynamic-biogeochemical model simulating pelagic physical (e.g. temperature, oxygen concentration) and biological (e.g. sedimentation, suspended organic matter) dynamics. It is based on the setup by Timmerman et al. (2012, J. Mar. Syst.), but implemented in a new modelling environment and with some considerable alterations.
The model reproduces measured time-series of benthic biomass from two coastal sites in the northern Baltic Proper and Gulf of Finland well. During the simulation period 1993-2005, a 13-fold increase in macrofaunal biomass, mostly due the bivalve *Macoma balthica,* has taken place in the Gulf of Finland site. This shift in community composition was reproduced by the model and suggested significantly altered pathways of organic matter degradation, with implications for the whole coastal ecosystem. From the early 2000s onward, the amount of sedimentation seems to determine the biomass of macrofauna, as ca 80% of organic carbon sedimentation was processed by the macrofauna in both sites. We used a sensitivity analysis to study the effects of changing nutrient loads and climate on simulated benthic biomass. While reduced nutrient loads might lead to improved oxygen conditions and recovery of benthic fauna in deep parts of the Baltic Sea, we expect a decrease in benthic biomass in the coastal zone due to decreased food availability, especially in combination with increased temperatures.

Assessment of nutrient concentrations and export for the Pregolya River (South-Eastern Baltic) by monitoring data 2014 – 2016

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To adequate assessment and modeling of nutrient export and retention in the Pregolya catchment the supplementary screening monitoring were fulfilled in the Kaliningrad Oblast (Russia) within the scope of the Soils2Sea BONUS Project (2014-2016). In contrast to the Russian state monitoring limited by inorganic forms of nutrients only the screening monitoring included laboratory analysis of organic nitrogen and phosphorus. Monitoring program covered all major tributaries of the Pregolya River within the Kaliningrad Oblast and included 12 monitoring points. Samples were collected seasonally in 2014 – 2016 and were analyzed in laboratory to get the information on water quality in terms of following parameters: total nitrogen, nitrate nitrogen, nitrite nitrogen, ammonia nitrogen, total phosphorus, phosphate phosphorus.

The concentrations of total nitrogen and total phosphorus significantly varied from year to year: within 0.37-12.91 mg/l and 0.02-0.49 mg/l respectively. The high concentration of nutrients was observed in the majority of studied streams of the Pregolya River basin during the spring flooding. The nutrients concentration reduced greatly in the most of studied streams after the spring flooding. Inorganic nitrogen mainly consisted of nitrates. The highest concentration of nitrate (above 2.0 mgN/l) was observed for all sample points of the Lava River, which is the largest tributary of the Pregolya River, that was probably due to an intensive flow from agricultural lands. The dynamics of nutrients concentration in the river system largely depend on the hydrometeorological factors, first of all precipitation and temperature conditions.

The highest concentrations of ammonia nitrogen, nitrites and phosphates were found in the Pissa River and the Pregolya River near the city of Kaliningrad. In these points their concentrations exceeded the Russian norms of Maximum Permeated Concentration ($NH4 \geq 0.4$ mgN/l; $NO2 \geq 0.02$ mgN/l; $PO4 \geq 0.2$ mgP/l) during certain periods. It is supposed that this is caused by anthropogenic pollution from point sources.

The spatial distribution of phosphorus and nitrogen concentrations in water of the Pregolya River and its tributaries was conditioned by the influence of a number of factors (runoff seasonality from the catchment area, anthropogenic pollution and seasonal succession of phytoplankton). Usually, nutrients input from the tributaries resulted in the permanent increase in nutrient concentration downward the Pregolya River. The downstream of the Pregolya River was characterized by the highest variability of nutrients concentrations which was significantly influenced by the pollution from Kaliningrad wastewaters, as well as interaction with the Vistula Lagoon waters, which can penetrate upstream the Pregolya River. Sometimes a significant decrease in concentration of nutrients was observed at the near mouth part of the Pregolya River that was a result of dilution with the lagoon waters pushed by wind upstream the river.

The selected network of monitoring stations is indicative and can be used in the future to assess the concentration of nutrients in the Pregolia River basin. The ratio of organic and inorganic forms of nutrients significantly varies in different seasons of the year and areas of Pregolia River catchment. Data for Pregolia River shown that shares of the organic nitrogen and phosphorus were 3-97% and 4-94% from the total values respectively. The statistical confident relation between organic and inorganic forms of nitrogen and phosphorus were not found. Therefore, the assessment of the nutrient load basing on inorganic forms of nutrients only provides the lowest estimation.

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Understanding shallow groundwater dynamics and the effect of tile drainage on flow paths around the redox inteface in a Danish till area

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Many agricultural fields are tile drained in order to lower the water table and thereby improve plant growth. In Denmark around 50% of the agricultural area is tile drained, especially the glacially derived clayey soils in the eastern part of the country. Tile drains have a large impact on the hydrology and flow paths in a catchment and therefore also on the nutrient loading to surface water. Tile drains act like a short cut from the field directly to streams and thereby the flow bypasses the natural reduction capacity in groundwater and wetlands, where N can be naturally removed. In order to manage nutrient loads from tile-drained catchments it is therefore essential to understand shallow groundwater and tile drain dynamics, especially the distribution between water going to tile drains and water crossing the redox interface, where nitrate reduction occurs.

The objectives of this study were i) to enhance our understanding of shallow groundwater and tile drain dynamics and to ii) evaluate on the effect of tile drainage on the groundwater flow paths around the redox interface. The study was conducted on a 33-hectare tile drained field within the Fensholt catchment in Norsminde, Denmark. The study consisted of an extensive field campaign carried out from summer 2014 to fall 2017 as well as a transient hydrological model of the drain catchment with a detailed representation of the drain network.

We were able to make the hydrological model fit the measurements of hydraulic head and water fluxes from the drain system. The field data show that the increase in the water level of the system when the autumn water surplus starts is extremely rapid, with heads increasing up to 1 m per day. This temporal dynamic was successfully modeled, as were most of the many highly transient peaks occurring in the drain water flow. The calibrated model was afterwards successfully validated by comparing with areally weighted measurements of the discharge in the stream draining the larger Fensholt catchment.

In order to assess the effect of tile drains on the flow paths, the vertical water fluxes between model layers were extracted for a tile drained area in the model and a non-drained area. For both areas a high downward flux is found in the upper model layers. In the non-drained area, the downward flux decreases gradually with increasing depth and at 3-4 meters depths, which is location of the redox interface in the area, there is still a relatively high downward flux. In the tile drained area, however, the downward water flux is high down to 1 m below ground surface i.e. the drain level, but below this level the downward flux decreases significantly, and at the redox interface the flux is much lower than for the non-drained area.

Our results thereby indicate, that tile drains have a large effect on the flow paths in the shallow groundwater and on the water flux across the redox interface. This change in groundwater flow paths have large implications on the nitrate transport in tile drained areas, since less nitrate will be transported below the redox interface and thereby less nitrate will be reduced in groundwater.

Methods of spatially targeting agricultural mitigation measures for reducing uncertainty of estimated nitrogen load reductions to aquatic systems

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Further reduction of nitrate (N)-load to coastal waters from agricultural areas in Denmark is necessary to comply with the EU Water Framework Directive. Therefore, we investigated how spatially targeting N-leaching reducing measures on agricultural land would achieve target N-load reduction with least effect on agricultural production (set-a-side on agriculture land area) for Norsminde catchment in Denmark. This was performed using N-leaching and total N-reduction (i.e. groundwater and surface water) input maps in 100m grid cells. Since the uncertainty of spatial input data propagates to the results of spatially targeted strategies, we addressed key issues of importance for determining the uncertainties critical to decision making. Uncertainty of 30 equally plausible N-reduction maps was found to lower the efficiency of spatially targeted strategies, since this effectively results in placing measures on areas with lower N-reduction that leading to higher N-load than anticipated. This study aimed: (i) to assess the uncertainty on estimated results of scenario analysis, where a number of mean N-reduction maps ensembles (i.e. mean maps were developed randomly from 2 maps up to 30 maps in a way that results in 30 maps for each possible average map, except the average of 30 maps) have been used to allocated the spatially targeted measure in the catchment, (ii) to reduce the uncertainty on the estimated N-load reductions through developing different methods for targeting the set-aside. These methods includes application of set-aside based on each individual N-reduction map compared to a mean N-reduction map, using spatial frequency of high N-load and using spatial frequency of low N-reduction. These maps were applied to select which grid cells are converted to set-aside to reach N-load reduction target of 20%. The resulting set-aside maps thereafter were used against each single N-reduction map to provide a probability distribution of N-load reduction. Hereafter, the efficiency of using different methods for reducing uncertainty was compared in terms of required set-aside area for achieving 50 or 80% probability of reaching the 20% N-load reduction requirement at catchment level. (iii) to analyze how uncertainty changes with increasing scale, where N-reduction maps were used in grid cell and sub-catchment scale. Overall, the results revealed that using ensembles of N-reduction maps decreased the variation in N-reduction and compared to using individual N-reduction map can improve the results of spatially targeted measures and lower the uncertainties substantially. The results showed that using a frequency map of set-aside with frequency threshold of 0.3 in both grid and sub-catchment scales compared to set-aside maps resulted from average N-reduction map and from using spatial frequency of low N-reduction is more effective in term of a lower set-aside areas required for achieving 20% N-load reduction target with probability of 50% and 80%. Investigation of analysis based on two different scale of N-reduction maps indicated on the one hand, that the finer the spatial detail, the greater is the uncertainty in estimated results of scenario analysis. On the other hand, the coarser the spatial detail the less difference in N-reduction among spatial entities and the less the efficiency gain of applying spatially differentiated measures.

Go4baltic Farm Survey

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The BONUS GO4BALTIC farm survey aims to provide information about how farmers in the Baltic Sea Region respond to multiple policy objectives and instruments, and what the implications might be for policy coherence. By asking questions as well as by a choice experiment the farm survey provide data for analyses on farmers' practices related to storage of manure, application of fertilizers and manure (amounts, timing, application methods), investments in technologies as well as land use practices, their use of subsidies and the motivations for this. We use the data for assessments of whether regulations and policies are conflicting or coherent, and the farm survey in BONUS GO4BALTIC has a dual purpose; to provide data for analyses of manure handling and fertilizer practices, incentives to improve them, as well as analysis of incentives with respect to nutrient and climate policies and, in particular, to different actual and potential subsidy schemes.

Agri-environmental scheme measures, implemented as part of the Rural Development Programme and the CAP Greening requirement, can change nutrient loads to the aquatic environment from agricultural soils, as well as agricultural GHG emissions. There are examples of measures that have positive effects on both GHG and nutrient loads to water, and on measures that have conflicting effects. An example is catch-crops, which is an abatement measure to reduce nitrogen leakage by increasing the retention but also transformation of N, might result in increased emissions of N2O.

Specific focus in the farm survey is on nutrient handling and on farmer's decisions (and motivation for these decisions) for improving nutrient utilisation and to implement measures. Similarly we focus on farmers choice of subsidy contracts based on payment levels and other contractual conditions as well as how factors as farm type and other characteristics explain the choices of contracts. We explore how farmers' perceive the incentives embedded in the policy instruments and how they make trade-offs between contracts, by asking farmers directly, instead of asking e.g. river basin managers. The study builds on the experiences from former Baltic surveys, e.g the Baltic Compass, the assessments made by the European Commission and the growing number of farm surveys conducted in Europe these years. The survey is being conducted in June 2017 – December 2017.

Groundwater and stream threshold values as a tool for compliance testing of groundwater and surface water chemical status and protection of the Baltic Sea – general principles and examples.

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The Groundwater directive (a daughter directive to the Water Framework Directive) stipulates that EU member states have to derive more stringent threshold values for groundwater if existing standards do not protect groundwater associated surface water bodies incl. transitional and coastal waters and ensure compliance with good status objectives of the Water Framework Directive. The general groundwater quality standard for nitrate (50 mg/l) frequently result in failure to achieve the environmental objectives of the Water Framework Directive, and nitrate is the pollutant that most frequently result in poor status of European groundwater bodies. Despite this fact, most EU member states do not derive groundwater threshold values for nitrate for protection of dependent terrestrial and associated aquatic ecosystems generally referring to a lack of data and knowledge as the main reason for not doing so. Here we present some general principles for derivation of nitrate thresholds for groundwater and streams for protection of associated aquatic ecosystems, and demonstrate the derivation of these in selected Soils2Sea examples including coastal catchments and a catchment hundreds of kilometres away from the Baltic Sea.

What was the nitrogen concentration in runoff water from Danish catchments to coastal waters around year 1900?

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Determining the reference conditions for the various water types (rivers, lakes and coastal areas) is a central element in the Water Framework Directive (WFD), as it sets the starting point for determining the boundaries between the quality classes, especially the boundary between good and moderate quality, as this line in general defines, whether or not a certain water body fulfills the objective. Aarhus University has decided to undertake an in-depth analysis of the main factors, that may have influenced the entire nitrogen cycle and to investigate the factors that may have influenced the annual mean nitrogen (N) concentrations from source to sea around the year 1900 in Denmark in order to estimate the N-concentration at that time. Fulfilling such an aim require that a range of parameters known to influence the N cycle, such as climate, hydrology, land use, agricultural practices, drainage, landscape, etc., are described for the period around the year 1900, as very few measurements of N concentrations in streams and rivers are available from that time.

A number of different methods, that could assist in estimating and/or finding indications of the N concentrations around the year 1900 in soil water, groundwater and surface waters, were assessed for Denmark – such as agricultural statistics, trends in climate and hydrology, review of historical measurements found in the international and Danish literature or use of model estimates. The aim of the analysis was to conduct an assessment of, what this range of indicators in combination point to in terms of the N-concentration in the water discharging into marine areas around the year 1900.

The assessment showed that the runoff from the Danish area was app. 25% lower in the year 1900 than today and the temperature was about 1.5°C cooler than now. Around the year 1900, 67% of the Danish land area was in croplans, 8% was bare fallow and 25% was nature areas. For the agricultural land it is estimated that the nitrate concentration in the leachate of the root zone would have been 12 mg N/l around the year 1900, which is in line with today's organic arable farming. Approximately 22% of the area used for agriculture was tile drained around the year 1900 (16% of the total area), as compared with today where app. 50% of the agricultural area is tile drained. Around the year 1900 point sources (cities, industry) may have had an impact locally, but the point source load of nitrogen was too low to have influenced the overall national nitrogen budget. Model calculations have shown, that the total retention (from root zone to the coast) was considerably higher than today – in the range of 76-87% around the year 1900. Routing of the estimated nitrogen concentration in the root zone combined with the estimated nitrogen removal in ground and surface water around the year 1900 results in a concentration range of 1-2 mg N/l.

For the assessment of N concentration in water running to the sea around the year 1900, many assumptions have to be made, which adds to uncertanty. However, a comparison of different indicators point to the same direction. Therefore, the best estimate of the nitrogen concentration in the water running into Danish coastal areas at the time around the year 1900 is within the range of 1-2 mg N/l.

Potential significance of riparian lowlands on nitrogen fluxes from agricultural drainage in Danish watersheds

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Worldwide efforts to combat agricultural nitrogen (N) losses to aquatic environments have raised the attention towards developing best management practice (BMP). In Denmark, BMP to reduce aquatic N loads have been adapted during several decades through the Danish actions plans for the water environment. Although the adaptation to these plans significantly have reduced agricultural N losses, the current water quality goals, set by the European Water Framework Directive, still requires substantial reductions of diffuse N loads from farmland in Denmark. This has called for a paradigm shift towards the development of more cost-efficient targeted mitigation strategies.
Tile drains connecting fields to receiving waters can act as subsurface highways for agricultural nutrient losses, and contributes to estimated 45-60% of total agricultural N losses in Denmark. Riparian lowlands intercepting upland agricultural fields from surface waters are considered key landscape components. Although riparian lowlands may cover relatively small areas of a catchment, they may have significant impact on the catchment nutrient balance, being able to transform N in drainage to nitrogen gas, and thereby reducing agricultural N loadings to downstream recipients. The hydrology and the biogeochemistry (mainly carbon content) of the lowland sediment control the transformation of N from upland agricultural drainage discharge. Decades of drainage and cultivation of riparian areas have resulted in significant decomposition of peat soils, decreasing carbon contents and increasing bulk density, which may weaken the ability of riparian soils in transforming N from upland drainage.
To evaluate the potential significance of riparian lowlands on N fluxes from agricultural drainage in Danish watersheds a catchment based analysis was conducted as part of the research project "TReNDS – Transport and Reduction of Nitrate in Danish Landscapes at various Scales" (www.nitrat.dk). Results demonstrated that the ratio of riparian lowland area to agricultural upland area in 90 Danish catchments varied from 1 to 50%, thus significantly influencing the overall impact of riparian lowlands on the catchment nitrogen balance. Peat soils largely constituted one fifth of the riparian lowland soils. Investigating the solute transport properties in drained, cultivated riparian lowland soils along an organic carbon (4-42%) and bulk density (284-1.153 kg m^{-3}) gradient demonstrated a significant variation in the soil hydro-physical properties and solute transport. A higher total porosity at high carbon contents was related to a markedly higher microporosity. Solute transport analysis demonstrated an increase in preferential flow with decreasing carbon content and increasing bulk density. Soil bulk density was identified as a key parameter explaining the observed differences in solute transport properties.

Drivers of participation in gypsum treatment of fields as an innovation for water protection

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The paper studies analytically and empirically the participants of a large-scale pilot that develops a new agri-environmental measure, gypsum treatment of arable fields, to reduce phosphorus loads to the Baltic Sea. We focus on motivations, experience, and evolvement of technological and agronomic knowledge and skills. The paper produces understanding on how to incentivize farmers with different goals, motivations, and characteristics to promote the gypsum concept and assesses its potential in agricultural water protection as part of the agri-environmental payment scheme.

We build an economic crop production model on the farmers' decision on the use of productive inputs and gypsum. We focus on three motivations of farmers to participate in developing the gypsum concept: profit-maximizing, utility from innovating new cultivation practices and stewardship attitudes towards the environment. Based on the analytical model and the previous literature on extrinsic and intrinsic motivations to participate in user innovation processes, we build a pattern of motivational statements to be ranked by participants in a 7-point scale. In 2016, a mixed-mode survey collected information on motivations, farm and farmer characteristics, cultivation practices and self-assessment of co-operation during the gypsum pilot. The data collection resulted in 47 responses. This corresponds to the response rate of 87% and 91% of the total of 1550 hectares of the gypsum treated area.

The confirmatory factor analysis validates the existence of three motivations in the sample and produces farmer specific indicators of the strength of each motivation (individual factor scores). Statistical analysis reveals that strong profit motivation is associated with large gypsum-treated areas, agricultural education and the agreement with the statement that gypsum treatment of fields is an easy measure for water protection. Strong environmental motivation is associated with small farm size, environmentally friendly cultivation technologies and the perceived need for more experience in gypsum treatment before its reliable use as a conservation measure. Both strong innovation and strong environmental motivations are associated with the perception of the impact of one's agricultural methods on the adjacent water system, implying the role of the belief in one's capability to make choices that affect the environment for developing an environmental innovation. The promise of gypsum treatment of fields as a new agri-environmental measure lies in its suitability for various types of farms, its ability to provide a variety of benefits and its appeal to multiple motivations.

Economic benefits from reaching a good status of the Baltic Sea

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Sustainable use and management of environmental resources requires information on the interactions within the ecosystem, including humans. This is apparent also for the marine ecosystem, where there are clear links between the ecosystem state and human welfare. The importance of the marine ecosystem to human welfare is recognized in the Marine Strategy Framework Directive (MSFD), which aims at achieving good environmental status (GES) of European marine waters by 2020. The MSFD requires economic and social analyses e.g. on the costs caused by the deterioration of the marine environment, and the economic benefits of introducing new measures to improve the environmental status.

Thus, the management of marine resources calls for estimates on the economic benefits of environmental changes, and the need for benefit estimates for policy support is increasing. Economic valuation methods are commonly used to fill this need, especially stated preference methods, such as the discrete choice experiment (CE) method. Choice experiment is a survey-based method, which elicits people's preferences for environmental changes by asking them to choose between alternatives described using attributes. One of the attributes is cost, which enables determining respondent's willingness to pay for environmental changes, both for individual attributes and entire scenarios.

This paper presents a three-country, Finland, Germany, Latvia, choice experiment designed to elicit citizens' preferences and values for changes in the Baltic Sea environment. The study was linked directly to the MSFD, capturing values for four characteristics used to describe the good environmental status: biodiversity, non-indigenous species, eutrophication and marine litter. The aim is to produce policy-relevant information that can be used in regional and national economic analyses of the marine environment. The results show the monetary value people perceive from improved quality of marine environment. The preliminary results show the importance of all four marine environment attributes included in the study, and especially the importance of biodiversity and eutrophication mitigation.

GHG marginal abatement cost curves for Finnish agriculture in the case of multiple pollutants and interrelations

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In order to design efficient policies to reduce agricultural environmental loads we need information on the marginal abatement costs (MAC) of different mitigation measures. MAC-curve orders measures from the cheapest to the most expensive one, thus providing the possibility to compare marginal costs with those applied in other sectors, such as transport or, for example, the carbon price in the EU-ETS. Separate analyses of agricultural MACs for GHG emissions and nutrient loads have been conducted in different studies. But neglecting impacts on nutrient runoff when targeting GHG emissions may increase or decrease the mitigation costs for the society, and vice versa. Neglecting interactions between measures leads to an overestimation of the abatement potential of an individual measure. In this study we will derive cost functions for reducing environmental loads from the Finnish agriculture. Based on these cost functions we will derive MAC curves in three cases when 1) only GHG emissions, 2) only nutrient runoff or 3) both GHG emissions and nutrient runoff are accounted for. Tentatively, measures studied include reducing nitrogen fertilization, increasing the share of a buffer strip, afforestation, legumes in crop rotations, green fallow, no till cultivation, biogas from silage and manure, manure separation, covering manure storages and livestock diet.

The making of the documentary film Soils2Sea: How narrative films complement scientific investigation

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BONUS SOILS2SEA undertook research in four cases study sites in Denmark, Sweden, Russia and Poland. In parallel to the field work of geologists, hydrologists, meteorologists, environmental scientists and others, a documentary film about the Soils2Sea project with special focus on the case study site in Poland was produced.
Poland, a country which holds 1st place in agricultural production in the European Union has not only be shaped by a difficult political and economic heritage but also still undergoes typical post-socialist transformation processes which are affecting the implementation of the EU nitrate directive in many ways. The film Soils2Sea portrays the historical and cultural origins of perceptions, values and preferences of farmers, rural citizen and institutional agricultural and related actors to issues of soil pollution in south central Poland. The film team undertook several trips to the Kocinka area where they observed, interviewed and filmed farmers, employees of water and sewage treatment plants, rural citizen, politicians and scientists.
The presentation will refer to the main messages of the film while emphasize the film genesis, encounters and observations during the recording, social and technical aspects, some obstacles and will finally formulate recommendation for further film making endeavors touching upon the question how films can complement scientific investigations and vise versa.

Interactive visualization for data exploration – The MIRACLE Visualization Tool

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The MIRACLE Visualization Tool is a web-based tool that has been designed to support the social learning process in the MIRACLE pilot areas around the Baltic Sea. The tool allows exploration of modelled data for four catchments as well as upscaled data for the Baltic Sea Region, and additional data of relevance (e.g. flood risk maps, land use mappings, etc.). The tool further presents pathways for each of the pilot areas as well as the costs and benefits of selected pathways and measures. The MIRACLE Visualization Tool is a highly interactive research tool, and its design and development included several iterations with the involved MIRACLE partners, as well as continuous user evaluations.

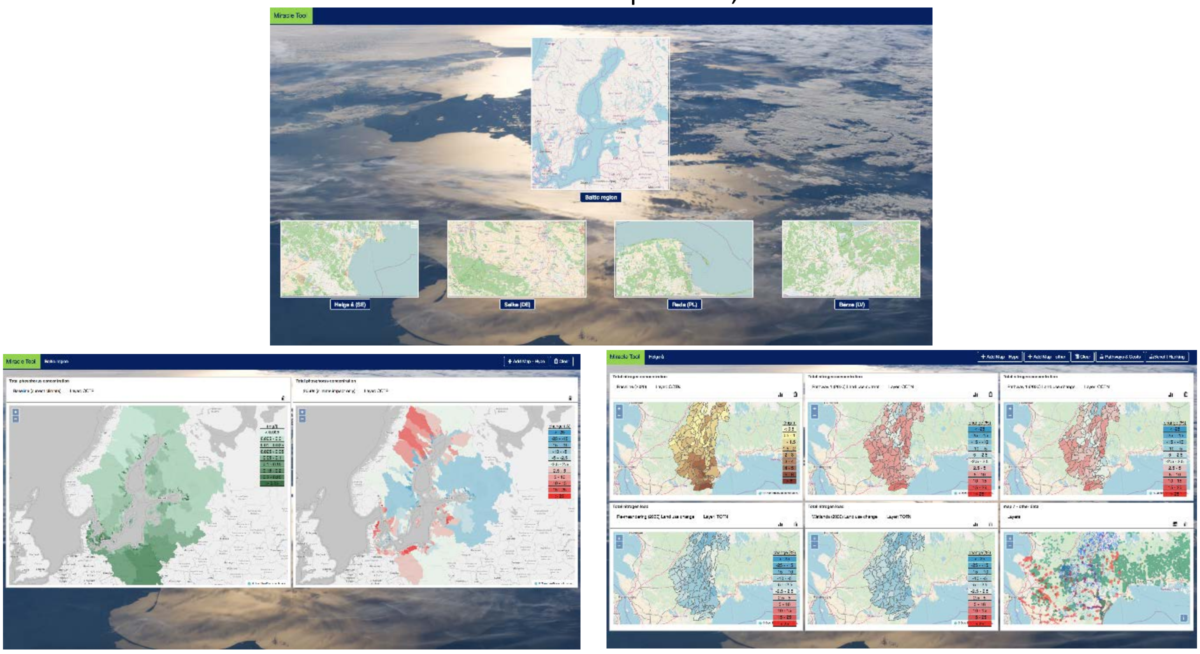

Figure 1: Screenshots of the BONUS MIRACLE Tool, presenting the entry page (top), an example for the BSR module (bottom left) and an example for the pilot areas (bottom right, presenting Helgeå)

The tool displays information for the four pilot areas (Helgeå/Sweden, Berze/Latvia, Reda/Poland and Selke/Germany), and supports the selection of multiple variables and scenarios. Linked multiple views enable the users to select and compare geospatial representations of hydrological and hydrochemical model results. These results are generated by the HYPE model (Hydrological Predictions for the Environment), an integrated rainfall-runoff and nutrient transfer model developed at SMHI. The modelled variables, e.g., nitrogen and phosphorus concentrations and loads, as well as discharges at sub-basin outlets are mapped for each of the pilot areas at the sub-basin scale. Users can also view and compare modelled results as graphical representations of the pathways with accompanying Sankey Diagrams that display the costs and benefits for each of the suggested measures.
In this presentation we discuss challenges, solutions and trade-offs that were part of the design and development process of the MIRACLE Tool, and outlines lessons learned for similar future endeavours.

Transport and transformation of nitrate in a Danish riparian lowland

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Riparian lowlands function as the interface between streams and upland areas and may thus have a great influence on the quality of the water entering the streams. Riparian lowlands are often considered as efficient landscape elements in mitigating leaching of excess nitrogen fertilizer from surrounding agriculture to streams. However, the efficiency of riparian lowlands may vary greatly, and some riparian lowlands may even function as a net source of nitrogen. Investigation of the factors controlling the efficiency of riparian lowlands is needed to enable proper implementation of this landscape element in large scale nitrogen retention models.
The present case study investigates the transport and transformation of nitrate entering a riparian wetland located in Fensholt, Denmark. Nitrate from the surrounding agricultural areas enters the wetland via drain water from drain pipes, which are cut off at the hillslope at the edge of the wetland. Four subareas of the riparian lowland, each with different settings of topographical gradient, lithology, travel distance from drain to stream, hydraulic loading, and presence of tile drains within the lowland itself are investigated.
Preliminary results show a large variation in nitrogen removal efficiency between the four subareas. The role of the riparian lowland seems to be controlled by the transport flow paths, which are largely controlled by the ratio of the hydraulic loading from the drain outlets to the infiltration capacity of the lowland soils. Nitrate appears to be efficiently removed from water that infiltrates into the soil. However, if the infiltration capacity of the soil is exceeded, nitrate may travel directly to the stream as overland flow. Concurrent decomposition of peat in the lowland releases organically bound nitrogen and the net role of the riparian lowland depends on the balance between nitrate removal and release of organic nitrogen. Presence of tile drains within the lowland itself adds further complexity to both flow pathways and conditions for decomposition of peat.

Mapping groundwater flow paths in riparian lowlands with geophysics - how deep do we need to go?

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Question: When doing site-specific geophysics with the goal of describing the major flow path ways in a riparian lowland, to what do we need our geophysics to cover with respect to depth and spatial extent? This is the question asked and answered (to a certain degree) in this study that combines three different geoelectric and electromagnetic (EM) geophysics.

Background: In catchments with large amounts of agricultural land use, there is a significant transport of nutrients in the groundwater system and in the tile drainage network and to apply a sound regulation on the application of nutrients on the fields, we must know the approximate flow paths in both regimes. In this part of the TReNDS project, we focus on the riparian lowlands, i.e. the near-stream areas that may vary greatly in depth and length but are generally assumed to have high nutrient retention capacitites due to different combinations of lithology, mineralogy, carbon content and redox levels.

Method: The common method to assess the hydrostratigraphy of the subsurface is a combination of geophysics and boreholes on top of whatever a priori knowledge there is available. Here, we have data from three different geophysical methods with markedly different resolution, penetration depth and spatial coverage; (1) SkyTEM data (time-domain EM) with penetration depth of 200-300 meters and relatively low resolution with extensive spatial coverage, (2) geoelectrical line surveys (ERT) with penetration depth to approx. 30 meters and (3) DualEM data (frequency-domain EM) with penetration depth of 4-5 meters, high resolution, and spatial coverage depending on terrain, soil condition among other factors.

Discussion: The three geophysical methods have markedly different costs with respect to time, human effort and price. The shallowest surveys (DualEM) shows approximate flow paths in the riparian aquifer itself but greater penetration is preferred when deeper flow paths are in play. Also, a priori knowledge about the general geology/hydrology in the area is of great value. Other geophysics could further resolve elements of the riparian lowland such as seismics, ground penetrating radar, IP geoelectrics, and low-footprint time-domain EM.

A study of the nitrate management discourse in Poland and a comparison with Denmark

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The most significant source of nitrate pollution in the European Union is attributed to agricultural activities, which poses a significant threat to marine and freshwater resources. The Nitrates Directive (91/676/EEC) is a key feature of the Water Framework Directive (2000/60/EC) which seeks to reduce nitrate pollution from agricultural sources to protect Europe's bodies of water. Compliance has proven to be problematic as demonstrated by the fact that every Member State has experienced difficulties in fulfilling their respective implementation duties. This study aims to examine the nitrate management discourse in Poland. Further, a comparison in management approaches between Poland and Denmark is made to provide a calibration in assessing implementation performance respective to another Member State.

The study takes a multi-method analytical approach, including both qualitative and quantitative assessments. The quantitative research is comprised of the results obtained from a social capital survey with farmers and compliance performance based on monitoring data of infringement cases. The qualitative research is comprised of an extensive literature review, content analysis of key stakeholder interviews, identification of influencing factors, and a theoretical analysis of street-level bureaucrats. Further, a comparison is made with Denmark of governance capacity elements (social capital, street-level bureaucrats, and political culture).The study contributes new insights in identifying the main factors affecting the ability of Member States to fulfill their implementation duties.

Based on the multi-method assessment, Poland and Denmark are categorized as laggard Member States, in regards to implementation performance of the Water Framework Directive. Despite differences in socio-political factors, cultural norms and levels of governance capacity, both Member States are in a position where domestic interests conflict with European Union ambitions for environmental protection. Nitrate management is situated within a context of a strong agrarian cultural tradition, which contributes to agriculture playing a significant role in the interests of each respective state. Simultaneously, Poland and Denmark face considerable pressure from the European Union to reduce nutrient loadings to the Baltic Sea.

The study further posits that divergent stakeholder views based on historical and cultural norms demonstrate that differentiated measures tailored to domestic conditions are necessary for effective fulfillment of the objectives set forth in European Union environmental legislation.

Nutrient retention in a remediated stream – evaluation of a tracer experiment with ^{15}N, ^{32}P and ^{3}H

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The increased attention to surface water quality problems together with the revealed importance of the stream water – hyporheic zone system for solute retention has highlighted the potential for surface water systems to reduce nutrient export to downstream recipients. As a consequence, the number of stream remediation projects during the last decades has increased significantly. However, to be able to design remediation measures as well as to assess the effectiveness of already implemented measures, quantitative knowledge of the hydrodynamic (substance independent) and the biogeochemical processes (substance dependent) retaining particular contaminating solutes along the transport pathway is needed.
In this work, we present the findings from a simultaneous injection of tritiated water ($^{3}H_2O$), phosphate ($^{32}PO_4^-$) and nitrate ($^{15}NO_3^-$) with the overall aim to evaluate the effectiveness of remediation actions implemented along a 6 km stretch of the Tullstorps Brook, a small agricultural stream in in the south part of Sweden. In contrast to many other tracer tests where different types of proxy substances are used, a key advantage of this study is the use of the substance of environmental interest, labelled-phosphorous as phosphate and labelled-nitrogen as nitrate, which enhances the significance of the results. In addition, the unique signal from the injected tracers allowed us to distinguish the added nutrients from other diffuse sources of nutrients from the surrounding landscape.
By using a physically based transport model to evaluate the tracer breakthrough curves at a number of subsequent sampling stations, we were able to contrast the response of different stream reaches both with respect to hydrodynamic and biogeochemical retention. In particular, we found a substantial importance of vegetation on the biogeochemical retention of ^{32}P, when comparing established reaches with dense in-stream vegetation with newly implemented reaches where vegetation was completely absent.

Optimal Abatement of Nitrogen and Phosphorus Loading from Spring Crop Cultivation

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Discrete dynamic optimization is applied to examine the difference between socially and privately optimal fertilization patterns and to develop an incentive mechanism for efficient simultaneous nitrogen (N) and phosphorus (P) loading management. The problem formulation accounts for the causal interactions between P and N fertilization, crop yield, P carry-over, and P and N loading into waterways. Our analysis shows that the balance between private and social shadow values of the P carry-over is an essential feature for the design of the input tax-subsidy scheme for both N and P. Numerical analysis carried out for spring barley on clay soils and current damage costs in Southern Finland suggests that the difference between privately and socially optimal steady-state fertilization levels is substantial. The economic losses for the producer from the tax-subsidy scheme internalizing the damage costs are in the range of 18-32% of the profits, even at simultaneously adjusted N and P fertilizer inputs. Our sensitivity analysis indicates that other abatement measures, such as catch crops, are often competitive to fertilizer input reductions. For the producer, the computed break-even level of a subsidy for catch crops is well in line with the current subsidy levels applied in Finland.

Keywords: phosphorus loss; nitrogen loss; catch crop; carry-over; steady-state; tax-subsidy scheme

Increased nutrient recycling in agriculture around the Baltic Sea: implications for eutrophication

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Decades of human inputs of nitrogen (N) and phosphorus (P) have caused severe eutrophication in the Baltic Sea, as well as in inland waters in its catchment. Although nutrient inputs to the Baltic Sea have been reduced during the past 20 years (17% for N and 20% for P), continued nutrient load reductions are needed to enable recovery. Agriculture is now the single largest source of new nutrients to the Baltic Sea, contributing almost half of total waterborne N and P inputs. Efforts to reduce nutrient losses from agriculture will not only benefit the sea, but also inland surface waters and groundwater.
To identify opportunities to reduce nutrient losses from agriculture, we constructed N and P budgets for the entire catchment, at both national and regional scales, and estimated nutrient use efficiency for crop production.
Nutrients are imported to the catchment mostly as mineral fertilisers and livestock feed. Trade out of the catchment (primarily as agricultural products) is small in relation to total imports, thus leading to accumulation of nutrients in the catchment and sea. Most of the N and P in the catchment pass through agriculture, with especially large flows in the livestock sector. About 70% of crop production in the catchment is fed to animals, together with imported feed. A major portion of imported mineral fertiliser and livestock feed is transformed into manure; however, the nutrients in manure are often not used efficiently in crop production. Nutrient use efficiency in crop production averages only 55% for nitrogen and 60% for phosphorus for the entire catchment. This inefficiency can result in the accumulation of nutrients in agricultural soils and increase the risk of losses to lakes, streams, groundwater, and the Baltic Sea. We developed different scenarios of improved nutrient use efficiency to estimate potential reductions in riverine inputs to Baltic Proper, Gulf of Finland, and Gulf of Riga. We used a steady-state marine model to understand the effect of reduced riverine loads on eutrophication. There is potential to reduce nutrient losses from agriculture by improving manure management and replacing imported mineral fertilisers with nutrients from manure. Reducing the import of livestock feed (producing a larger share of the feed locally) and reducing the number of livestock in regions with high densities can also reduce agricultural nutrient surpluses.

Method for logging subsurface redox signature with a novel Redox Probe

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Oxidation reduction potential has long been known to control microbial activity in the soil. The so known redox interface, marking the transition from aerobic to anaerobic conditions, is of crucial importance for transformation of nitrate leaching the root zone. Detailed knowledge on the location of the redox interface is thus vital in assessing the natural removal of nitrate in the subsurface and its spatial variation. Observations of the redox conditions have up to now been based on borehole data, i.e. sediment colours, sediment samples or water samples. Boreholes are, however, expensive, and cost-effective methods are needed to measure the redox conditions in the subsurface. In the frame of the research project TReNDS (Transport and Reduction of Nitrate in Danish landscapes at various Scales), a new innovative method and field instrument have been developed for cost-effective local scale measurements of depth to the redox interface.
The measurement method uses the Redox Probe (patent pending) to measure the potential difference between a silver chloride reference electrode and a noble metal electrode. The voltages range between +/-1000mV. The probe is penetrated the soil with a boring rig with a technology like direct push. Specially developed electronics couple the depth of the probe with the voltage measurement with mV precision. Present measurement rate is 1Hz. Electrical resistivity can also be logged during the same log, for extensive interpretation of the geology.
The first results have shown an impressive proof of concept, and further validation and repeatability tests have been carried out against geological boreholes. Figure 1 shows repeatability of measurements in the vicinity of an existing borehole. Until now, the method has shown redox values down to a depth of 15m in clay using 6.35cm rods, but deeper logs can be obtained in the future with thinner rods and softer geologies. The current rate of operation is approx. 80m/day, and the commercial price per meter is 75 USD.

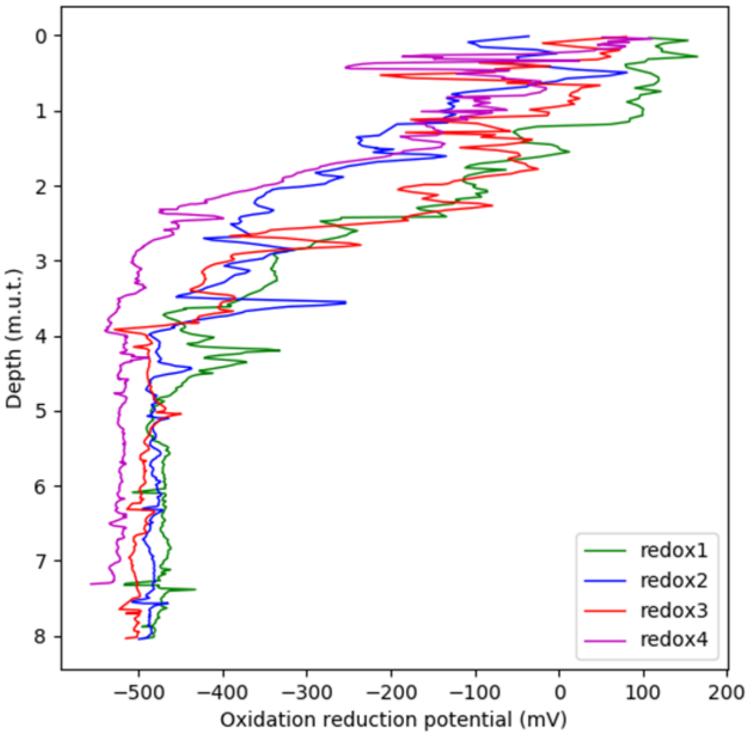

Figure 1. Four measurements were performed in a radius of 2 m in the vicinity of a known redox interface around 2.5 m.b.t..

Questions for modelling on the local scale – case study area of Reda catchment

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It has been confirmed that it is useful to use mathematical models, which are an attempt to describe in detail the processes related to water cycle in the environment, to determine mutual interconnections and relations between them, and also to determine forms of quantification of values characteristic to the evaluation of quantity and quality of water resources. The models allow to obtain detailed information on the current and prospective state of water resources (taking into account the influence of potential climate change). It is necessary to mention that the launching of models, entering appropriate data in appropriate formats and calibration is not an easy task.

One of the pilot catchments in the MIRACLE project was the Reda catchment whose outlet is in the bay of Puck, part of the bay of Gdansk. Modeling with the HYPE tool poses an assessment of the current status and evaluation of planned activities to limit nitrogen and phosphorus compounds in Reda river. It should be emphasized that the pilot basins in the MIRACLE project, ie Berze, Helge, Selke and Reda, differ significantly in spatial development and population density. Regarding the modelling for Reda two groups of questions were identified and discussed.

First group covers the problems with the data. In the case of the Reda catchment, difficulties are caused by an inconsistency between the location for flow measurements and those for water quality measurements. The longest time series of observation when it comes to water quality exists for the monitoring point, located below the mouth of tributary of Reda. As a result, some assumptions were made to interpolate the results of quality measurements. In Reda catchment the systemic issue is flooding. This specific problem can be defined as shortage of retention solutions to reduce flood risk. Lack of a unified, accessible to users, and not questionable database focused on potential and/ or planned investments and water consumption in the Reda catchment was also indicated.

Second group of questions is related to the upscaling of the results for the whole Baltic Sea Region. Assuming upscaling of climate change to the Baltic Sea region, the sensitivity to these changes in pilot catchment areas remains varied. This aspect must be taken into account in planning activities and implementation of measures even common developed for the whole Baltic Sea Region.

Lagtime of pollutant transport through catchments: reducing nutrient loadings to the Baltic Sea

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Containment of the ongoing eutrophication of the Baltic Sea requires substantial reductions of nutrient loads (N and P) reaching the coastal zones of this important marine ecosystem. The BONUS Soils2Sea project is elaborating the concept for spatially differentiated regulations to support effective reduction of nutrient loadings originating from agricultural activities. The effectiveness of spatially differentiated measures could be evaluated in two aspects: (i) reduction of nutrient loads to the Baltic Sea via groundwater and stream pathways; (ii) response time of marine ecosystem to nutrient load reduction. Transport of conservative contaminants through groundwater systems (e.g. nitrate under oxidized conditions) is significantly delayed when compared to movement of those contaminants through surface water compartments. Characteristic time scales of groundwater movement can easily reach tens or hundreds of years. Contaminant transport in the subsurface, when compared to transport through surface and near-surface runoff (drainage), is necessarily characterized by significant delay (lagtime), which can be further separated into two components: (i) the delay associated with travel time of water and contaminants through the unsaturated zone, and (ii) the delay linked to timescales of groundwater flow, from the recharge area down to the discharge zone (river). Thus, total travel time of water through unsaturated and saturated zones can be considered a quantitative measure of the lagtime of contaminants.

Lagtime of nutrients in the unsaturated zone on the territory of Poland was assessed using the concept of mean residence time of water (MRT) in this zone, whereas the time spent in the saturated zone was approximated by the travel time (Tsat) of water flowing along the local hydraulic gradient to the closest river. The total lagtime (MTR + Tsat) for the Polish part of the Baltic Sea catchment is in the order of 25 years (range from 10 to 60 years corresponding to one standard deviation). Spatial distribution of lagtime values in the Polish territory allows to identify agricultural regions for which implementation of differentiated regulations will result in fastest response of the system in terms of N and P loads in the rivers discharging to the sea.