SOILS2SEA DELIVERABLE NO. 1.10

Final Report

May 2018

Project acronym: BONUS SOILS2SEA

Project title: Reducing nutrient loadings from agricultural soils to the Baltic Sea via groundwater and streams

Period covered: from January 2014 to March 2018

Project coordinator: Professor Jens Christian Refsgaard,
Geological Survey of Denmark and Greenland (GEUS)
Tel: +4530709830
Email: jcr@geus.dk

Project website address: www.soils2sea.eu

SOILS2SEA

Reducing nutrient loadings from agricultural soils to the Baltic Sea via groundwater and streams

This report is a confidential deliverable of the BONUS Soils2Sea project. The present work has been carried out within the project 'Reducing nutrient loadings from agricultural soils to the Baltic Sea via groundwater and streams (BONUS Soils2Sea)', which has received funding from BONUS, the joint Baltic Sea research and development programme (Art 185), funded jointly from the European Union's Seventh Programme for research, technological development and demonstration and from Innovation Fund Denmark, The Swedish Environmental Protection Agency (Naturvådsverket), The Polish National Centre for Research and Development, The German Ministry for Education and Research (Bundesministerium für Bildung und Forschung), and The Russian Foundation for Basic Research (RFBR).

This report may be cited as:

Refsgaard JC, Sejerslev J, Olesen JE, Jacobsen R, Wörman A, Bartosova A, Stelljes N, Wachniew P, de Jonge H, Chubarenko B. BONUS Soils2Sea Deliverable 1.10. Final Report. Geological Survey of Denmark and Greenland, Copenhagen, May 2018, www.Soils2Sea.eu

Table of Contents

1. Scientific/Technological results achieved

1.1 WP1 Coordination and dissemination

1.1.1 Project meetings, Advisory Panel, BONUS coordination and reporting

The eight BONUS SOILS2SEA project meetings organised and conducted during the project period have been crucial for the scientific coordination of the project, in particular with respect to monitoring progress and coordinating activities across workpackages. A Steering Committee Meeting was held at the end of each of the project meetings. Furthermore, many meetings have been conducted on specific issues, both within and between workpackages. In addition to physical meetings, many skype meetings were held, both at the Steering Committee and at workpackage levels.

The Advisory Panel met three times in connections with project meetings in Stockholm 8-9 September 2014, Krakow 30 September – 2 October 2015, and Berlin 17-19 May 2017. The composition of the Advisory Panel is shown in Table 1. The panel basically consists of seven members of which two members have been replaced due to retirements (Philip Axe by Ann-Karin Thoren and Leonid K Korovin by Natalia Oblomkova) and the BONUS COCOA representation was split between two persons.

Table 1. Composition of the Advisory Panel and contributions to the three meeting and commenting on the Policy Brief.

Name	Affiliation	Country	Stock holm	Kra-kow	Ber-lin	Policy Brief
Flemming Gertz	Senior Advisor, SEGES (Agricultural knowledge Centre)	Denmark		X	X	X
Tomasz Walczykiewicz	Head of Division of Water Management, Institute of Meteorology and Water Management	Poland	X	X	X	X
Philip Axe	Swedish Agency for marine and Water Management	Sweden	X			
Ann-Karin Thoren				X	X	X
Rune Halgren	Swedish Farmers Association	Sweden	X	X		
Rüdiger Wolter	Umweltbundesamt	Germany	X		X	X
Leonid K Korovin	General Director St Petersburg Public Organisation Ecology and Business, Chairman HELCOM Land	Russia	X			
Natalia Oblomkova	Institute for Engineering and Environmental Problems in Agricultural Production	Russia			X	X
Jacob Carstensen	BONUS COCOA Aarhus University	Denmark		X		X
Bo Gustafsson	BONUS COCOA Stockholm University	Sweden	X		X	X

The Advisory Panel provided important advice during the project, both on scientific issues and, especially, on issues related to stakeholder and policy views. At each of these project

meetings a special session was dedicated for receiving and discussing response from the Advisory Panel. Reports from these sessions were prepared and included in Periodic Reports. Finally, the Advisory Panel was invited to comment on a draft version of the SOILS2SEA Policy Brief in February 2018 – here we received valuable comments from all members of the Advisory Panel.

The SOILS2SEA coordinator and other SOILS2SEA scientists participated in a number of coordination efforts initiated by BONUS.

One of the coordinated BONUS efforts was the 3rd BONUS Symposium (see Section 1.1.3 below) which was arranged jointly between four BONUS projects. To coordinate the timing of this event with the need of all four projects, BONUS SOILS2SEA applied for and was granted a project extension of three months, so that the formal project period became January 2014 – March 2018.

Project progress and results have been reported in deliverables, including the annual progress reports. All deliverables have been submitted at this point in time.

1.1.2 Project website and dissemination to stakeholders and end users

The project website www.Soils2Sea.eu was created at the beginning of the project. The structure and intended content of the website was reported in deliverable D1.1. The site has been continuously updated with news and publications. Today all deliverable reports can be downloaded from the website.

In addition to the website the following initiatives have been pursued to disseminate results:

- A project flyer and three newsletters have been prepared for distribution at conferences and meetings and via electronic newsletters. The flyer and the three newsletters can be downloaded from the website.
- Project results have been published in international scientific journals as well as in popular science journals.
- Project results have been presented broadly at conferences, seminars, and workshops.
- Project results have been presented at workshops and meetings with stakeholders.
- Information on the project has been disseminated by several project scientists through Research Gate.
- Information on the project has been disseminated by several scientists through LinkedIn.
- Project results have been promoted through a broad range of science-policy interfaces (See Chapter 4).
- Information on the project and on the water quality issues in the Baltic Sea basin has been disseminated in media and social media. The BONUS SOILS2SEA film has for instance been viewed more than 1600 times on YouTube.
- Results of the scenarios simulated with Baltic HYPE were incorporated in the SMHI's dissemination website "HYPEweb"

A list of recorded dissemination actions is provided in Appendix I.

1.1.3 Final conference

Four BONUS projects SOILS2SEA, BONUS GO4BALTIC, BONUS BALTICAPP and BONUS MIRACLE jointly organised the 3rd BONUS Symposium in Gdansk 14-16 March 2018 as the joint final conference for the four projects. Information on the Symposium can be found in deliverable D1.8. The Symposium was a great success with many interesting results, excellent keynote presentations and moderated panel discussions – attended by more than 120 scientists, policy makers and stakeholders from 11 countries.

1.2 WP2 Land2Soils: Climate change, land use and nutrient load

The aim is to analyse how combinations of changes in land cover, land management and climate may affect the source loading of nitrogen and phosphorus from the land to the groundwater, drains and surface waters for catchments around the Baltic Sea. The following specific objectives were pursued:

1. To analyse how changes in land cover, agricultural practices and climate may affect the nutrient (nitrogen and phosphorus) losses from land areas (deliverable D2.1 and D2.3)
2. To test how robust nutrient load reduction measures are towards plausible climate change and land use scenarios (deliverable D2.3)
3. To develop coherent climate and land use/management scenarios for individual catchments and the entire Baltic basin (deliverable D2.2 and contributions to D5.4)
4. To estimate field scale N flows and N leaching losses under baseline and scenario conditions for individual catchments and the entire Baltic basin (deliverable D2.3 and contributions to D5.4)
5. To estimate risk of P losses under baseline and scenario conditions individual catchments and the entire Baltic basin (deliverable 2.4)

1.2.1 Review of scenario analyses

Deliverable D2.1 was a review of scenario analyses to reduce agricultural nitrogen (N) and phosphorus (P) loading to the aquatic environment (Hashemi et al., 2016). Over the recent two decades there has been a great increase in the use of scenario-based analyses of strategies to combat excessive nutrient loadings. The review shows that scenario studies have been performed over a broad range of climatic conditions, with a large focus on measures targeting land cover/use and land management for reducing the source load of N and P in the landscape. Some of the studies considered how to manage the flows of nutrients, or how changes in the landscape may be used to influence both flows and transformation processes. Few studies have considered spatially targeting measures in the landscape, and such studies are more recent. Spatially differentiated options include land cover/use modification and application of different land management options based on catchments characteristics, cropping conditions and climatic conditions. Most of the studies used existing catchment models, and the choice of the models may also have influenced the setup of the scenarios.

Scenarios of changes in land use and climate were created for the future for combinations of climate model projections for the period 2040-2060 as defined for emission scenarios under the RCP8.5 emission pathways. These were then combined with three different socio-oeconomic scenarios (SSPs). Four regional climate projections were used all of which are part of the CORDEX database. They consist of an assumed evolution of the greenhouse gas concentrations as described by a representative concentration pathway (RCP8.5), a global circulation model (GCM) and a nested regional climate model (RCM).

1.2.2 Climate change and land use change scenarios

The variation in future land use is represented through three selected Shared Socio-economic Pathways (SSPs), SSPs are used in the climate research community to explore uncertainty in mitigation, adaptation and impacts associated with alternative climate and socio-economic futures and can be viewed as boundary conditions that provide the framing for more complex assumptions for regions and/or sectors. They are quantitative and qualitative narratives of possible socio-economic futures up to the end of the century. These SSPs were developed for the Baltic Sea region by Zandersen et al. (submitted) to cover aspects also related to nutrient loadings to the Baltic Sea. The three SSPs used here include SSP1, SSP2 and SSP5.

SSP1 (sustainability) describes a world making relatively good progress towards sustainability. For the Baltic Region it is assumed that there is a 10% reduction in agricultural land use and most of this is converted to forest. This scenario involves a 50% reduction in meat consumption in the Baltic States, and this is implemented as a 50% reduction in manure N, and the effective N amount applied is reduced to 5 % below current level. SSP2 (middle of the road) describes a world, where trends typical of recent decades continue, with some progress towards achieving development goals. For the Baltic Region there is no change in agricultural land use. Livestock and manure production is maintained at current levels, and the effective N amount applied is maintained at current level. SSP5 (fossil-fuelled development) defines a world that stresses conventional development oriented towards economic growth as the solution to social and economic problems. For the Baltic Region it is assumed that there is a 10% increase in agricultural land use and most of this is taken from forest. This scenario involves a 50% increase in meat consumption in the Baltic Sea countries, and this is implemented as a 50 % increase in manure N. The effective N amount applied is increased to 5 % above current level.

A methodology was developed to develop spatial changes in land use and management under the different combinations of climate change scenarios and SSPs (Jabloun and Olesen, in preparation). The Land Cover-CCI (LC-CCI) global land cover map was used as baseline to generate the map projections for the three SSPs and the four different climate models. The land use map has a resolution of 300 m and represents the year 2010. The land-use (LU) classes had been reclassified and regrouped into seven land-use/cover classes (i.e. forest, grassland, cropland, wetland, urban/built up area, bare/spare vegetation, and water bodies).

A stratified random sample of 10,000 points for each LU class with points separated by >1000 m were selected. Only forest, grassland, cropland and bare/sparse vegetation LU

classes were considered. For each point, we extracted values for the LU class and all the explanatory variables available including coordinates, soil characteristics, topographical information, climate indices and an enrichment factor. The generated stratified random points were used to build a land use model. The Random Forest (RF) classification tree was used to fit the land use model. RF is an ensemble model which uses bagging (bootstrap aggregated sampling) to build many individual classification trees to generate a final classification. The algorithm uses a random subset of predictor variables to split observation data into homogenous subsets. The performance of the fitted RF model was assessed using the Kappa statistic, which expresses the agreement between two categorical datasets corrected for the expected agreement. The Kappa scores obtained for the RF model was 0.73 suggesting that the generated land use map for the baseline using the RF model was close to the observed baseline map. Therefore, the RF land use model was used to generate the probability maps of each of the LU classes under the different climate projections.

These probability maps were then used to generate the different future land use maps for the different SSP story lines that were defined for the Baltic Sea catchment. It was assumed that only forest, agricultural, and urban/built up areas are subject to changes under the different SSPs. A similar method as used to model changes in cultivation of autumn sown crops as affected by climate change across the Baltic Sea Basin.

1.2.3 Catchment scale nitrogen scenarios

The study on catchment scale scenario analyses of N measures under future climate and land use analysed the effect of a combination of land use and climate scenarios on N leaching from two Baltic Sea catchments: Norsminde in Denmark and Kocinka in Poland. The work has been reported in deliverable D2.3 and is being written up for a paper in Ambio (Olesen et al., in preparation). 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 fueled 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 the baseline period of 1991-2010, using four different climate model runs, 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^{-1} in the baseline land use and climate, which increased to 71-88 kg N ha^{-1} under projected climate change. Under baseline climate, SSP1 reduced N leaching by 9-10 kg N ha^{-1} and SSP5 increased leaching by 10-11 kg N ha^{-1}. These differences increase under projected climate

change due to the higher N 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 agricultural land was 28-34 kg N ha^{-1} in SSP2 under baseline climate, and this increases to 38-52 kg N ha^{-1} under projected climate change. The leaching in SSP1 was reduced by 2-3 kg N ha^{-1} under baseline climate and 3-5 kg N ha^{-1} under future climate. In SSP5 N leaching was increased by 3 kg N ha^{-1} under baseline climate and 4-5 kg N ha^{-1} under projected future climate.

A scenario analysis was conducted for Norsminde to explore how large an agricultural area would be needed for spatially targeted set-aside to meet an N load reduction target of 20% compared to the baseline. For SSP2 this set-aside area is about 850 ha under baseline climate increasing to 1400-2200 ha under future climate conditions. For SSP1 and SPP5 this range is 650-1400 ha and 2150-3000 ha, respectively, under future climate conditions.

1.2.4 Catchment scale phosphorus scenarios

The study on catchment scale scenario analyses for spatially differentiated P measures also included effects of changes in climate and land use. This study combined experimental and modelling activities for the Fensholt subcatchment within the Norsminde catchment in Denmark and was reported in deliverable D2.4. For the example of the Fensholt catchment, this report explored which information with practical relevance for risk assessment is generally available in Denmark and how it relates to measured P losses. Additionally, the report analyzed scenarios of land use and climate change for the risk of soil erosion as well as sediment and P delivery to streams. Specifically the objectives are i) to briefly describe spatial data that are typically used for assessing the risk of P loss at the field scale; ii) to model the effect of changed land use, cropping and rainfall on soil redistribution; and iii) to summarize P losses from the Fensholt catchment during the monitoring period May 2015 to April 2017.

Measurements over two runoff seasons showed annual total P (TP) loads at the catchment outlet of 1.1 to 2.4 kg TP ha^{-1}. This is higher than the estimated average annual P load of 0.5 kg TP ha^{-1} for agricultural land in Denmark and similarly lower than the modelled TP load using the E-HYPE model. The TP in drainage water was found to contribute to about half of the TP in the stream with 0.2-0.9 and 0.9-1.3 kg TP ha^{-1} in the two respective runoff seasons, depending on drainage station. Model-based estimates of stream bank erosion suggested that this contributed between 25-50% of the TP load. Modelling of surface erosion suggest that this was by far the smallest contribution, although this may have been underestimated, given the high contributions from drainage.

The projected climate change for 2040-2060 under RCP8.5 indicate higher rainfall intensity, which as translated into a 20% increase in erosivity. This enhanced the area at risk of high soil erosion by ca. 30-100%, depending on agricultural cropping practices. The increase in

area of moderate erosion risk was smaller, ca. 20%. The soil erosion was further substantially affected by land use change, where establishing 60 m wide riparian buffer zones reduced delivery of sediments (and P) to streams to 20% of the baseline load. In contrast, the expansion of agricultural land had very little effect on sediment load to the streams. However, the erosion was only a minor part of the total P load from this catchment, and therefore the overall effects will be small. However, it may be expected that similar effects of climate change though rainfall intensity will be seen on P transported through drains and possibly from stream bank erosion.

1.3 WP3 Soils2Streams: Transport and retention in subsurface waters

1.3.1 Hillslope field sites

The field studies on transport and retention of nutrients from soils to streams through drain and groundwater have taken place at the Danish Norsminde site and the Polish Kocinka site. The field sites and installations in these are described in deliverable D3.1 “Field site installations for groundwater studies in Norsminde and Kocinka”, describing the setting, geologies and sampling systems and methods applied, while actual results are presented in later deliverables.

1.3.2 Upscaling

WP3 also comprises a study on the upscaling of catchment scale studies to the Baltic Sea scale presented in deliverable D3.2 “.Upscaling methodologies” in order to address the impact of differentiated regulation on the Baltic Sea scale where the E-HYPE model is used. An upscaling methodology is found for the groundwater system based on catchment scale numerical modelling and for surface waters based on an analytical model and the approaches are tested. It is concluded that the presented methodologies are likely to simulate the correct trends and order of magnitudes, though it is also discussed that the lag times related to the groundwater systems with long residence times such as the Kocinka catchment should be kept in mind when interpreting the E-HYPE model results where lag times are not considered. Still the upscaling method and the resulting E-HYPE simulations on the Baltic Sea scale may provide a sound base for large scale policy analysis. The upscaling methodology for groundwater was published in Hansen et al. 2018. In addition an upscaling methodology for surface water remediation was developed and described in deliverable D3.2.

The upscaling methodology was prepared in close collaboration with WP5 who subsequently applied the results for the entire Baltic Sea drainage basin. To support the Baltic Sea drainage basin modelling a map showing the N-reduction in groundwater was prepared as a joint effort between several SOILS2SEA partners and invited external experts (Højberg et al., 2017).

1.3.3 New sensor for flux measurements

As part of WP3 it was the aim to develop a cost efficient technology for measuring nutrient fluxes from drain systems based on the Sorbisense technology. Drain water is a major source of the nutrient fluxes to surface waters, so the technology would provide a direct way of measuring the impacts of measures, such as differentiated regulation of nutrient inputs. The development and testing is described in detail in deliverable D3.3 “Prototype of new sensors for flux measurements of N and P”. Though the technology was found to work well in a lab setting, the results from field trials show that though it is possible to obtain good measurements of the average nitrate concentrations in the drain water, it appears that issues such as ice formation in winter period and evaporation in the summer period interfere, so average fluxes obtained did not match direct flow meter measurements. To protect the sensors from weather impacts, installation in a well will be needed.

1.3.4 Hillslope field and modelling studies

The detailed hill slope studies carried out at the Danish field site focused on a detailed flow model description at a scale where the individual drain pipes were included and was supplemented by a study of the processes affecting reactive nitrogen in the till aquitard system. The hill slope study from the Polish site focused on deriving rates of nitrate reduction in the aquifer system as well as sources of the nitrate from stable isotope measurements of the nitrate. The results are described in detail in deliverable D3.4” Hill slope studies in Fensholt, Norsminde, Denmark - and Kocinka, Poland” and is intended published in Hansen et al. (submitted) and Jakobsen et al. (in preparation). At the Danish site it was found that most of the nitrate reduction takes place at a redox boundary by oxidation of pyrite leading to elevated sulfate concentrations. A 2D data set shows that the redox boundary shows small scale undulation, but within a limited range indicating that the current modelling approach for larger scales, such as the numerical model used in deriving the upscaling methodology (D3.2) where an average depth to the redox front is applied are adequate given the uncertainties present at this scale. The high resolution model setup for the hill slope catchment with the detailed description of the drainage system turned out to be able to, quite accurately, capture the extreme dynamics of the drain water flow and provides a tool for assessing drainage flow and nutrient fluxes under varying degrees of drainage and climatic conditions. The results underline the importance of drainage water for total nutrient fluxes to streams. Results from the Polish hill slope study shows that retention of nitrate is limited to the upper quaternary sediments and even here only about 30% of the nitrate is reduced. Stable isotope results indicate that most of the nitrate found in the aquifer is related to agriculture. Seen together the results imply that nutrient fluxes to the stream are mainly controlled by the leaching from the agricultural activities.

1.3.5 Spatially differentiated regulation of N

Part of WP3 looked specifically on the possible gains that could be obtained from differentiated regulation under typical Danish conditions. The results of this analysis are described in deliverable D3.5 “Gains from differentiated regulation of nitrate in groundwater dominated Danish catchments” and published in Hansen et al. (2017) and in Hashemi et al. (2018a,b,c). The analyses shows that for the two Danish catchments included in the analy-

sis, the gains obtainable through relocation of crops within the catchment depend strongly on the local setting. In the studied catchment in Odense N-loads could be reduced by 17-26% depending on the restrictions put on the relocation, while in the catchment for Norsminde Fjord the range is only 5-8%. The possible gains depend strongly on the actual variation in the nitrate retention available within the catchment, but also on the variation in leaching from the particular crops on the particular soils, obviously a higher variation implies a higher potential for reduction.

The analysis of the potential for differentiated regulation in the Kocinka catchment described in deliverable D3.6 “Proposal for differentiated regulations for Kocinka catchment” shows that in this system, regulations cannot rely on localized areas of higher nutrient retention as in Danish systems. The reason is that in the Kocinka aquifer the retention is mainly a function of residence time in the quaternary deposits where nitrate reduction rates are low and dispersed when seen on field scale (D3.4). In the underlying Jurassic sediments the nitrate reduction appears negligible. This implies that an optimization in terms of lowering nutrient fluxes requires knowledge of nitrate reduction rates and residence times which depend primarily on the small-scale geological conditions. These parameters need to be derived from observations and measurements made within the catchment and modelling of the aquifer system.

1.4 WP4 Streams2Sea: Transport and retention in surface waters

1.4.1 Reservoir operation

Reservoir management alters the hydrological flow regime and can have significant impact on the transport of phosphorus. Reducing the phosphorus load to downstream areas is of great importance to aquatic habitats as well as the overall health of coastal areas. This study, reported in deliverable D4.1 and published in Zwijewski and Wörman (2017), addresses the regulation of a network of reservoirs in River Dalälven, Sweden. The transport of phosphorus is analysed using a multi-objective optimisation approach. The model integrates hydropower production and flood control objectives with the objective of minimizing total phosphorus effluent mass export. The optimization model is used to derive trade-off curves between the two objectives, thereby demonstrating the method for use in valuation between possible usages for water management. The effect of management of River Dalälven on phosphorus transport is examined as a possible remediation method for mitigating phosphorus transport from the controlled river network. Further, the efficacy of valuation of ecological constraints using multi-objective reservoir optimization is demonstrated illustrating a possible real-world application quantifying the cost in the form of loss of total hydroelectric power. It is shown that a 2% reduction of the nutrient discharge can be achieved with a limited loss of future power production (<5 %), but that additional reduction is associated with a significant loss in power production.

1.4.2 Tracer test in stream

Deliverable D4.2 describes the first major stream-tracer test using ^{3}H (as $^{3}H_2O$), ^{32}P-phosphate (in the form of phosphoric acid), $^{15}NO_3^-$ (in the form of potassium nitrate). A main reason for using tritiated water ($^{3}H_2O$) is that this gives an independent signal of the hydrological response of the stream system that can be used to interpret the transport of reactive solutes represented by the signals of ^{32}P-phosphate and $^{15}NO_3^-$. A main purpose of this study is

- To use the tracer approach for quantification of the effect of remediation actions in agricultural streams
- To describes the tracer injection methodology, safety aspects and evaluation methods.

The report also describes several independently conducted tracer tests using Rhodamine WT in the same stream. All solutes were simultaneously injected in Tullstorps Brook, Skåne, Sweden, using a pump system and concentration vs. time (so-called breakthrough) curves were determined from water samples taken at five (5) downstream located sampling stations. This report describes the tracer injection methodology, safety aspects of radioactive tracer injections, basic evaluation methods for breakthrough curves and tentative results in the form of certain model parameters. Prior to the main tracer test an extensive field campaign was conducted in Tullstorps Brook with the objective to gain general knowledge about the hydrodynamic behavior of the system, including Rhodamine WT tracer tests and independent measurements of the stream hydro-morphology. Methodologies and results from this field campaign are also included in deliverable D4.2.

1.4.3 Design of water-course remediation measures to increase nutrient mitigation

This part of workpackage 4 aimed to investigate how the introduction of in-stream features affects hyporheic exchange and the consequent mitigation of nutrient, focusing on nitrate. Based on previous studies we derived analytical models that were combined and extended. Most of the theory and results are presented in deliverable D4.3 and published in Morén et al. (2017). The effects of four different generic streambed designs were compared with regards to reaction rate in the hyporheic zone and the increased retention in the hyporheic zone. Furthermore, the effect of restoration actions in the Tullstorps Brook, Sweden, was evaluated based on conservative (i.e. non-reactive) tracer tests that were performed to understand the changes in hyporheic exchange due to the remediation action.

Based on the tracer tests in Tullstorps Brook and reach scale scenario analysis the main conclusions were the following:

- The model that was developed within this project can provide guidance for stream remediation projects aiming to improve water quality.
- Stream remediation actions that affect the fluctuation in hydraulic head at the streambed have the potential to improve reach scale water quality. Much of the effect is related to decreases in the stream water velocity, but also changes in hyporheic exchange can have a considerable effect.

- In Tullstorps Brook, the measured hydraulic parameters indicate that remediation actions were effective in terms of an increased hyporheic residence time, hyporheic zone depth and in stream velocity. The two stated remediation targets, reach scale mass loss of nitrate and total residence time in the stream was also larger in the remediated compared to the non-remediated reach. According to monitoring data the effect of remediation actions on nitrate transport is only seen in summer, probably because the stream has lower potential for biogeochemical reactions in winter than what was assumed here. It should also be noted that hydrologic conditions can vary largely over the year, something that is not captured by a single tracer test.
- Features that cause fluctuation in the surface water profile can increase the retention factor and hyporheic reaction rate more than small bed forms in low velocity streams. In most cases, steps in the surface water profile is most effective, but if reaction rates are low or the hyporheic zone is constrained to a shallow depth due to upwelling groundwater or low hydraulic conductivity, smoother head variations, for example induced by riffle and pool structures are preferable.
- There exist complex interactions between hyporheic exchange patterns and biogeochemical conditions of the hyporheic zones that should be considered in stream remediation projects. Prior to any changes of the stream design it is important to diagnose the stream, particularly to evaluate if the current hyporheic reaction rate is reaction or transport controlled.

1.4.4 In-stream measures for reducing nutrient loads to the Baltic Sea

In order to reach the goals of the WFD, the BSAP and other policies and to investigate if stream remediation actions could be a cost-effective part of the solution, we need more knowledge about the effectivity of stream remediation actions on the Baltic Sea scale. The work reported in deliverable D4.4, and planned published in Morén et al (in preparation), aims to assess the potential of in-stream remediation actions for reducing nitrate/nitrogen loads from local streams to the main stream network, under the assumption that remediation actions were successfully implemented in all local streams of Sweden. In the applied model, the stream network is divided into two types of compartments, the local and the main stream. Local streams are headwater streams, receiving all the runoff within a catchment, while the main streams are receiving loads from point sources, upstream catchments and local streams. Within the Soils2Sea project, the effect of remediation actions was first evaluated on the reach scale, based on field measurements of hydraulic parameters in remediated and non-remediated parts of Tullstorps Brook (D4.3; Morén et al., 2017). Here, we used two different scenarios to evaluate the effect of remediation actions at the national scale. First a baseline scenario was defined, aiming to quantify the current mitigation of nitrate/nitrogen in all streams of Sweden. In order to recognize the large variety of hydraulic, chemical, geomorphologic and biological conditions that exist in the streams of Sweden, a range of possible residence times and denitrification rates were included in the scenario. Thereafter, a remediation scenario was defined, where the alterations of important hydraulic parameters observed in Tullstorps Brook were implemented in all local streams of Sweden, giving an estimate of the maximum possible potential of remediation actions in Swedish streams. A simple network model was used to model the transport of nutrients through local streams in the whole country of Sweden. The model was driven by input data in terms

of nitrogen loads from point sources and diffuse sources derived by the Swedish Meteorological and Hydrological Institute (SMHI) in the S-HYPE model version 4.13.2 (SMHI, 2017).

Results from this study show that the remediation scenario may increase the mass removal in local streams with between 27±20% and 93±15 %, which means that between 300±160 kg and 460 000±340 000 kg could be removed from each catchments every year. The total mass removal in all catchments of Sweden becomes 24 000 ± 11 000 ton nitrogen per year and in relative terms this is a decrease in the mass load to the main surface water system of Sweden of 62 ± 23 %.

1.5 WP5 Catchment2Sea: Transport and retention at Baltic Sea basin scale

This WP focused on the Baltic Sea drainage basin. E-HYPE, a pan-European model developed by SMHI, played a central role in the analyses. It is based on a Hydrologic Predictions for the Environment (HYPE) model, an integrated rainfall-runoff and nutrient transport model developed by SMHI under a Creative Commons open source licence (Lindström et al., 2010). A new version of E-HYPE, E-HYPE v.3.1.4, was developed during the SOILS2SEA project timeline in order to better compare efforts among the coordinating BONUS projects. The model files were updated to a more recent reference period and the model recalibrated in an attempt to better represent nitrogen cycling processes in soils and surface waters (see deliverable D5.1).

Baltic HYPE is the part of E-HYPE v.3.1.4 that drains to the Baltic Sea. The updated and recalibrated model was used to simulate impacts of climate and socio-economic changes on freshwater and nutrient inputs to Baltic Sea (see deliverable D5.4). 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. The effects of spatially differentiated measures with respect to reduction of nitrogen in groundwater and surface water were also evaluated using the Baltic HYPE model (see deliverable D5.4). The results of the scenario simulations are available online at SMHI's website "HYPEWeb" (see deliverable D5.5).

Baltic HYPE was also used together with the observed monitoring data on nutrient concentrations to evaluate trends in nutrient concentrations and what role the possible trends in weather play in the trends (see deliverable D5.3). A case study was conducted on Pregolya Basin (see deliverable D5.2).

1.5.1 Baltic HYPE

The full update process and calibration are described in deliverable D5.1. The updates in E-HYPE v.3.1.4 included (a) point sources based on the Urban Wastewater Treatment Di-

rective (UWWTD), (b) crop data, and (c) deep soils with active aquifers. The new data represent 2010-2012, a period that is more recent than the one in the previous versions and that is comparable with other BONUS projects.

E-HYPE was then recalibrated using the stepwise, representative gauged basin approach described in Strömqvist et al. (2011) and Donnelly et al. (2016). In addition to evaluating model performance based on comparing simulated and observed concentrations at observation points, the E-HYPE model performance was also reviewed with respect to three process-based data: baseflow fraction, nitrogen leaching, and reduction of nitrogen in groundwater. The objective was to refine the description of the internal model processes that affect nitrogen cycling in soils, groundwater, and streams. While the updated and recalibrated model achieves similar performance as the previous version of E-HYPE with respect to calibration criteria, there are significant differences in the transport and transformation processes in the recalibrated areas that can affect the outcomes of the future scenario analyses.

1.5.2 Pregoyla catchment scenario studies

The Pregolya catchment, a transboundary catchment between Russia (Kaliningrad) and Poland, was simulated with the E-HYPE model. The model setup and results including scenarios for future climate and socio-economic development in the region are summarized in deliverable D5.2 and planned to be published in Chubarenko et al. (in preparation). The uniqueness of the Pregolya scenarios was that it includes government planned developments comprising a very large expansion of agricultural activities, including an increase in pig production by a factor 8.5, in the Russian part of the catchment.

1.5.3 Climate and Socio-Economic Impacts on Inputs to Baltic Sea in 2050s

Baltic HYPE was used to simulate impacts of climate and socio-economic development in the 2050s. The scenarios and results are fully described in deliverable D5.4 and planned published in Bartosova et al. (in preparation). We selected RCP 8.5 together with three SSPs: SSP1 (Sustainability), SSP2 (Middle of the road), and SSP5 (Fossil-fuelled development). SSPs were interpreted within the context of the RCP 8.5 to project land use and agriculture practices as well as changes in wastewater discharges to the 2050s. A mini-ensemble of four climate models was selected to represent the projected range of changes in precipitation and air temperature in the region.

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

1.5.4 Spatially Differentiated Measures at Baltic Sea Scale

The potential mitigation impact of spatially differentiated regulation was evaluated at two levels (D5.4): first, the potential to reduce nitrogen concentrations in local runoff in local catchments, and second, the potential to reduce nitrogen loads to the Baltic Sea. Two types of measures were evaluated with Baltic HYPE: measures targeting reduction of nitrogen in groundwater and measures targeting the reduction of nitrogen in surface water. Groundwater-oriented measures were applied to all catchments in Baltic Sea region with more than 3% agricultural land and reduction of nitrogen in groundwater higher than 5%. Surface water-oriented measures were applied to all catchments in Baltic Sea region with more than 5% agricultural land but the extent of the application was limited to streams classified as being under hydromorphologic pressure.

Groundwater-oriented measures were projected to have a higher impact than surface water-oriented measures. The highest simulated reduction at a local level was 47% in a single catchment for groundwater-oriented measures; however, in most catchments the local total nitrogen concentration decreased by 1% to 10%. For surface water-oriented measures, the highest simulated reduction was 5% in a single catchment and in most catchments the local total nitrogen concentration decreased by 1% to 2.5%

The reduction in local concentrations does not necessarily translate to the same reduction of nitrogen loads to the Baltic Sea. The nitrogen goes through additional transport and retention processes on its way from local runoff to Baltic. The highest percentages of reductions in nitrogen loads to the Baltic Sea were simulated for the groundwater-oriented measures applied in agricultural catchments in Denmark, Germany, and Poland. Nitrogen load was reduced by more than 25% for 21 Baltic Sea drainage basins but most of these were relatively small drainage basins in Denmark with smaller overall contribution to the Baltic Sea. Overall, this resulted in 5% reduction of total nitrogen load to the Baltic Sea (25 thousand tons of nitrogen per year on average). The impact was much higher locally in the Western Baltic Basin (17% reduction). Groundwater measures were modelled to be effective for reduction of peak total nitrogen loads during winter high flows.

Surface water-oriented measures resulted in 0.6% reduction in total nitrogen load to Baltic Sea (3.5 thousand tons of nitrogen per year on average). Comparison with local case studies show that Baltic HYPE produces similar impacts for groundwater-oriented measures (Section 1.3.5) but much lower impacts for surface water-oriented measures (Section 1.4.4). The results for surface water oriented measures at a Baltic Drainage Basin scale should thus be considered highly uncertain.

1.5.5 HYPEWeb platform

The results from the climate and socio-economic scenarios were incorporated into HYPEWeb (http://hypeweb.smhi.se/soils2sea/), a platform established and maintained by SMHI to disseminate modelling results for various areas around the world. The results are presented in an interactive way where the user may choose an aggregation level, a variable, and a scenario. The impact of the selected scenario is then shown as a map of relative change in the selected variable at the chosen aggregation level.

1.6 WP6 Governance, monitoring and stakeholder processes

This workpackage assessed the requirements to governance regime under spatially differentiated regulation. Two avenues were explored in this regard: the groundwater threshold value instrument defined in the Groundwater Directive and stakeholder processes analysing stakeholder views on governance and monitoring.

1.6.1 Groundwater thresholds

The Water Framework Directive (WFD) and the Groundwater Directive (GWD) stipulate that EU member states have to ensure good status of all European water bodies including groundwater, streams, lakes, transitional and coastal waters. The GWD specifically requires EU member states to derive and establish groundwater threshold values to ensure compliance with good status objectives of the WFD. The good status objectives include good ecological status of groundwater dependent terrestrial and associated aquatic ecosystems (surface water bodies).

Despite this requirement most EU member states still have not established groundwater threshold values for e.g. total reactive nitrogen or nitrate for protection of groundwater dependent or associated ecosystems neither in the first nor the second river basin management plans.

In deliverable D6.1 we have presented some general principles for development of groundwater (incl. drains) and stream threshold values for nitrate (or total reactive nitrogen) and illustrated these with concrete examples from the Norsminde and Kocinka catchments in Denmark and Poland. The report analyses and discusses challenges related to implementation of the GWD groundwater threshold policy instrument when used in relation to spatially uniform and spatially differentiated regulation.

1.6.2 Stakeholder proceses

One of the goals of the BONUS SOILS2SEA project was to find new and innovative approaches to further reduce nutrient loads to the Baltic Sea. Stakeholder process in the project considered the potential of spatially differentiated approaches for achieving further reductions in nutrient loads 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.

Stakeholder consultations took place twice in the three case study areas. The first round of workshops were undertaken in the beginning of the project in 2014, mainly with the focus to introduce the project to relevant stakeholders in that region and discuss water quality issues. Stakeholders invited to the workshops included local farmers, land owners, land

managers and their organisations, NGOs, community members and (local) political decision-makers. These workshops provided a first point of exchange between the BONUS SOILS2SEA project and local stakeholders. Measures for improved water quality were discussed differently in each case study region depending on local needs and previous work.

The ethnographic study was carried out in the three case study areas with special focus on the Polish case study area. The studies – which consisted of interviews and observations - provided insights into the culture of institutional and non-institutional stakeholders in their different societal settings in each of the case study areas. Information was mainly collected through desk-research and narrative qualitative interviews with key stakeholders. In general it can be stated that the socio-cultural-political and economic contexts of the people living and working in the three case studies 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. Results of the study were captured in a film that was shown at different occasions (for example at the up-scaling workshops, at external events in spring 2017 in Mecklenburg-Vorpommern, and at a school in Częstochowa) and can be found at the project website and on YouTube.

On the basis of the ethnographic study and the first round of workshops, different policy options emerged providing possibilities to reduce the nitrogen losses to the aquatic environment. For most of the options, the concept of spatially differentiation can be applied. For the second round of workshops, three governance approaches were discussed in detail with a focus on a co-governance approach. The results of these studies have been published in deliverable D6.2.

Simultaneously to the work on governance approaches, a study (D6.3) was undertaken on how a monitoring system could be implemented in a co-governance approach from a governance and law perspective. The results are also synthesised in a scientific paper (Albrecht and Gerstetter, submitted).

The results from the local case study workshops were the basis for the up-scaling workshops held in 2017. The deliverable 6.4 covers the outcome of the up-scaling workshops and also takes the results from the case study workshops into consideration. The main focus of the report was the question of how to implement a spatially differentiated approach in practice. This work is planned published in Stelljes et al. (in preparation).

The final Policy Brief (D6.5) summarized the project results and is available in five different languages.

1.7 Key multidisciplinary achievements

BONUS SOILS2SEA research has been organised in WPs that more or less follow traditional disciplinary lines. But the research has at the same time focussed on multidisciplinary aspects. Thus, all WPs were required to deliver outputs to and were dependent on receiving inputs from other WPs and the most important scientific outputs were results of multi-

disciplinary efforts produced by several WPs. Therefore, we organised a scientific workshop for WP leaders in month 4 and compiled the improved mutual understandings into a Requirements Report (D1.2) in month 6.

Although the achievements of the multidisciplinary research have been disseminated through WP-led deliverables, and hence reported in the previous WP structured sections, they deserve special attention by being emphasised here. The key multidisciplinary achievements are:

- The *definition of scenarios* combining changes in climate, land use and agricultural practices. This was a collaborative effort requiring inputs from all disciplines, which is reflected in deliverable D2.2 being co-authored by seven project partners.
- The *upscaling methodologies* developed by the project required inputs from partners being responsible for modelling of study catchments and from the partner modelling the Baltic Sea drainage basin. It involved expertise in groundwater, surface water and large scale hydrological modelling. This was a collaborative effort requiring input from four project partners using knowledge being produced in three WPs. This is reflected in deliverable D3.2 being co-authored by four project partners as well as multi-institutional authorships in Hansen et al. (2018) and Refsgaard et al. (in preparation).
- The development of a scientific basis for differentiated regulations in case study sites embraced a *holistic approach with the integration of physical and biogeochemical processes occurring in the surface and subsurface* compartments of catchments.
- *Scenario analyses for N in catchments* requiring inputs from four partners and knowledge from three WPs. This is reflected in deliverable 2.3 being co-authored by four partners as well as the multi-institutional authorships in Olesen et al. (in preparation).
- *Scenario analyses for the Baltic Sea drainage basin* requiring inputs from three partners and knowledge from three WPs. This is reflected in deliverable D5.4 being co-authored by three partners as well as the multi-institutional authorships in Bartosova et al. (in preparation).
- The *stakeholder processes* were driven by the WP6-lead partner but required comprehensive inputs with expertise in agriculture, groundwater and surface water at both the local and the regional workshops.
- The *Policy Brief* synthesizing the key findings and messages of relevance for stakeholders and policy makers were prepared with input from all WPs. This is reflected by deliverable D6.5 being co-authored by five project partners.

2. Summary of produced scientific and technological foreground

With a single exemption all the scientific and technological foreground produced by BONUS SOILS2SEA is disseminated using the open science business model, also promoted by BONUS. This implies that all results are published in scientific journals, some of them as open access publications, and that the data and models are publicly available. An example of this is the improved HYPE model code and the data for the HYPE model setup.

The exemption to this open science is the sensor technologies developed by Sorbisense/Eurofins (deliverable D3.3) which have been patented and are being exploited commercially by a private company.

In our view many of our other scientific achievements are also foreground that are not less valuable to societies than commercial products. In principle, we might have exploited them commercially - the reason we do not use this is because the missions of our respective research institutions are rather to provide such foreground free-to-use to our societies, where they are being used by local stakeholders, national and international policy makers (such as HELCOM and EC) as well as the scientific community.

3. Further research needed

3.1 Upscaling

Evaluating the impacts of field level spatially differentiated measures at the 1.8 million km^2 Baltic Sea drainage basin poses a particular challenge. The E-HYPE model used at this scale (deliverable D5.1) is not able to simulate small-scale spatially differentiated measures, because i) the model operates at a much coarser spatial resolution (median catchment size of 215 km^2) than the measures; ii) it does not include small-scale data but rather aggregated data, which vary in quality and resolution between countries; and iii) it has simplified process descriptions adequate for the input data complexity but inadequate to simulate specific measures, e.g. for N-reduction in rivers, wetlands and groundwater. Such measures can be simulated by comprehensive and data demanding small-scale models (Hansen et al., 2017) that, however, for computational and data access reasons are not operational at the Baltic Sea drainage basin scale. Therefore, a method must be applied for upscaling the results from suitable small-scale models to models operating at the Baltic Sea scale.

In both the groundwater (D3.2; Hansen et al., 2018) and surface water (D3.2 Appendix C) cases the impact of spatially differentiated measures exploiting small scale heterogeneities in natural or modified systems is calculated explicitly by the small scale models and subsequently used to modify a parameter value in E-HYPE, so that E-HYPE can reproduce the same effect. In the groundwater case the small scale model is a numerical model (MIKE SHE/NLES), while for the surface water case it is an analytical model. However, the upscaling principle is the same: use a small scale model to derive a relationship by which E-HYPE parameters can be modified to simulate the desired impact.

Although use of different models in the same study are not uncommon, few other studies (e.g. Bronstert et al., 2007) have utilised this in an upscaling approach, where the local scale model is applied to train or develop a relationship for the large scale model. With the increased use of large scale models and the need to describe impacts of local scale interventions at the large scale, we believe that this approach holds a large potential for further development and wider application.

A critical assumption in this regard is that the relationships developed with the small scale models will also be valid in other parts of the Baltic Sea Basin. The issue here is not whether the large scale model simulation can match the small scale model in all aspects, but rather to which extent the large scale model can reproduce the same sensitivities to changes in system properties (spatially differentiated measures).

Simulating impacts of measures targeting reduction of nitrogen at a large basin scale is therefore highly uncertain, especially for surface water-oriented measures. There is a lack of studies that bridge small, field scale experiments to large scale simulations. Long-term catchment-scale studies would be needed to properly upscale the local impacts.

Similarly, it would be helpful to have local case studies from different parts of Baltic Sea Drainage Basin to adequately assess the local variability. Information about groundwater-

oriented measures and surface water-oriented was available only from Denmark and Sweden, respectively.

Finally, a critical issue is whether the upscaling relationship, derived under present climate and land use will also be valid under future conditions with changes in both land use and climate.

Consequently, many aspects related to upscaling require further research to quantify and reduce the uncertainties generated by the upscaling procedure.

3.2 Impacts of changes in climate, land use change and agricultural practices on nutrient loads to the Baltic Sea

3.2.1 Climate change projections

Four climate models were selected for the evaluation of climate change by 2050s using only one future emission pathway (RCP8.5). Climate change under more emission pathways and using more complete ensembles of climate models should be tested to better represent the future uncertainties, especially for nitrogen where both air temperature and precipitation significantly affect the nitrogen cycling and losses.

3.2.2 Data available for modelling the Baltic Sea drainage basin

Water quality data used for the calibration of models such as E-HYPE at a large-scale are typically collected for the purpose of evaluating long-term trends in water quality and for reporting the status for the WFD. However, the frequencies are not sufficient to properly constrain the model parameters during calibration. Monitoring programs designed for load calculation would be better suited to provide such data. Additional processes that affect nutrient cycling should also be monitored and reported consistently across countries draining to Baltic Sea.

3.2.3 Impact models – ensemble approach

It is widely recognised in literature that impact models used to predict effects of changes in climate and land use are uncertain and that use of an ensemble of models is highly recommended (Refsgaard et al., 2014; Karlsson et al., 2016).

BONUS SOILS2SEA applied the E-HYPE model for simulating effect of land use and climate on N loads to the Baltic Sea basin (D6.4; Bartosova et al., in preparation). The results of the E-HYPE model showed only small effects of climate change on N leaching and loads in some areas of the Baltic Sea drainage basin. This contrasts with the much greater increases in N leaching simulated with the Daisy and NLES models at catchment scale (Norsminde and Kocinka) (D2.3; Olesen et al, in preparation). These large differences may have several causes. The structure of the different models is likely one of them, although

bias correction and downscaling of the GCMs/RCMs to different reference stations due to different spatial resolution played a significant role. Such large changes warrant further studies to better quantify the projected changes and their drivers.

The E-HYPE results on the impacts of in-stream remediation measures showed a decrease in N-loads for Sweden of 0.6% (D5.4; Bartosova et al., in preparation), while the corresponding results achieved by using the methodologies derived from the Tullstorp study for the entire Sweden resulted in a much higher N-removal of more than 40% (D4.4; Morén et al.,in preparation). This large difference is likely caused by a combination of differences in model structure and assumptions on parameter values.

These two examples illustrate that the present impact model predictions must be considered highly uncertain. At the same time, the results support the need for using an ensemble modelling approach to achieve robust predictions. Hence, there is a need for further research to supplement HYPE with other models capable of simulating the Baltic Sea drainage basin and carry out ensemble model simulations to assess the uncertainties of the impact predictions.

3.3 More local data

A significant part of the potential gain from spatially differentiated regulation lies in exploiting the variability in N-reduction within catchments, i.e. at scales where we usually have limited data. We know that prediction uncertainties based on the existing data often can be so large at field scale that this in practice makes spatially differentiated regulation infeasible. We also know that the uncertainties in estimating N-reduction in groundwater typically can be significantly decreased by using more data (Hansen et al., 2014). However, data collection with traditional sampling schemes is expensive.

One way to obtain more local data and at the same time get ownership among farmers is to empower farmers to collect data from their own fields and let these data become part of the overall decision basis. Such citizen data collection approaches require new affordable data collection techniques and at the same time pose new challenges with respect to assessing data uncertainty and using large amounts of data with larger uncertainty than traditional high-quality governmental monitoring data.

Thus, there is a need for further research on citizen data collection and integrations of such data into our databases and modelling tools. The cheap passive sampling method tested in BONUS SOILS2SEA (D3.3) is only a small appetizer for the boom we see in citizen data collection techniques in these years.

3.4 Uncertainty and spatial scales – a governance challenge

With the existing data, the N-reduction maps required for implementing spatially differentiated regulation strategies are highly uncertain at field level (1-10 ha), but much more reliable for average reductions over larger areas such as a farm or a subcatchment (100-1,000 ha) (Hansen et al., 2014). However, to exploit the full potential of spatially differentiated

regulations, maps with a fine spatial resolution (100m – 500m) are required (D3.5; Hansen et al., 2017).

N-reduction maps with fine spatial resolution are necessary to exploit the potential benefits of spatially differentiated regulation, but the uncertainties of maps with such fine resolution are so large that they appear to prevent authorities from using them within existing governance regimes. This paradox poses a major challenge. Seen from a societal point of view spatially differentiated regulation strategies are cost-effective, but the uncertainty is a barrier for practical implementation. The problem is closely related to handling of uncertainty. With an existing governance regime, where central authorities make all decisions and impose very specific regulations of what farmers are allowed to and must do in their fields, the government implicitly takes the responsibility for the uncertainty. Farmers, on the other hand, take many decisions under uncertainty, e.g. related to daily and seasonal weather and market conditions, but this is at their own risk.

Studies in BONUS SOILS2SEA showed that by using an ensemble of maps for N-reduction in groundwater representing the uncertainty of the groundwater N reduction, novel approaches could be developed for spatially locating mitigation measures that enhanced the efficiency of the measure (Hansen et al., 2017; Hashemi et al., 2018b). This is a potentially very promising approach that needs to be tested further, also on terms of acceptability by farmers and regulatory authorities.

Thus, there is a need for research on how the inevitable uncertainties should be handled so that uncertainties do not prevent the use of spatially differentiated regulation strategies.

3.5 Stakeholder involvement

3.5.1 Scenario definitions

The review of scenario studies by Hashemi et al. (2016) shows that the use of stakeholders for designing scenarios and for communication of results does not seem to be a widespread practice. It would be recommendable for future scenario studies to have a more in-depth involvement of stakeholders for the elaboration and interpretation of scenarios, in particular to enhance their relevance for farm and catchment management and to foster better policies and incentives.

3.5.2 Co-governance for spatially differentiated regulation strategies

The socio-political and ethnographic studies carried out by the project team highlight that for spatially differentiated approaches to be successful, implementation must be embedded within existing governance systems and socio-cultural contexts. Workshops were conducted with farmers and other stakeholders at local case study level and at a regional level with stakeholders from across the Baltic Sea region. The findings from these workshops show that a differentiated approach can, in theory, be applied in different governance settings.

However, the most promising application of spatial differentiation can be expected within a co-governance approach.

Under co-governance, farmers (and other stakeholders) in a defined area (catchment or sub-catchment level) can determine differentiated mitigation measures using local knowledge of the area and N-reduction maps as supporting (rather than regulatory) tools. In comparison with the traditional top-down approach, the co-governance approach shifts a large amount of the responsibility to local farmers or to catchment councils. While the responsibility would not include the definition of the reduction targets, it does include the responsibility for fulfilling reduction commitments. This includes designing and implementing mitigation measures (placing of wetlands, change of land-use, etc.), collaboration among the farmers within the catchment, as well as the monitoring of measures and loadings. Trust, along with a repetition of the situation (same people and activities) and the reputation of others' past actions are crucial to the success of such collective action. The reason a co-governance approach has the most potential for differentiated regulation is because it allows for a transparent and flexible approach that can be adapted according to the impacts of climate and land-use change, technological advances as well as socio-economic drivers and emerging political priorities.

There is a need for further research to more precisely assess how co-governance frameworks should be defined to support spatially differentiated regulation in practise.

3.6 New cropping systems and technologies

The scenario analyses of changes in nitrogen fluxes in the Norsminde and Kocinka catchments under projected climate and land use change show that land use change and management scenarios impact N loads at levels similar to climate change. Thus, the sustainability scenario under the projected climate change resulted in N leaching and N loads similar to those obtained for the baseline conditions under the current climate. Since there is currently a considerable requirement to reduce N loadings to the Baltic Sea, not even the conceived sustainability scenario may be sufficient to meet targets under a future climate.

Therefore, new cropping systems, management methods and technologies need to be developed and implemented to meet targets.

3.7 Improved understanding of flow, transport and transformation processes for nutrients

3.7.1 Nitrate loading

In order to fully exploit the potential of implementing differentiated regulation as a measure for reducing nutrient fluxes from soils to surface waters it is obvious that we need to know the retention and the transport both through the space of the aquifer system and through the drainage system carrying a large part of the flux. The reduction of nitrate in Danish groundwater systems is for instance very dependent on what fraction of the circulating

groundwater goes below the redox front. Assessment of this has to be performed by use of models, because it cannot be measured. As both the depths to the redox front and the flow paths are uncertain, simulations of nitrate reduction in groundwater will inevitably become highly uncertain at field scale.

For the Danish systems this becomes even more complicated by tile drains, which cover around half of the agricultural areas. The hill slope studies (D3.4) suggest that introducing tile drains to the specific field might have resulted in a substantial increase in N-load, because the N-reduction in groundwater is decreased by about 20%, by lowering the flux that goes below the redox interface. As this has not been studied elsewhere, we do not know the general validity of this quantification.

For the Polish catchment Kocinka the flow system is complicated by having very long residence times – up to several decades. While some knowledge exists on residence times from a few other case areas, such knowledge is generally not available throughout the Baltic Sea drainage basin, which hampers efficient water management.

The study of the N-reduction in groundwater at the Baltic Sea drainage basin scale (Højberg et al., 2017) revealed considerable lack of knowledge in most countries around the Baltic Sea on how large a fraction of the N-leaching from fields are removed by N-reduction in groundwater.

Altogether, although BONUS SOILS2SEA has enhanced state-of the-art on process understanding in some aspects, there is substantial need to obtain improved knowledge on processes governing flow, transport and transformation processes for nitrogen, both locally and at the Baltic Sea drainage basin scale.

3.7.2 Phosphorus loading

The study of the catchment-scale phosphorus loading points to a range of uncertainties in quantifying P losses as affected by climate change and land use change. First, it was not possible to obtained detailed maps of the soil P status in the catchment, and the large contribution of TP from drainage suggests that at least some parts of the agricultural fields have high soil P status contributing to this loading. This suggests a need for improved spatial mapping of risk areas for P losses, also when evaluating how this may be affected by climate change and to better target spatially differentiated measures for reducing P losses. Such measures need not only to target critical source areas, but also loss pathways, e.g. surface erosion or subsurface drainage systems.

4. Science-policy interface (Statistics 1-4)

4.1 Statistics #1: Regulations, policies and management practices

- A SOILS2SEA scientist has participated in several meetings as member of the CIS Working Group on Groundwater supporting the implementation of the Groundwater Directive and the Water Framework Directive. The Soils2Sea activity related to thresholds of nutrient in groundwater bodies (deliverable D6.1) is being actively promoted through this working group *(Klaus Hinsby, GEUS, 2014-2015-2016*).
- A SOILS2SEA scientist gave an invited lecture "Problems of nutrient pollution of the Baltic Sea: from local to international level" at the Inception Workshop in Kaliningrad in the frame of the ICLD Program on cooperation between municipal and regional authorities of self-governmental level of Sweden and Russia, 08 November, 2016, Kaliningrad (*Boris Chubarenko, Dmitriy Domnin*, *ABIORAS, 2016*)
- A SOILS2SEA scientist gave an oral presentation at the HELCOM-BALTICAPP regional workshop on the use of ecological-economic research to support marine policy implementation in the Baltic Sea region, Stockholm, 29-30 March 2017 *(Alena Bartosova, SMHI, 2017)*
- Three SOILS2SEA scientists participated in a workshop organised by HELCOM, Stockholm, 6 November 2017, where the SOILS2SEA coordinator presented preliminary results and key messages for policy makers *(Jens Christian Refsgaard, GEUS; Anders Wörman, KTH; Nico Stelljes, Ecologic Institute; 2017)*.

4.2 Statistics #2: Public policies and governance

- Presentation and debate of Sorbisense environmental monitoring concept to the Danish minister of Environmental, Mrs. Kirsten Brosbøl (*Sorbisense, 2014*)
- Presentation and debate meeting with Danish farmer organization "Bæredygtigt landbrug", with over 400 participants (*Sorbisense, 2014*)
- Debate and panel meeting organized by Branche organization "Dansk Miljøteknologi", with delegates of the Danish Ministry of Environment (*Sorbisense, 2014*)
- A paper has been produced that contains a methodology for evaluating the quantitative effect of local remediation actions in streams on hyporheic exchange, such as from riffle structures, bed substrate and meanders *(KTH, 2015)*
- A SOILS2SEA scientist gave presentation on "Perspectives with spatially targeted measures and regulation" at a workshop in Thyregod Denmark 12th June 2017 with participation of stakeholders, scientists as well as government authorities from three levels (ministry, region and municipality) *(Jens Christian Refsgaard, GEUS, 2017)*.
- A SOILS2SEA scientist presented a proposal on organisation of Working Group on Adaptation to Climate Changes at the meeting of Public Council on Nature Use and Ecology of the Ministry of Environment of the Government of the Kaliningrad Oblast on October 30, 2017 *(Boris Chubarenko, ABIORAS, 2017)*

4.3 Statistics #3: Stakeholder committee memberships

- Boris Chubarenko is a member of the Public Council at ROSPRIRODNADZOR (environmental control) authority – six times (*ABIORAS, 2014*)
- Member of European Working Group on Groundwater under the Common Implementation Strategy (CIS) for the Water Framework Directive *(Klaus Hinsby, GEUS, 2014-2015-2016*)
- Member of stakeholder committee in the project "Future land use in Denmark" executed by the Danish Board of Technology and Aalborg University - http://www.tekno.dk/article/danmarks-areal-i-fremtiden/ *(Klaus Hinsby, GEUS, 2014-2015-2016*)
- Member of HELCOM-VASAB MSP working group *(Boris Chubarenko, ABIORAS, 2015-2016)*
- Member of Public Council at ROSPRIRODNADZOR (environmental control in Kaliningrad) *(Boris Chubarenko, ABIORAS, 2015-2016)*
- Member of Scientific Technological Board, Joint Programming Initiative Water, Water JPI *(Jens Christian Refsgaard, GEUS, 2015-2016-2017)*
- Member of Regional Public Council on Coastal Protection, Ministry of Construction, the Government of the Kaliningrad Oblast (*Boris Chubarenko, ABIORAS, 2016-2017*)
- Member of the Public Ecological Council at the Ministry of Environment of the Government of the Kaliningrad Oblast (*Boris Chubarenko, ABIORAS*)
- Expert of the Water Users Partnership of Gurjevsk Municipality, Kaliningrad Oblast (*Dmitri Domnin, ABIORAS*)
- Member of the Scientific Advisory Board of Joint Programming Initiative Agriculture Food Security and Climate Change, FACC JPI *(Jørgen E Olesen, AU, 2017)*

4.4 Statistics #4: Stakeholder events organised

- Soils2Sea Advisory Panel meeting in Stockholm 8-9 September 2014. Six participants representing the following sectors (*KTH, GEUS*)
    - Agricultural stakeholder: 1
    - National water management authority: 3
    - Helcom land: 1
    - BONUS research project (COCOA): 1

- Stakeholder workshop in Tullstorp, 22 November 2014 with 13 participants representing the following sectors (*Ecologic Institute, SMHI, KTH*)
    - Landowners: 4
    - NGOs (Naturskyddsföreningen Trelleborg): 2
    - Authorities (Länsstyreslen Skåne, HaV): 2
    - Tullstorpsånprojektet: 1
    - Research Institutions (Ecologic Institute, SMHI, KTH): 4

- Stakeholder workshop in Norsminde, 11 December 2014 with 21 participants representing the following sectors (*Ecologic Institute, GEUS, AU*)
    - Farmers: 10
    - Agricultural advisors: 2

  - NGOs (Danish Nature Conservations Association and Danish Ornitological Association): 2
  - Authorities (Municipality and Ministry): 2
  - Politicians, member of Odder Municipality council: 2 (of which 1 local farmer)
  - Knowledge Centre for Agriculture: 2
  - Research Institutions (GEUS, Aarhus University): 2
  - Research Institutions (GEUS, Aarhus University): 2

- Stakeholder workshop in Kocinka, 11 December 2014 with 12 participants representing the following sectors (*Ecologic Institute, AGH*)
  - Farmers: 3
  - Authorities (Kłobuck County, Community of Mykanow): 3
  - Fisheries Association: 1
  - Water Works in Częstochowa: 1
  - Research Institutions (Ecologic Institute, AGH): 4

- Soils2Sea Advisory Panel meeting in Krakow, 30 September – 2 October 2015. Five participants representing the following sectors:
  - Agricultural stakeholder: 2
  - National water management authority: 2
  - BONUS research project (COCOA): 1

- 2nd Stakeholder workshop in Norsminde catchment organised jointly by GEUS and Ecologic in collaboration with SEGES and Norsminde Catchment Council, 24 November 2016.
  - Farmers: 26
  - Machine pool (Odder Maskinstation) working for farmers: 3 (local farmers)
  - Agricultural advisor: 1
  - NGO (Danmarks Jægerforbund – Danish Hunters' Association): 1
  - Authorities (Odder Municipality): 1
  - Politicians, member of Odder Municipality council: 1 (local farmer)
  - SEGES (Knowledge Centre for Agriculture): 1
  - Research Institutions (GEUS, Ecologic Institute, Aarhus University): 5

- 2nd Stakeholder workshop in Tullstorps Brook catchment organized jointly by KTH, SMHI and Ecologic, 15./16. November 2016.
  - Swedish Farmer:3
  - Swedish Agency for Marin and Water Management: 2
  - Tulstorpsåprojektet: 4
  - Polish Farmer: 4
  - County Administrative Board in Skåne: 1
  - Czestochowa County, Poland: 1
  - Polish Anglers Association: 1
  - Mykanów Community, Poland: 1
  - Research Institutions (SMHI, Ecologic Institute, KTH; AGH): 10

- 2nd Stakeholder workshop in Kocinka catchment organised jointly by AGH and Ecologic, 13./14. October 2016.
  - Polish Farmer: 6
  - County Administrative Board in Skåne: 1
  - Czestochowa County, Poland: 2
  - Polish Anglers Association: 1

  - Mykanów Community, Poland: 2
  - Water Treatment Plant. 1
  - Research Institutions (Ecologic Institute; AGH): 5

- Film-screening and discussion of the Soils2Sea documentary in Berlin, 15.12.2016
  - Soils2Sea partners (Ecologic Institute, AGH): 8
  - External research institutes (TU Berlin, Adelphi, Hafen City University Hamburg, IASS): 5
  - NGOs (WWF, GRÜNE LIGA e.V., MitOst): 4
  - Political organisation: 1
  - Students: 3
  - Interested public: 2
  - Other: 3
- First Governance Up-Scaling Workshop, Berlin, Germany May 2017 (26 persons from authorities, NGO, HELCOM, and project partner from riparian Baltic Sea countries participated)

- Second Governance Up-Scaling Workshop, Gothenburg, Sweden, October 2017 (eight persons from authorities, agricultural services, and project partner participated)

- Third Governance Up-Scaling Workshop, Olstyn, Poland, November 2017 (17 persons from authorities, municipality, farmers, and project partner participated)

- BONUS SOILS2SEA Advisory Panel meeting as part of the project meeting, Berlin 17-19 May (6 persons from 6 different BONUS countries participated)

- 3rd BONUS Symposium “Sustainable Ecosystem Governance under Changing Climate and Land Use in the Baltic Sea Region” Gdansk 14-16 March 2018, organised jointly with BONUS GO4BALTIC, BONUS BALTICAPP and BONUS MIRACLE. Among the more than 120 attending participants, were 19 BONUS SOILS2SEA scientists plus eight stakeholders and 2 keynote speakers invited and sponsored by BONUS SOILS2SEA.

4.5 Other important science-policy events

- 5th Annual Forum of the EU Strategy for the Baltic Sea Region (EUSBSR) jointly with the 16th Baltic Development Forum Summit, 3-4 June 2014, Turku, Finland. Grit Martinez participated in a panel discussion on “Successful cooperation: research, development and innovation.” (*Ecologic Institute, 2014*)
- *BONUS Kick-off conference, 26-27 August 2014, Riga, Latvia.* Jens Christian Refsgaard presented the Soils2Sea project and he and Grit Martinez participated in the discussions. (*GEUS, Ecologic Institute, 2014*)
- *POLEKO, 14-17 September, Poznan, Poland.* POLEKO is the most important exhibition of advanced environmental protection in Eastern Europe, taking place every year in Poznan, Poland. Dr. Grit Martinez and Dr. Nico Stelljes from the Ecologic Institute presented the project at an information booth hosted by the Federal Ministry of Education and Research (BMBF). Meetings with representatives from Polish research, science and industry were arranged and different projects were presented. (*Ecologic Institute, 2014*)

- *BONUS Information event*, 2 December 2015, Brussels. Jens Christian Refsgaard presented the Soils2Sea project at the stakeholder event. (*GEUS, 2015*)
- BONUS Soils2Sea was presented by Klaus Hinsby at the *28th Working Group Groundwater plenary meeting 14-15 April 2015 under the Common Implementation Strategy of the Water Framework Directive*, European Commission. *(GEUS, 2015)*
- *Global Soil Week* (April 2015). Dr. Grit Martinez hosted a world-café table at the workshop 'Soils and Seas in the Nexus - Linking Sustainable Land Management and the Coastal and Marine Environments' that was held as part of the Global Soils Week in Berlin (http://globalsoilweek.org/global-soil-week/gsw-2015) *(ECOLOGIC, 2015)*
- The SOILS2SEA coordinator participated in the INTERREG Baltic Sea Region workshop on "Clear Waters – Added value of cooperating in project platforms", Berlin 28th March 2017. *(GEUS, 2017).*
- The SOILS2SEA coordinator participated in the BONUS 10 year Jubilee, the triple plenary meeting and the BONUS coordinators meeting, Helsinki 3-4 May 2017. *(GEUS, 2017).*
- BONUS Soils2Sea results were presented 89 times at international conferences and workshops by project partners. See Appendix I for details.
- BONUS Soils2Sea scientists were interviewed to newspapers and TV on 39 occasions during 2016. See Appendix I for details.

4.6 List of peer-reviewed publications arising from the project research and defended PhD dissertations

International Journal Papers with authors from at least two different participating states (Statistics #8)

- Graversgaard M, Hedelin B, Gertz F, Højberg AL, Langford J, Martinez G, Mostert E, Ptak E, Peterson H, Smith L, Stelljes N, van den Brink C, Refsgaard JC (2018) Opportunities and barriers for water co-governance – a critical analysis of seven cases of diffuse water pollution from agriculture in Europe, Australia and North America. Sustainability. http://dx.doi.org/10.3390/su10051634
- Højberg AL, Hansen AL, Wachniew P, Zurek A, Virtanen S, Arustiene J, Strömqvist J, Rankinen K, Refsgaard JC (2017) Review and assessment of nitrate reduction in groundwater in the Baltic Sea Basin. Journal of Hydrology: Regional Studies, 12, 50-68. http://dx.doi.org/10.1016/j.ejrh.2017.04.001
- Jacobsen BH, Hansen AL (2016) Economic gains from targeted measures related to non-point pollution in agriculture based on detailed nitrate reduction maps. Science of the Total Environment 556, 264-275.
- Reusch TBH, Dierking J, Andersson H, Bonsdorff E, Carstensen J, Casini M, Czajkowski M, Hasler B, Hinsby K, Hyytiäinen K, Johannesson K, Jomaa S, Jormalainen V, Kuosa H, Kurland S, Laikre L, MacKenzie BR, Margonski P, Melzner F, Oesterwind D, Ojaveer H, Refsgaard JC, Sandström A, Schwarz G, Tonderski K, Winder M, Zandersen M (2018) The Baltic Sea as a time machine for the future coastal ocean. Science Advances, 4, eaar8195.

International Journal Papers Published[1] **(**alphabetical order – including the above three papers**)**

- Andersson JCM, Pechlivanidis IG, Gustafsson D, Donnelly C, Arheimer B (2015) Key factors for improving large-scale hydrological model performance. European Water, 49, 77-88.[OBS]

[1] All publications listed here have been supported by BONUS Soils2Sea. Some of the papers have also been supported by other funding. The papers marked with [OBS] at the end have failed to formally acknowledge the BONUS funding in the paper itself.

- Boano F, Harvey JW, Marion A, Packman AI, Revelli R, Ridolfi L, Wörman A (2014) Hyporheic flow and transport processes: Mechanisms, models, and biogeochemical implications", Reviews of Geophysics, 52(4), 603–679. http://dx.doi.org/10.1002/2012RG000417. OBS
- Donnelly C, Andersson JCM, Arheimer B (2015) Using flow signatures and catchment similarities to evaluate the E-HYPE multi-basin model across Europe. Hydrological Sciences Journal. http://dx.doi.org/10.1080/02626667.2015.1027710. OBS
- Graversgaard M, Hedelin B, Gertz F, Højberg AL, Langford J, Martinez G, Mostert E, Ptak E, Peterson H, Smith L, Stelljes N, van den Brink C, Refsgaard JC (2018) Opportunities and barriers for water co-governance – a critical analysis of seven cases of diffuse water pollution from agriculture in Europe, Australia and North America. Sustainability. http://dx.doi.org/10.3390/su10051634
- Hansen AL, Refsgaard JC, Olesen JE, Børgesen CD (2017) Potential benefits of a spatially targeted regulation based on detailed N-reduction maps to decrease N-load from agriculture in a small groundwater dominated catchment. Science of the Total Environment, 595, 325-336. http://dx.doi.org/10.1016/j.scitotenv.2017.03.114
- Hansen AL, Donnelly C, Refsgaard JC, Karlsson IB (2018) Simulation of nitrate reduction in groundwater – an upscaling approach from small catchments to the Baltic Sea basin. Advances in Water Resources, 111, 58-69. http://dx.doi.org/10.1016/j.advwatres.2017.10.024
- Hashemi F, Olesen JE, Dalgaard T, Børgesen CD (2016) Review of scenario analyses to reduce agricultural nitrogen and phosphorous loading to the aquatic environment. Science of the Total Environment, 573, 608-626. http://dx.doi.org/10.1016/j.scitotenv.2016.08.141
- Hashemi F, Olesen JE, Hansen AL, Børgesen CD, Dalgaard T (2018) Spatially differentiated strategies for reducing nitrate loads from agriculture in two Danish catchments. Journal of Environmental Management, 208, 77-91. http://dx.doi.org/10.1016/j.jenvman.2017.12.001.
- Hashemi F, Olesen JE, Jabloun M, Hansen AL (2018) Reducing uncertainty of estimated load reduction to aquatic systems through spatially targeting agricultural mitigation measures using groundwater nitrogen reduction. Journal of Environmental Management, 218, 451-464. http://dx.doi.org/10.1016/j.jenvman.2018.04.078.
- Hashemi F, Olesen JE, Børgesen CD, Tornbjerg H, Thodsen H, Dalgaard T (2018) Potential benefits of farm scale measures versus landscape measures for reducing nitrate loads in a Danish catchment. Science of the Total Environment, 637-638, 318-335. https://doi.org/10.1016/j.scitotenv.2018.04.390.
- Hundecha Y, Arheimer B, Donnelly C , Pechlivanidis I (2016) A regional parameter estimation scheme for a pan-European multi-basin model. Journal of Hydrology: Regional Studies, 6, 90-111. http://dx.doi.org/10.1016/j.ejrh.2016.04.002. OBS
- Højberg AL, Hansen AL, Wachniew P, Zurek A, Virtanen S, Arustiene J, Strömqvist J, Rankinen K, Refsgaard JC (2017) Review and assessment of nitrate reduction in groundwater in the Baltic Sea Basin. Journal of Hydrology: Regional Studies, 12, 50-68. http://dx.doi.org/10.1016/j.ejrh.2017.04.001
- Jacobsen BH, Hansen AL (2016) Economic gains from targeted measures related to non-point pollution in agriculture based on detailed nitrate reduction maps. Science of the Total Environment 556, 264-275.
- Morén I, Riml J, Wörman A (2018) Design of remediation actions in streams for retention and degradation of nutrients in the hyporheic zone. Water Resources Research, 53(11), 8872–8899. https://doi.org/10.1002/2016WR020127
- Refsgaard JC, Højberg AL, He X, Hansen AL, Rasmussen SH, Stisen S (2016) Where are the limits of model predictive capabilities? Hydrological Processes, Keith Beven Tribute. http://dx.doi.org/10.1002/hyp.11029
- Reusch TBH, Dierking J, Andersson H, Bonsdorff E, Carstensen J, Casini M, Czajkowski M, Hasler B, Hinsby K, Hyytiäinen K, Johannesson K, Jomaa S, Jormalainen V, Kuosa H, Kurland S, Laikre L, MacKenzie BR, Margonski P, Melzner F, Oesterwind D, Ojaveer H, Refsgaard JC, Sandström A, Schwarz G, Tonderski K, Winder M, Zandersen M (2018) The Baltic Sea as a time machine for the future coastal ocean. Science Advances, 4, eaar8195. http://advances.sciencemag.org/content/advances/4/5/eaar8195.full.pdf
- Riml J, Wörman A (2015) Spatiotemporal decomposition of solute dispersion in watersheds. Water Resources Research, 51, 2377–2392. http://dx.doi.org/10.1002/2014WR016385. OBS
- Åkesson A, Wörman A, Riml J, Seibert J (2015) Change in streamflow response in unregulated catchments in Sweden over the last century, Water Resources Research. http://dx.doi.org/10.1002/2015WR018116 OBS
- Zmijewski N, Wörman A (2017) Trade-Offs between Phosphorous Discharge and Hydropower Production Using Reservoir Regulation. Journal of Water Resources Planning and Management, 143(9), Article Number 04017052. http://dx.doi.org/10.1061/(ASCE)WR.1943-5452.0000809

Manuscripts submitted to International Journals

- Albrecht S, Gerstetter C. Towards co-governance in monitoring of spatially differentiated regulation for good water quality – Common pool resources and EU law. Submitted to Environmental Science and Policy
- Hansen AL, Jakobsen R, Refsgaard JC, Højberg AL, Iversen BV, Kjærgaard C. Shallow groundwater dynamics and the effect of tile drainage on flow across the redox inteface in a Danish till area. Submitted to Andvances in Water resources
- Zandersen M, Hyytiainen K, Meier MHE, Tomczak M, Bauer B, Haapasaari P, Olesen JE, Gustaffson BG, Refsgaard JC, Fridell E, Pihlainen S, Le Tissier MDA, Kosenius AK, van Vuuren DP. Extending Shared Socioeconomic Pathways for the Baltic Sea region for use in studying regional environmental problems. Submitted to Regional Environmental Change

PhD dissertations

- Riml J (2014) Solute transport across scales: Time series analysis of water quality responses to quantify retention and attenuation mechanisms in watersheds, PhD Thesis, TRITA-LWR PHD-2014:05, 62p
- Domnin D. (defended in September 2017) Geoecological assessment and zoning of catchment areas of the Kaliningrad Oblast. PhD. Immanuel Kant Baltic Federal University, Kaliningrad. - 130pp.
- Hashemi F (defended in May 2018) Methods for Assessing Spatially Differentiated Nitrogen Mitigation in Agriculture. Aarhus University, Denmark, 173 pp.

5. Research collaboration (Statistic 5)

- GEUS is via the EuroGeoSurveys (European Geological Surveys) developing a framework for collaboration with the Joint Research Centre of the European commission within areas of groundwater and integrated hydrological modelling of river basins, marine raw materials mapping etc. A collaboration which is very relevant for the implementation of the research findings of Soils2Sea in a future sustainable management of water resources in Europe. (*GEUS, 2014-2015-2016-2017*)
- SMHI has initiated a collaborative experiment using the SWITCHON platform (http://www.water-switch-on.eu) with a research partner in the UK (JBA consulting) . The title of the experiment is “Estimating riverine nutrient concentrations in agricultural catchments” and the experiment should lead to improved understanding of water quality models to variations in data input and in the longer term to improvements in the models used to make the scenario runs in Soils2Seas. (*SMHI, 2014*)
- KTH has participated in an international collaboration in terms of a writing project that resulted in an extensive review paper on biogeochemical processes in the hyporheic zone of streams and which is recently published in Reviews of Geophysics. The hyporehic zone in streams has a central role as a filter for stream water that is pumped into and out of the zone due to various natural stream processes. Recent two to three decades of research has learnt us the key role that the hyporheic zone has for e.g. nutrient processes and benthic fauna. This review paper provides an exhausted compilation of key findings in the area and should be of general help to scientists and practitioners with an interest in stream water quality. The collaboration has been a joint effort between Northwestern University and USGS in U.S.A., Politecnico di Torino and University of Padua in Italy and the Royal Intsitute of Technology. (*KTH, 2014*)
- A cooperation has been undertaken with Utah State University and Indiana State University, U.S.A., which has resulted in a common scientific paper (Water Resources Research) on how to delineate spatially variable parameters in streams *(KTH, 2015)*
- *GEUS (Jens Christian Refsgaard, Anker L Højberg, Emilia Ptak) and Ecologic (Grit Martinez, Nico Stelljes)* participated in a writing-workshop in Copenhagen, 28-29 November 2016 to prepare a common scientific paper on international comparison of water co-governance examples. The workshop had participants from Denmark, Sweden, Australia, USA, UK, Germany and The Netherlands.(2016)
- *AGH* has cooperated with Laboratoire de glaciologie et géophysique de l'environnement (LGGE) in Grenoble, France on analyses of stable isotope composition of nitrates in water samples collected in the Kocinka catchment (2016)
- SMHI *(Alena Bartosova)* has participated in International Workshop on Estimation of nitrogen loads to the marine environment around the time of the year 1900 and presented on evolution of landscape processes and hydrology with respect to nitrogen concentrations (2016)
- SMHI *(Alena Bartosova, Berit Arheimer)* has participated in an IAHS-driven initiative to identify “23 Unsolved Problems in Hydrology “ (2017-2018)

6. Progress compared to original plans

6.1 Research plan

All milestones have been achieved.

6.2 Deliverables

All deliverables have been submitted and accepted by BONUS. A list of deliverables is provided in Table 2 below.

Table 2. BONUS SOILS2SEA deliverables. All deliverables can be downloaded from www.Soils2Sea.eu

Deliv-erable	Title	Authors	Date	Number of pages
D1.1	Website	Refsgaard JC, Myren R, Hoelstad T	June 2014	14 pp
D1.2	Requirements Report	Refsgaard JC, Jacobsen R, Hinsby K, Højberg AL, Hansen AL, Olesen JE, Kjærgaard C, Heckrath G, Wachniew P, Zurek A, Wörman A, Riml J, Capell R, Knoblauch D, Stelljes N, Reid A, Frelih-Larsen A, Gerstetter C, Martinez G, Naumann S, de Jonge H, Chubarenko B, Domnin D	June 2014	178 pp
D1.3	Dissemination Plan and Material	Reid A, Knoblauch D, Refsgaard JC	September 2014	18 pp
D1.4	Periodic Report No. 1	Refsgaard JC, Myren R, Olesen JE, Jacobsen R, Wörman A, Donelly C, Knoblauch D, Wachniew P, Chubarenko B	February 2015	39 pp
D1.5	Periodic Report No. 2	Refsgaard JC, Myren R, Olesen JE, Jacobsen R, Wörman A, Donelly C, Knoblauch D, Wachniew P, Chubarenko B	September 2016	71 pp
D1.6	Updated dissemination material	N Stelljes	October 2016	14 pp
D1.7	Periodic Report No. 3	Refsgaard JC, Sejerslev J, Olesen JE, Jacobsen R, Wörman A, Bartosova A, Stelljes N, Wachniew P, Chubarenko B	June 2017	64 pp
D1.8	Proceedings from the 3rd BONUS Symposium, Gdansk, 14-16 March 2018	Refsgaard JC, Stelljes N (Editors)	March 2018	140 pp
D1.9	Periodic Report No. 4	Refsgaard JC, Sejerslev J, Olesen JE, Jacobsen R, Wörman A, Bartosova A, Stelljes N, Wachniew P, de Jonge H, Chubarenko B	May 2018	75 pp
D1.10	Final Report	Refsgaard JC, Sejerslev J, Olesen JE, Jacobsen R, Wörman A, Bartosova A, Stelljes N, Wachniew P, de Jonge H, Chubarenko B	May 2018	61 pp
D2.1	Review report on existing scenario studies of nutrient reductions	Hashemi F, Olesen JE	August 2015	62 pp
D2.2	Soils2Sea scenarios for nutrient reductions	Olesen JE, Hashemi F, Jabloun M, Donelly C, Hansen AL, Wörman A, Chubarenko B, Steljes N	February 2016	48 pp
D2.3	Scenario analyses of spatially differentiated N measures in catchments under future climate and land use	Olesen JE, Børgesen CD, Jabloun M, Wachiniew P, Bar D, Zurek A, Hansen AL, Refsgaard JC, Bosshard, T	March 2018	70 pp

D2.4	Scenario analyses for spatially differentiated P measures in catchments	Heckrath G, Onnen N, Pugliese L, Pop A, Iversen, BV	March 2018	30 pp
D3.1	Field site installations for groundwater studies in Norsminde and Kocinka	Jakobsen R, Wachniew P, Hansen AL, Myren R, Refsgaard JC	April 2016	28 pp
D3.2	Upscaling methodologies	Refsgaard JC, Jakobsen R, Hansen AL, Højberg AL, Żurek AJ, Różański K, Witczak S, Wachniew P, Donnelly C, Capell R, Bartosova A, Strömqvist J, Wörman A, Morén I	November 2016	98 pp
D3.3	Prototype of new sensors for flux measurements of N and P	De Jonge H	January 2018	14 pp
D3.4	Hill slope studies in Fensholt, Norsminde, Denmark. And Kocinka, Poland. Biogeochemical processes and flow paths	Jakobsen R, Hansen AL, Wachniew P, Bar-Michalczyk D, Michalczyk T., Zięba D	February 2018	92 pp
D3.5	Gains from differentiated regulation of nitrate in groundwater dominated Danish catchments	Refsgaard JC, Hansen AL, Hashemi F, Olesen JE, Børgesen CD	October 2017	66 pp
D3.6	Proposal for differentiated regulations for Kocinka catchment	Wachniew P., Bar-Michalczyk D., Michalczyk T., Zięba D., Kania J., Różański K., Witczak S., Żurek A.J., 2017	February 2018	40 pp
D4.1	Impacts on damming on nutrient export and optimized reservoir operation with multi-objectives	Zmijewski N, Wörman A	December 2015	26 pp
D4.2	Tracer Tests and the effect of solute retention and attenuation on the stream reach scale	Riml J, Morén I, Wörman A, Zięba D, Wachniew P	December 2016	38 pp
D4.3	Design of water-course remediation measures to increase nutrient mitigation	Morén I, Riml J, Wörman A	November 2017	28 pp
D4.4	In-stream water management strategies for reducing nutrient loads to the Baltic Sea	Morén I, Riml J, Wörman A	March 2018	70 pp
D5.1	HYPE model for the Baltic Sea Basin	Bartosova A, Donnelly C, Strömqvist J, Capell R, Tengdelius-Brunel J.	May 2017	34 pp
D5.2	A scenario analysis of socio-economic and climate changes to the nutrient loads from the Pregolya River to the Baltic Sea	Domnin D, Gorbunova J, Chubarenko B, Donnely C, Capel R	February 2017	256 pp
D5.3	Water quality changes in the Baltic Sea basin within the HYPE modelling framework	Bartosova A, Strömqvist J, Simmonson L	March 2018	30 pp

D5.4	Projected Impacts of Climate, Anthropogenic Changes, and Remedial Measures on Nutrient Loads to the Baltic Sea	Bartosova A, Capell R, Olesen JE, Jabloun M, Donnelly C, Strandberg G, Strömqvist J, Morén I, Tengdelius-Brunell J	March 2018	74 pp
D5.5	Baltic HYPE scenario results in HypeWeb platform	Bartosova A, Capell R, Sahlin J	March 2018	18 pp
D6.1	Thresholds for nitrogen in groundwater and streams - a new concept for differentiated regulation and protection of the Baltic Sea and its coastal waters	Hinsby K, Refsgaard JC, Hansen AL, Højberg AL, Jakobsen R, Zurek A, Wachniew P	March 2018	34 pp
D6.2	Proposals for new governance concepts and policy options	Stelljes N, Albrecht S, Martinez G, McGlade K	May 2017	104 pp
D6.3	Towards co-governance in monitoring of spatially differentiated regulation for good water quality – Common pool resources and EU law	Albrecht S, Gerstetter C	April 2017	30 pp
D6.4	Results from stakeholder workshops on governance concepts	Stelljes N, McGlade K, Martinez G	December 2017	32 pp
D6.5	Policy Brief	Stelljes N, Refsgaard JC, Bartosova A, McGlade K, Olesen JE, Wachniew P, Wörman A	March 2018	54 pp

7. Wider societal implications

7.1 Implications at national and international levels

BONUS SOILS2SEA results have shown that climate change during the coming decades will increase nutrient loads to the Baltic Sea. The climate change impacts are not yet accounted for in the action plans from the EU Water Framework Directive or in the HELCOM Baltic Sea action plan. Due to the significant impact that climate change is now projected to have on nutrient loads, it is essential that these are fully considered and integrated in future EU and HELCOM action plans.

Regional changes to societal activities (e.g. land use and agricultural practice) can have effects that are as important as climate change for nutrient loads to the Baltic Sea. The analyses also show that changes that directly affect the sources of nutrients (such as the type and extent of agriculture or urbanization) have much more profound impact on nutrient loads than individual measures designed to mitigate the impacts. It is therefore important to continue to address impacts of agriculture, human waste, and other anthropogenic activities on nutrient loads.

Spatially differentiated strategies that are adapted to the natural conditions of a particular area make it possible to significantly and efficiently reduce nutrient loads without reducing agricultural productivity. BONUS SOILS2SEA analyses suggest that spatially differentiated strategies have a potential to provide a substantial part of the reduction of nutrient loads that are required to achieve the environmental goals for the Baltic Sea and its coastal water bodies. Spatial differentiation is, however, a new avenue in nutrient regulation and hence a number of challenges with respect to e.g. data availability and governance frameworks need to be addressed before we can exploit this potential for reduction in nutrient loads.

BONUS SOILS2SEA has further developed the principle of water quality thresholds that are central elements in the EU Water Framework Directive and the Groundwater Directive towards differentiated groundwater and stream thresholds.

BONUS SOILS2SEA has presented its findings for HELCOM as well as for representatives of national authorities responsible for implementation of the EU WFD.

7.2 Implications for stakeholders and policy development at local and national level

In addition to projections of nutrient loads at the Baltic Sea scale, BONUS SOILS2SEA has analysed nutrient load conditions and possible mitigation measures at local scale through comprehensive catchment studies and stakeholder involvement in Denmark, Poland, Sweden and Russia. This has had widespread implications, e.g.:

- BONUS SOILS2SEA has developed methodologies and analyses to support spatially differentiated regulations, which for instance in Denmark has influenced the discussion on a choice of mitigation measures and use of co-governance.

- With the case studies, discussions among different stakeholder on new aspects were initiated. For example, new concepts on spatially differentiated regulation and co-governance were introduced and received initial support to a varying degree in the different countries.
- Results of model-based analyses of uncertainties in groundwater N reduction showed that using information on this uncertainty from multiple N reduction maps allowed the efficiency of application of targeted measures to be enhanced considerably. However, this requires a new approach to understanding and applying uncertainty in decision making within regulatory frameworks.
- New knowledge from the catchment studies contributed to an improved understanding at the national scene. In Poland, new knowledge and methods on estimation of nitrate export at the field and catchment scales contribute to an application of the Water Framework Directive and especially the Nitrate Directive, whose implementation in Poland has been problematic. In Russia, quantification of flows and nutrient loads today and under future climate and socio-economic scenarios contribute new knowledge. In Denmark, the finding on the effects of tile drains for nitrate reduction in groundwater is an important contribution to the ongoing discussion on how to regulate nitrate in the landscape. In Sweden, the findings of the impact of in-stream remediation measures contribute new knowledge on the use of such mitigation measures.
- Key stakeholders in the Kocinka catchment were identified and the new approaches to agricultural management in catchments as well as the scientific knowledge on the sources and fate of nitrate in the catchment were disseminated among them. Project workshops and other meetings with stakeholders were found to be effective means of knowledge transfer and building links with local community.
- Local stakeholders were exposed to issues in other countries. For example, Polish stakeholders from the Kocinka case study were invited to take part in the workshop and an excursion in Sweden (Tullstorp). A Danish farmer participated in the regional stakeholder workshop in Berlin discussing problems and solutions with stakeholders from other countries. And a transboundary workshop in the Pregolya catchment in Olstyn (Poland) brought Polish and Russian stakeholders together for a workshop and a networking dinner.
- The BONUS SOILS2SEA film and a series of interviews for national scale and regional media on the problem of agricultural nitrogen pollution of groundwaters and surface waters contributed to the discussion on these issues in Poland as shown by personal communications and responses to on-line materials.
- The BONUS SOILS2SEA film transports the ideas of the project to a wider audience. The video has been viewed over 1600 times (by May 2018) on YouTube and was shown at serval occasions (project workshops, screening, etc.). It is planned to use this film for schools in the region of Częstochowa and the water company of Częstochowa also plans to use the film for visitor guidance at the company.
- At the 3rd BONUS Symposium, results of the project were presented to a wider audience.
- Three Newsletters and one Policy Brief have been produced, translating project results in an easy accessible language. The Policy Brief is available in five different languages.

8. References

Albrecht S, Gerstetter C (submitted) Towards co-governance in monitoring of spatially differentiated regulation for good water quality – Common pool resources and EU law. Environmental Science and Policy (in review)

Bartosova A, Strömqvist J, Olesen JE, Jabloun M, Capell R, Refsgaard JC, Arheimer B (in preparation) Change in nutrient loads to the Baltic Sea Basin with changing climate, socioeconomic impacts, and agriculture practices. To be submitted to Special Issue Ambio.

Bronstert A, Bardoddy A, Bismuth C, Buiteveld H, Disse M, Engel H, Fritsch U, Hundecha Y et al. (2007) Multi-scale modelling of land-use change and river training effects on floods in the Rhine Basin. River Research and Applications, 23, 1102-1125.

Chubarenko B, Gorbunova J, Domnin D, Refsgaard JC, Donnelly C, Capel R (in preparation) A scenario analysis of socio-economic and climate related changes in nutrient emission and retention for the Pregolya River catchment (South-Eastern Baltic). To be submitted to Special Issue Ambio.

Donnelly C, Andersson JCM, Arheimer B (2015) Using flow signatures and catchment similarities to evaluate the E-HYPE multi-basin model across Europe. Hydrological Sciences Journal.

Hansen AL, Gunderman D, He X, Refsgaard JC (2014) Uncertainty assessment of spatially distributed nitrate reduction potential in groundwater using multiple geological realizations. Journal of Hydrology. 519, 225-237.

Hansen AL, Refsgaard JC, Olesen JE, Børgesen CD (2017) Potential benefits of a spatially targeted regulation based on detailed N-reduction maps to decrease N-load from agriculture in a small groundwater dominated catchment. Science of the Total Environment, 595, 325-336.

Hansen AL, Donnelly C, Refsgaard JC, Karlsson IB (2018) Simulation of nitrate reduction in groundwater – an upscaling approach from small catchments to the Baltic Sea basin. Advances in Water Resources, 111, 58-69.

Hansen AL, Jakobsen R, Refsgaard JC, Højberg AL, Iversen BV, Kjærgaard C (submitted) Shallow groundwater dynamics and the effect of tile drainage on flow across the redox inteface in a Danish till area. Andvances in Water resources (in review)

Hashemi F, Olesen JE, Dalgaard T, Børgesen CD (2016) Review of scenario anal-yses to reduce agricultural nitrogen and phosphorous loading to the aquatic environment. Science of the Total Environment 573, 608–626.

Hashemi F, Olesen JE, Hansen AL, Børgesen CD, Dalgaard T (2018a) Spatially differentiated strategies for reducing nitrate loads from agriculture in two Danish catchments. Journal of Environmental Management, 208, 77-91.

Hashemi F, Olesen JE, Jabloun M, Hansen AL (2018b) Reducing uncertainty of estimated load reduction to aquatic systems through spatially targeting agricultural mitigation measures using groundwater nitrogen reduction. Journal of Environmental Management, 218, 451-464.

Hashemi F, Olesen JE, Børgesen CD, Tornbjerg H, Thodsen H, Dalgaard T (2018c) Potential benefits of farm scale measures versus landscape measures for reducing nitrate loads in a Danish catchment. Science of the Total Environment, 637-638, 318-335.

Højberg AL, Hansen AL, Wachniew P, Zurek A, Virtanen S, Arustiene J, Strömqvist J, Rankinen K, Refsgaard JC (2017) Review and assessment of nitrate reduction in groundwater in the Baltic Sea Basin. Journal of Hydrology: Regional Studies, 12, 50-68.

Jabloun M, Olesen JE (2018) Identifying hotspots of future land use spatial pattern under CMIP5 climate projections within the Baltic Sea Drainage Basin (in prep).

Jakobsen R, Hansen AL, Hinsby K, Postma D, Refsgaard JC (in preparation) Reactive Nitrogen in a Clay Till Hill Slope Field System. To be submitted to Special Issue Ambio.

Karlsson IB, Sonnenborg TO, Refsgaard JC, Trolle D, Børgesen CD, Olesen JE, Jeppesen E, Jensen KH (2016) Combined effects of climate models, hydrological model structures

and land use scenarios on hydrological impacts of climate change. Journal of Hydrology, 535, 301-317.

Lindström G, Pers CP, Rosberg R, Strömqvist J, Arheimer B (2010) Development and test of the HYPE (Hydrological Predictions for the Environment) model – A water quality model for different spatial scales. Hydrology Research, 41(3-4), 295-319.

Morén I, Riml J, Wörman A (2017) Design of remediation actions in streams for retention and degradation of nutrients in the hyporheic zone. Water Resources Research, 53(11), 8872–8899.

Morén I, Riml J, Wörman A (in preparation). Scenario analysis for stream restoration actions assessing the potential to reduce nutrient export to the Baltic Sea from agricultural catchments. To be submitted to Special Issue Ambio.

Olesen JE, Bar-Michalczyk D, Bosshard T, Børgesen CD, Hansen AL, Jabloun M, Refsgaard JC, Wachniew P (in preparation) Nitrogen leaching losses from two Baltic Sea catchments under scenarios of changes in land use, land management and climate. To be submitted to Special Issue Ambio.

Refsgaard JC, Madsen H, Andreassian V, Arnbjerg-Nielsen K, Davidson TA, Drews M, Hamilton DP, Jeppesen E, Kjellström E, Olesen JE, Sonnenborg TO, Trolle D, Willems P, Christensen JH (2014) A framework for testing the ability of models to project climate change and its impacts. Climatic Change, 122(1), 271-282.

Refsgaard JC, Bartosova A, Chubarenko B, Hashemi F, Højberg AL, Jakobsen R, De Jonge H, Hansen AL, Hinsby K, Olesen JE, Stelljes N, Wachniew P, Wörman A (in preparation) Spatially differentiated regulation measures to reduce nitrate load from agricultural areas to the Baltic Sea. To be submitted to Special Issue Ambio.

SMHI (2017) SMHI vattenweb - Modelldata hela Sverige, viewed december 2017, http://vattenwebb.smhi.se/modelregion/

Stelljes N, Martinez G, McGlade K (in preparation) Stakeholder perceptions of spatially differentiated regulation to manage nutrient loads in the Baltic Sea. To be submitted to Special Issue Ambio.

Strömqvist J, Arheimer B, Dahné J, Donnelly C, Lindström G (2011) Water and nutrient predictions in ungauged basins – Set-up and evaluation of a model at the national scale. Hydrological Sciences Journal, 57:2, 229-247

Zandersen M, Pihlainen S, Hyytiäinen K, Meier M, Kosenius A-K, Haapasaari, P, Olesen JE, Refsgaard JC, Le Tissier MDA, Bauer B, Tomzcak MT, Fridell E, van Vuuren D, Gustafsson BG (2018) Extending Shared Socioeconomic Pathways for the Baltic Sea region for use in studying regional environmental problems. Global Environmental Change (submitted).

Zmijewski N, Wörman A (2017) Trade-Offs between Phosphorous Discharge and Hydropower Production Using Reservoir Regulation. Journal of Water Resources Planning and Management, 143(9), Article Number 04017052.

Appendix I: Dissemination status

Dissemination – status May 2018

International Journal Papers

Published (alphabetical order)[1]

- Andersson JCM, Pechlivanidis IG, Gustafsson D, Donnelly C, Arheimer B (2015) Key factors for improving large-scale hydrological model performance. European Water, 49, 77-88.[OBS]
- Boano F, Harvey JW, Marion A, Packman AI, Revelli R, Ridolfi L, Wörman A (2014) Hyporheic flow and transport processes: Mechanisms, models, and biogeochemical implications", Reviews of Geophysics, 52(4), 603–679. http://dx.doi.org/10.1002/2012RG000417. [OBS]
- Donnelly C, Andersson JCM, Arheimer B (2015) Using flow signatures and catchment similarities to evaluate the E-HYPE multi-basin model across Europe. Hydrological Sciences Journal. http://dx.doi.org/10.1080/02626667.2015.1027710. [OBS]
- Graversgaard M, Hedelin B, Gertz F, Højberg AL, Langford J, Martinez G, Mostert E, Ptak E, Peterson H, Smith L, Stelljes N, van den Brink C, Refsgaard JC (2018) Opportunities and barriers for water co-governance – a critical analysis of seven cases of diffuse water pollution from agriculture in Europe, Australia and North America. Sustainability. http://dx.doi.org/10.3390/su10051634
- Hansen AL, Refsgaard JC, Olesen JE, Børgesen CD (2017) Potential benefits of a spatially targeted regulation based on detailed N-reduction maps to decrease N-load from agriculture in a small groundwater dominated catchment. Science of the Total Environment, 595, 325-336. http://dx.doi.org/10.1016/j.scitotenv.2017.03.114
- Hansen AL, Donnelly C, Refsgaard JC, Karlsson IB (2018) Simulation of nitrate reduction in groundwater – an upscaling approach from small catchments to the Baltic Sea basin. Advances in Water Resources, 111, 58-69. http://dx.doi.org/10.1016/j.advwatres.2017.10.024
- Hashemi F, Olesen JE, Dalgaard T, Børgesen CD (2016) Review of scenario analyses to reduce agricultural nitrogen and phosphorous loading to the aquatic environment. Science of the Total Environment, 573, 608-626. http://dx.doi.org/10.1016/j.scitotenv.2016.08.141
- Hashemi F, Olesen JE, Hansen AL, Børgesen CD, Dalgaard T (2018) Spatially differentiated strategies for reducing nitrate loads from agriculture in two Danish catchments. Journal of Environmental Management, 208, 77-91. http://dx.doi.org/10.1016/j.jenvman.2017.12.001.
- Hashemi F, Olesen JE, Jabloun M, Hansen AL (2018) Reducing uncertainty of estimated load reduction to aquatic systems through spatially targeting agricultural mitigation measures using groundwater nitrogen reduction. Journal of Environmental Management, 218, 451-464. http://dx.doi.org/10.1016/j.jenvman.2018.04.078.
- Hashemi F, Olesen JE, Børgesen CD, Tornbjerg H, Thodsen H, Dalgaard T (2018) Potential benefits of farm scale measures versus landscape measures for reducing nitrate loads in a Danish catchment. Science of the Total Environment, 637-638, 318-335. https://doi.org/10.1016/j.scitotenv.2018.04.390.
- Hundecha Y, Arheimer B, Donnelly C , Pechlivanidis I (2016) A regional parameter estimation scheme for a pan-European multi-basin model. Journal of Hydrology: Regional Studies, 6, 90-111. http://dx.doi.org/10.1016/j.ejrh.2016.04.002. [OBS]
- Højberg AL, Hansen AL, Wachniew P, Zurek A, Virtanen S, Arustiene J, Strömqvist J, Rankinen K, Refsgaard JC (2017) Review and assessment of nitrate reduction in groundwater in the Baltic Sea Basin. Journal of Hydrology: Regional Studies, 12, 50-68. http://dx.doi.org/10.1016/j.ejrh.2017.04.001

[1] All publications listed here have been supported by BONUS Soils2Sea. Some of the papers have also been supported by other funding. The papers marked with [OBS] at the end have failed to formally acknowledge the BONUS funding in the paper itself.

BONUS SOILS2SEA has received funding from BONUS (Art 185) funded jointly from the European Union's Seventh Programme for research, technological development and demonstration, and from Baltic Sea national funding institutions.

- Jacobsen BH, Hansen AL (2016) Economic gains from targeted measures related to non-point pollution in agriculture based on detailed nitrate reduction maps. Science of the Total Environment 556, 264-275.
- Morén I, Riml J, Wörman A (2017) Design of remediation actions in streams for retention and degradation of nutrients in the hyporheic zone. Water Resources Research, 53(11), 8872–8899. https://doi.org/10.1002/2016WR020127
- Refsgaard JC, Højberg AL, He X, Hansen AL, Rasmussen SH, Stisen S (2016) Where are the limits of model predictive capabilities? Hydrological Processes, Keith Beven Tribute. http://dx.doi.org/10.1002/hyp.11029
- Reusch TBH, Dierking J, Andersson H, Bonsdorff E, Carstensen J, Casini M, Czajkowski M, Hasler B, Hinsby K, Hyytiäinen K, Johannesson K, Jomaa S, Jormalainen V, Kuosa H, Kurland S, Laikre L, MacKenzie BR, Margonski P, Melzner F, Oesterwind D, Ojaveer H, Refsgaard JC, Sandström A, Schwarz G, Tonderski K, Winder M, Zandersen M (2018) The Baltic Sea as a time machine for the future coastal ocean. Science Advances, 4, eaar8195. http://advances.sciencemag.org/content/advances/4/5/eaar8195.full.pdf
- Riml J, Wörman A (2015) Spatiotemporal decomposition of solute dispersion in watersheds. Water Resources Research, 51, 2377–2392. http://dx.doi.org/10.1002/2014WR016385. OBS
- Åkesson A, Wörman A, Riml J, Seibert J (2015) Change in streamflow response in unregulated catchments in Sweden over the last century, Water Resources Research. http://dx.doi.org/10.1002/2015WR018116 OBS
- Zmijewski N, Wörman A (2017) Trade-Offs between Phosphorous Discharge and Hydropower Production Using Reservoir Regulation. Journal of Water Resources Planning and Management, 143(9), Article Number 04017052. http://dx.doi.org/10.1061/(ASCE)WR.1943-5452.0000809

Accepted

Submitted

- Zandersen M, Hyytiainen K, Meier MHE, Tomczak M, Bauer B, Haapasaari P, Olesen JE, Gustaffson BG, Refsgaard JC, Fridell E, Pihlainen S, Le Tissier MDA, Kosenius AK, van Vuuren DP. Extending Shared Socioeconomic Pathways for the Baltic Sea region for use in studying regional environmental problems. Submitted to Regional Environmental Change
- Albrecht S, Gerstetter C. Towards co-governance in monitoring of spatially differentiated regulation for good water quality – Common pool resources and EU law. Environmental Science and Policy (in review)
- Hansen AL, Jakobsen R, Refsgaard JC, Højberg AL, Iversen BV, Kjærgaard C. Shallow groundwater dynamics and the effect of tile drainage on flow across the redox inteface in a Danish till area. Andvances in Water resources (in review)

Planned/in preparation

- Bartosova A, Strömqvist J, Olesen JE, Jabloun M, Capell R, Refsgaard JC, Arheimer B. Change in nutrient loads to the Baltic Sea Basin with changing climate, socioeconomic impacts, and agriculture practices. *To be submitted to Special Issue Ambio.*
- Chubarenko B, Gorbunova J, Domnin D, Refsgaard JC, Donnelly C, Capel R. A scenario analysis of socio-economic and climate related changes in nutrient emission and retention for the Pregolya River catchment (South-Eastern Baltic). *To be submitted to Special Issue Ambio.*
- Jakobsen R, Hansen AL, Hinsby K, Postma D, Refsgaard JC. Reactive Nitrogen in a Clay Till Hill Slope Field System. *To be submitted to Special Issue Ambio.*
- Morén I, Riml J, Wörman A. Scenario analysis for stream restoration actions assessing the potential to reduce nutrient export to the Baltic Sea from agricultural catchments. *To be submitted to Special Issue Ambio.*
- Olesen JE, Bar-Michalczyk D, Bosshard T, Børgesen CD, Hansen AL, Jabloun M, Refsgaard JC, Wachniew P. Nitrogen leaching losses from two Baltic Sea catchments under scenarios of changes in land use, land management and climate. *To be submitted to Special Issue Ambio.*
- Refsgaard JC, Bartosova A, Chubarenko B, Hashemi F, Højberg AL, Jakobsen R, De Jonge H, Hansen AL, Hinsby K, Olesen JE, Stelljes N, Wachniew P, Wörman A. Spatially differentiated regulation measures to reduce nitrate load from agricultural areas to the Baltic Sea. *To be submitted to Special Issue Ambio.*

BONUS SOILS2SEA has received funding from BONUS (Art 185) funded jointly from the European Union's Seventh Programme for research, technological development and demonstration, and from Baltic Sea national funding institutions.

- Stelljes N, Martinez G, McGlade K. Stakeholder perceptions of spatially differentiated regulation to manage nutrient loads in the Baltic Sea. *To be submitted to Special Issue Ambio.*
- Strömqvist et al. Multi-basin, fine resolution integrated modelling of hydrology and surface water temperatures in Swedish rivers and lakes
- AGH + Ecologic Two dimensions of nitrate pollution in an agricultural catchment.
- Zieba D et al. Factors affecting spatiotemporal patterns of nitrates in an agricultural catchment.
- Kania J et al. 3D numerical modeling of nitrate transport.
- Żurek A et al. Sources and transformations of nitrate pollution in a GW system .
- Bartosova A, Donnelly C, Strömqvist J. Spatial and temporal trends in European water quality..
- KTH + AGH. Joint paper on the stream tracer tests using P32, N15 and tritiated water in Tullstorps Brook. In prep.
- Jabloun M, Olesen JE. Identifying hotspots of future land use spatial pattern under CMIP5 climate projections within the Baltic Sea Drainage Basin.

National Journal Papers (alphabetical order)

- Bar-Michalczyk D, Michalczyk T, Żurek A, Witczak S (2016) Potential use of HYPE model in the assessment of groundwater recharge in groundwater balance areas based on river basins. Chapter in monograph: Practical methods of groundwater flow modeling, S. Witczak & A. Żurek (eds.), ISBN: 978-83-88927-38-6, pp. 213–222.
- Bar-Michalczyk D, Michalczyk T, Witczak S, Żurek A (2017) Evaluating the HYPE model for estimating groundwater recharge in a groundwater dominated catchment in Poland. Geology, Geophysics & Environment, 43(3), 171 – 180.
- Bar-Michalczyk D, Malina G, Wachniew P, Martinez G, Stelljes N (2017) Nothing about us without us – stakeholders participation in the BONUS Soils2Sea project. Chapter in monograph: Remediation, Reclamation and Rewitalisation, G. Malina (ed.), PZiTS o/wielkopolski, Poznan, pp. 11-25. In Polish.
- Chubarenko B, Esiukova E, Domnin D, Leytsina L (2014) Assessment of probable climate changes on the Vistula Lagoon and its catchment. [In] Processes in Geomedia: Paper collection. Moscow: Institute of Problems of Mechanics of Russian Academy of Sciences. 2014. No 1 (1). P. 170-178. In Russian.
- Domnin D (2014) System of GIS based indicators for geoecological assessment of the catchments of the Kaliningrad Oblast. Natural and Technical Sciences. 2014. No 11-12 P. 193-198. In Russian.
- Domnin D (2015) Geoecological regionalization of the catchments of the Kaliningrad Oblast using the indicator approach and cluster analysis. Prospects of Science. 2015. No 11 (74). P. 174-180. In Russian.
- Domnin D, Chubarenko B (2015) Methodology for development of the Atlas of transboundary catchment for the Vistula Lagoon. Natural and Technical Sciences. 2015. No 6. P. 254-259. In Russian.
- Domnin D, Sokolov A (2014) Modelling of river runoff from the Vistula Lagoon catchment and saltwater intrusion of the saline waters upstream the Pregolya River. Transacts of the Kaliningrad State Technical University. 2014. No 35. P.11-20. In Russian.
- Gorbunova J, Domnin D, Chubarenko B (2015) Analysis of agricultural sector development in the Vistula Lagoon catchment as a main factor of nutrient load. Transacts of the Kaliningrad State Technical University. 2015. No 39. P.11-18. In Russian.
- Malina G, Wachniew P, Żurek A, Bar D, Michalczyk T, Zięba D, Kania J, Różański K, Witczak S (2015). Reducing nutrient loadings from agricultural soils to the Baltic Sea via groundwater and streams : the Soils2Sea project. Chapter in monograph: Remediation, Recultivation and Revitalisation, G. Malina (ed.), PZiTS o/wielkopolski, Poznań, pp. 213-224. In Polish.
- Michalczyk T, Bar-Michalczyk T (2015). Determination of investigative groundwater monitoring sites based on the time of exchange of water in catchment scale numerical models. Przegląd Geologiczny, 63 (10/2) 931-934. In Polish.

BONUS SOILS2SEA has received funding from BONUS (Art 185) funded jointly from the European Union's Seventh Programme for research, technological development and demonstration, and from Baltic Sea national funding institutions.

- Zieba D, Michalczyk T, Bar-Michalczyk D, Jaszczur M, Żurek A, Wachniew P (2015). Identification of groundwater contributions to streamflow in a medium size catchment. Przegląd Geologiczny, 63 (10/2) 1161-1165. In Polish.
- Żurek A, Wachniew P, Witczak S (2017). Assessment of the index of potential nitrate reduction in groundwater in the area of Poland. Przegląd Geologiczny, 65 (11/2) 1416-1420. In Polish.

International conferences and workshops

Papers in proceedings (chronological order)

- Domnin D., Chubarenko B., Capell R (2016) Mathematical modeling of nutrient loading from small catchments of the Vistula . Proceedings of International Conference "Managing risks to coastal regions and communities in a changing world" (EMECS'11 - SeaCoasts XXVI, St. Petersburg, 22-27.08.2016). Moscow, RIOR Publ., 2016.
- Gorbunova J., Chubarenko B., Domnin D., Refsgaard JC (2016) Assessment of nutrient load on the Pregolya River basin (Vistula Lagoon catchment) from the anthropogenic sources . Proceedings of International Conference "Managing risks to coastal regions and communities in a changing world" (EMECS'11 - SeaCoasts XXVI, St. Petersburg, 22-27.08.2016). Moscow, RIOR Publ., 2016
- Jacobsen and Hansen (2015) Economic gains from targeting measures based on detailed nitrate reduction maps. Proceedings of International Conference "20th International Farm Management Congress". Québec, Canada, ISBN 978-92-990062-3-8

Oral presentation (chronological order)

- Capell R, Bartosova A, Strömqvist J, and Arheimer B (2018) Using E-HYPE for estimating nutrient transport – experiences and challenges. European Geosciences Union General Assembly, Vienna, Austria, 8-13 April 2018
- Bartosova A, Strömqvist J, Capell R, Olesen JE, Jabloun M, Arheimer B, Donnelly C, Hyytiäinen K, Pedersen SM, Zilans A, Tonderski K, and Zandersen M (2018) Change in nutrient loads to the Baltic Sea Basin with changing climate, socioeconomic impacts, and land management practices. The 3rd BONUS symposium: Sustainable Ecosystem Governance under Changing Climate and Land Use in the Baltic Sea Region. Gdansk, Poland, 14-16 March 2018.
- Capell R, Bartosova A, Strömqvist J, and Arheimer B (2018) Modelled source apportionment of nutrient loads to Baltic Sea basins under current and future conditions. The 3rd BONUS symposium: Sustainable Ecostystem Governance under Changing Climate and Land Use in the Baltic Sea Region. Gdansk, Poland, 14-16 March 2018.
- Chubarenko B, Gorbunova J, Domnin D (2018) 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. The 3rd BONUS symposium: Sustainable Ecostystem Governance under Changing Climate and Land Use in the Baltic Sea Region. Gdansk, Poland, 14-16 March 2018.
- Hansen AL, Børgesen CD, Olesen JE, Refsgaard JC (2018) Impact of future climate changes on hydrology, N-reduction and N-load in a Danish groundwater-dominated catchment. The 3rd BONUS symposium: Sustainable Ecostystem Governance under Changing Climate and Land Use in the Baltic Sea Region. Gdansk, Poland, 14-16 March 2018.
- Højberg AL, Hansen AL, Wachniew P, Żurek AJ, Virtanen S, Arustiene J, Strömqvist J, Rankinen K, Refsgaard JC (2018) Utilising data and studies within the Baltic Sea Basin to develop a map for nitrogen reduction in groundwater. The 3rd BONUS symposium: Sustainable Ecostystem Governance under Changing Climate and Land Use in the Baltic Sea Region. Gdansk, Poland, 14-16 March 2018.
- Jabloun M, Olesen JE, Zandersen M, Hyytiäinen KP, Smedberg E (2018) Land use and land cover projections in the Baltic Sea Basin under different SSPs and future climate change. The 3rd BONUS symposium: Sustainable

BONUS SOILS2SEA has received funding from BONUS (Art 185) funded jointly from the European Union's Seventh Programme for research, technological development and demonstration, and from Baltic Sea national funding institutions.

ecosystem governance under changing climate and land use in the Baltic Sea Region. Gdansk, 14-16 March 2018.

- Jakobsen R, Hansen AL, Hinsby K, Refsgaard JC (2018) Geochemical processes affecting reactive nitrogen in a clay till, hill slope field system. The 3rd BONUS symposium: Sustainable Ecostystem Governance under Changing Climate and Land Use in the Baltic Sea Region. Gdansk, Poland, 14-16 March 2018.
- Kania J, Michalczyk T, Witczak S, Bar-Michalczyk D, Rozanski K, Dulinski M, Najmann J (2018) Modelling of nitrate contamination in fissured-porous karstic aquifer underlying Kocinka catchment using tracer-calibrated flow and transport model. The 3rd BONUS symposium: Sustainable Ecostystem Governance under Changing Climate and Land Use in the Baltic Sea Region. Gdansk, Poland, 14-16 March 2018.
- Martinez G (2018) Employing narratives and ethnographic studies to inform policy options for nutrient reductions. The 3rd BONUS Symposium Sustainable Ecosystem Governance under Changing Climate and Land Use in the Baltic Sea Region, Gdańsk, Poland.
- Morén I, Wörman A, Riml J (2018) Design of stream remediation measures for nutrient retention and attenuation in the hyporheic zone. The 3rd BONUS symposium: Sustainable Ecostystem Governance under Changing Climate and Land Use in the Baltic Sea Region. Gdansk, Poland, 14-16 March 2018.
- Olesen JE, Bar-Michalczyk D, Bosshard T, Børgesen CD, Hansen AL, Jabloun M, Refsgaard JC, Wachniew P (2018) Nitrogen leaching losses from two Baltic Sea catchments under scenarios of changes in land use, land management and climate. The 3rd BONUS symposium: Sustainable ecosystem governance under changing climate and land use in the Baltic Sea Region. Gdansk, 14-16 March 2018.
- Refsgaard JC, Olesen JE, Wachniew P, Wörman A, Bartosova A, Steljes N, De Jonge H, Chubarenko B, Jakobsen R (2018) Reducing nutrient loads from agricultural soils to the Valtic Sea via groundwater and stream. The 3rd BONUS symposium: Sustainable Ecostystem Governance under Changing Climate and Land Use in the Baltic Sea Region. Gdansk, Poland, 14-16 March 2018.
- Refsgaard JC, Hansen AL, Højberg AL, Olesen JE, Hashemi F, Wachniew P, Wörman A, Bartosova A, Steljes N, De Jonge H, Chubarenko B (2018) Spatially differentiated regulation – can it save the Baltic Sea from excessivbe nutrient loads, and is it possible? The 3rd BONUS symposium: Sustainable Ecostystem Governance under Changing Climate and Land Use in the Baltic Sea Region. Gdansk, Poland, 14-16 March 2018.
- Stelljes N, McGlade K, Martinez G (2018) Spatially differentiated regulation of nutrients – stakeholder perceptions in three different case study sites. The 3rd BONUS Symposium Sustainable Ecosystem Governance under Changing Climate and Land Use in the Baltic Sea Region, Gdańsk, Poland.
- Wachniew P, Martinez G, Bar-Michalczyk D, Kania J, Malina G, Michalczyk T, Różański K, Witczak S, Zieba D, Żurek AJ, Berrini A (2018) Two dimensions of nitrate pollution management in an agricultural catchment. The 3rd BONUS symposium: Sustainable Ecostystem Governance under Changing Climate and Land Use in the Baltic Sea Region. Gdansk, Poland, 14-16 March 2018.
- Wörman A, Riml J, Capell R, Morén I (2018) Scenario analysis for stream restoration actions aimed at reducing nutrient loads to the Baltic Sea. The 3rd BONUS symposium: Sustainable Ecostystem Governance under Changing Climate and Land Use in the Baltic Sea Region. Gdansk, Poland, 14-16 March 2018.
- Zandersen M, Hyytiäinen K, 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 (2018) Using extended socio-economic scenarios to investigate drivers and pressures on the Baltic Sea up to 2100. The 3rd BONUS symposium: Sustainable Ecostystem Governance under Changing Climate and Land Use in the Baltic Sea Region. Gdansk, Poland, 14-16 March 2018.
- 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 (2018) Long term impacts of societal and climatic changes on nutrient loading to the Baltic Sea. The 3rd BONUS symposium: Sustainable Ecostystem Governance under Changing Climate and Land Use in the Baltic Sea Region. Gdansk, Poland, 14-16 March 2018.

BONUS SOILS2SEA has received funding from BONUS (Art 185) funded jointly from the European Union's Seventh Programme for research, technological development and demonstration, and from Baltic Sea national funding institutions.

- Bartosova A (2018) Nutrients in Runoff to Baltic Sea: What can we say about the future? Baltic Sea Future Congress – Innovation, vision and leadership for a sustainable Baltic Sea region. Stockholm, Sweden, 8-9 March 2018
- Bartosova A (2017) From Source to Sea: Fostering Global Water Quality Knowledge and Community. IAHS-ICWQ-Panta Rhei Workshop on Water quality – a component of the water-energy-food nexus. Guangzhou, China, 4-5 December 2017.
- Martinez G (2017) Ethnographic Studies and governance, "The frontier of sustainability transitions. Cultural adaptations of sustainability policies in European peripheral regions" presentation at a workshop organised by University of Eastern Finland, Catania, Italy
- Martinez, G (2017) Management of Anthopogenic Processes under Different Cultural Memory Regimes at European Society for Environmental History Biennial Conference, Zagreb, Croatia
- Żurek A, Różański K, Witczak S (2017) Lagtime of pollutant transport through catchments: reducing nutrient loadings to the Baltic Sea. 44th annual congress of the International Association of Hydrogeologists (IAH), Dubrovnik, Croatia.
- Bartosova A, Arheimer B, Capell R, Donnelly C, Strömqvist J (2017) Spatial patterns and trend analyses on pan-European scale: modelling of riverine nutrient concentrations. International Interdisciplinary Conference on Land Use and Water Quality: Effect of Agriculture on the Environment. The Hague, Netherlands, 29 May – 1 June 2017.
- Hansen AL, Refsgaard JC, Olesen JE, Børgesen CD, Karlsson IB (2017) Potential benefits of a spatially targeted regulation based on detailed N-reduction maps to reduce N-load from agriculture in groundwater dominated catchments. International Interdisciplinary Conference on Land Use and Water Quality: Effect of Agriculture on the Environment. The Hague, Netherlands, 29 May – 1 June 2017.
- Refsgaard JC (2017) Can distributed catchment models provide reliable predictions at the scales relevant for the Water Framework Directive and the Flood Directive? European Geosciences Union General Assembly, Vienna, Austria 23-28 April, 2017.
- Malina G (2017) Scientific and social dimensions of reducing nutrient loadings from agricultural soils to the Baltic Sea. Presentation at XXIII Int. Conference on: Remediation - Reclamation - Revitalisation, PZiTS Poznan – Kolobrzeg, 26-28 April 2017. In Polish.
- Wachniew P, Bar-Michalczyk D, Kania J, Malina G, Różański K, Michalczyk T, Różański K, Witczak S, Zięba D, Żurek A (2016) Understanding of a coupled groundwater - surface water system as a framework for mitigation of nitrate pollution in an agricultural catchment. 43rd IAH Congress, Montpellier, 25-29.09. 2016
- Refsgaard JC, Chubarenko B, De Jonge H, Donnelly C, Jacobsen R, Olesen JE, Stellies N, Wörman A, Wachniew P (2016) Spatially differentiated regulation measures to reduce nutrient load from agricultural areas to the Baltic Sea – potential and methodologies. Invited keynote at International Groundwater Quality Conference, GQ16, Shenzhen, China, 24-28 July 2016.
- Michalczyk T, Bar-Michalczyk D, Kania J, Malina G, Szklarczyk T, Witczak S, Żurek A, Różański K, Wachniew P, Zięba D (2016) Rating migration of nitrates in the area of power supply underground water Wierzchowisko in the light of the BONUS-Soils2Sea project (in Polish). Conference on Current Problems of Groundwater Intakes and Exploitation, 2-3 June 2016, Częstochowa, Poland.
- Wachniew P, Zięba D, Różański K, Michalczyk T, Bar-Michalczyk D, Kania J, Żurek A, Malina G,Witczak S (2016) The use of surface watercourses in monitoring of the quality of exploited groundwater reservoirs (in Polish). Conference on Current Problems of Groundwater Intakes and Exploitation, 2-3 June 2016, Częstochowa, Poland.
- Bartosova A, Arheimer B, Capell R, Donnelly C, Strömqvist J (2016) Pan-European modelling of riverine nutrient concentrations. European Geosciences Union General Assembly, Vienna, Austria, 17-22 April 2016.
- Riml J, Wörman A (2016) Spectral scaling of hydrochemical responses – decomposition of water quality time series, Abstract of EGU General Assembly 2016, Session HS2.3.7 - Controls on non-stationary catchment response and spatial water quality dynamics: EGU2016-11558

BONUS SOILS2SEA has received funding from BONUS (Art 185) funded jointly from the European Union's Seventh Programme for research, technological development and demonstration, and from Baltic Sea national funding institutions.

- Wörman A, Morén I, Riml J (2016) Using a spectral approach to compare dynamic and static head driven hyporheic exchange, Abstract of EGU General Assembly 2016, Session HS2.3.7 - Controls on non-stationary catchment response and spatial water quality dynamics: EGU2016-15568
- Morén I, Riml J, Wörman A (2016) Predicting mean residence time and exchange velocity in the hyporheic zone of restored streams, Abstract of EGU General Assembly 2016, Session HS10.11 - GW-SW interactions: biogeochemical and ecologic processes: EGU2016-8319
- Wörman A, Lindström G, Riml J (2015) Climatic and land-use driven change of runoff throughout Sweden. Paper No. H44C-03, America Geophysical Union Fall Meeting, San Francisco, 14 - 18 December 2015.
- Strömqvist J, Arheimer B, Capell R, Donnelly C, Simonsson L (2015) Analysis of observed and modelled nutrient concentrations in Europe. UNESCO-IHP Regional Consultation Meeting. Water Quality in Europe: Challenges and Best Practices. Koblenz, Germany 1-4 Dec 2015.
- Domnin D, Chubarenko B, Gorbunova J, Vorobjeva E (2015) Scientific-methodological approach to assessment of nutrient load on marine areas in the South-Eastern Baltic within the activities of Russia on execution of HELCOM Action Plan for the Baltic Sea. XIV All-Russia Forum «Strategic planning in the regions and cities of Russia». Saint-Petersburg, 19 October 2015.
- Hansen AL, Gunderman D, He X and Refsgaard JC (2015) Uncertainty assessment of spatially distributed nitrate reduction potential in groundwater using multiple geological realizations. Land Use and Water Quality 2nd conference, Vienna, Austria, 21-24 September 2015
- Malina G (2015) The role of groundwater in reducing nutrients of agricultural origin loadings into the Baltic Sea – the Soils2Sea project. Presentation at XXI Int. Conference on: Remediation - Reclamation - Revitalisation, PZiTS Poznan – Kolobrzeg, 15-18 April 2015. In Polish.
- Różański K (2015) Timescales of groundwater flow: A contemporary perspective. European Society of Isotope Research (ESIR) Workshop XIII, Zadar, Croatia, September 20-24, 2015.
- Wachniew P, Zięba D, Michalczyk T, Bar D, Jaszczur M, Żurek A, Różański K, Witczak S (2015) The influence of groundwater on streamflow and on water quality In a lowland catchment. Aqua 2015 42nd IAH Congress, Rome, Italy, 13-18 September 2015.
- Kania J, Witczak S, Szklarczyk T, Michalczyk T, Różański K, Duliński M, Zięba D, Wachniew P (2015) Use of environmental isotope tools for the assessment of groundwater resources and their vulnerability in a fissured-carbonate aquifer.Aqua 2015 42nd IAH Congress, Rome, Italy, 13-18 September 2015.
- Hinsby K, Refsgaard JC (2015) Reducing nutrient loadings from agricultural soils to the Baltic Sea via groundwater and streams – BONUS Soils2Sea. 28th Working Group Groundwater Plenary Meeting, European Commission, Brussels, 14-15 April, 2015.
- Åkesson A, Wörman A (2015) A streamflow routing approach to address temporal change in streamflow response. Abstract of EGU General Assembly 2015, Session HS2.4.3
- Zmijewski N, Wörman A, Bottacin-Busolin A (2015) Incorporating routing into reservoir planning optimization models. Abstract of EGU General Assembly 2015, Session ERE3.8/HS5.6
- Morén I, Riml J, Wörman A (2015) Linking transient storage parameters to exchange mechanisms and reach characteristics. Abstract of EGU General Assembly 2015, Session HS10.
- Riml J, Wörman A (2015) Analyses of tracer time series to decompose the watershed response across a spectrum of spatio-temporal scales. Presentaion No. EGU2015-12773 at the Annual General Assembly of the European Geosciences Union, 12-17 April, 2015
- Wörman A, Riml J (2015) Spectral decomposition of time-scales in hyporheic exchange. Abstract of EGU General Assembly 2015, Session HS10.11
- Domnin D, Refsgaard JC, Chubarenko B (2015) Assessment of transportation and retention of nutrients by surface waters of catchments: objectives and first results of the Soils2Sea project. Proc. of XVI International Ecological Forum “Baltic Sea Days". Saint-Petersburg, 18-20 March, 2015, - Saint-Petersburg: Ecology and Business, 2015, P. 302-304.

BONUS SOILS2SEA has received funding from BONUS (Art 185) funded jointly from the European Union’s Seventh Programme for research, technological development and demonstration, and from Baltic Sea national funding institutions.

- Domnin D, Chubarenko B (2014) Experience in the development of program for the integrated management of transboundary segments of Kaliningrad Oblast coastal zone // XIII All-Russian Forum "Strategic Planning in the Regions and Cities of Russia" - St. Petersburg. - October 27-28, 2014.
- Domnin D, Kesoretskih I (2014) GIS maps for the Neman and Pregolya River Basins in Kaliningrad oblast: classification criteria, information sources and confidence level // Technical workshop "GIS mapping of water bodies in Lithuania, Poland, Belarus and Kaliningrad Oblast (Russia) for management of transboundary Neman and Pregolya river basins", Ryn, Poland, October 5-7, 2014.
- Åkesson A, Wörman A (2014) Geomorphological control on streamflow response. AGU Chapman Conference, Luxembourg 23 – 26 September 2014.
- Domnin D, Chubarenko B (2014) Assessment of nutrient load to the Vistula Lagoon from small catchment of Kaliningrad Oblast // 10th Basin Council. - Kaliningrad. - July 29-30, 2014
- Chubarenko B, Domnin D (2014) Numerical modeling assessment of nutrient load from small transboundary watersheds of the Kaliningrad Oblast // Baltic Sea Days 15. - St. Petersburg. - March 19-21, 2014.

Poster presentations (chronological order)

- Bartosova A, Capell R, Strömqvist J, Olesen JE, and Arheimer B (2018) Nutrient concentrations and transport at Pan-European scale – from 1900s to 2050s. European Geosciences Union General Assembly, Vienna, Austria, 8-13 April 2018
- Gorbunova J, Domnin D, Chuarenko B (2018) Scenarios for socio-economic development as drivers for nutrient load for the transboundary Pregolya River catchment (the Vistula Lagoon). 8th European Coastal Lagoons Symposium. Athens, Greece, from 20 - 23 March 2018.
- Bartosova A, Strömqvist J, Capell R, Simonsson L, and Arheimer B (2018) Patterns and trends in riverine water quality in the Baltic Sea basin: modeling nutrients with HYPE. The 3rd BONUS symposium: Sustainable Ecostystem Governance under Changing Climate and Land Use in the Baltic Sea Region. Gdansk, Poland, 14-16 March 2018.
- Domnin D, Chubarenko B, Voropaev R (2018) Scenario analysis of the Pregolya River discharge as response to changing climate conditions. The 3rd BONUS symposium: Sustainable Ecostystem Governance under Changing Climate and Land Use in the Baltic Sea Region. Gdansk, Poland, 14-16 March 2018.
- Gorbunova J, Domnin D, Chuarenko B (2018) Assessment of nutrient concentrations and export for the Pregolya River (South-Eastern Baltic) by monitoring data 2014 – 2016. The 3rd BONUS symposium: Sustainable Ecostystem Governance under Changing Climate and Land Use in the Baltic Sea Region. Gdansk, Poland, 14-16 March 2018.
- Hansen AL, Jakobsen R, Refsgaard JC, Højberg AL, Iversen BV, Kjærgaard C (2018) Understanding shallow groundwater dynamics and the effect of tile drainage on flow paths around the redox inteface in a Danish till area. The 3rd BONUS symposium: Sustainable Ecostystem Governance under Changing Climate and Land Use in the Baltic Sea Region. Gdansk, Poland, 14-16 March 2018.
- Hashemi F, Olesen JE, Jabloun M, Hansen AL (2018) Methods of spatially targeting agricultural mitigation measures for reducing uncertainty of estimated nitrogen load reductions to aquatic systems. The 3rd BONUS symposium: Sustainable ecosystem governance under changing climate and land use in the Baltic Sea Region. Gdansk, 14-16 March 2018.
- Martinez G, Berrini A (2018) The making of the documentary film Soils2Sea: How narrative films complement scientific investigation. The 3rd BONUS Symposium Sustainable Ecosystem Governance under Changing Climate and Land Use in the Baltic Sea Region, Gdańsk, Poland.
- Ptak EN, Busck AG, Refsgaard JC (2018) A study of the nitrate management discourse in Poland and a comparison with Denmark. The 3rd BONUS symposium: Sustainable Ecostystem Governance under Changing Climate and Land Use in the Baltic Sea Region. Gdansk, Poland, 14-16 March 2018.
- Riml J, Morén I, Wörman A, Zięba D, Wachniew P (2018) Nutrient retention in a remediated stream – evaluation of a tracer experiment with ^{15}N, ^{32}P and ^{3}H. The 3rd BONUS symposium: Sustainable Ecostystem

BONUS SOILS2SEA has received funding from BONUS (Art 185) funded jointly from the European Union's Seventh Programme for research, technological development and demonstration, and from Baltic Sea national funding institutions.

Governance under Changing Climate and Land Use in the Baltic Sea Region. Gdansk, Poland, 14-16 March 2018.

- Żurek AJ, Różański K, Witczak S (2018) Lagtime of pollutant transport through catchments: reducing nutrient loadings to the Baltic Sea. The 3rd BONUS symposium: Sustainable Ecostystem Governance under Changing Climate and Land Use in the Baltic Sea Region. Gdansk, Poland, 14-16 March 2018.
- Stelljes (2017) Future governance approaches for reducing nutrients at local farm scale – insights from the project Soils2Sea. ECCA 2017, Glasgow, Scotland.
- Zięba D, Najman J, Bar-Michalczyk D, Michalczyk T, Żurek A, Wachniew P, Różański K (2017) Identification of nitrate origin in groundwater by measurements of δ15N and δ18O and N2 excess. 44th annual congress of the International Association of Hydrogeologists (IAH), Dubrovnik, Croatia.
- Bar-Michalczyk D, Michalczyk T, Kania J, Żurek A (2017) Modelling impact of changing in agricultural land use on the nitrogen outflow from middle size catchment in S Poland. 44th annual congress of the International Association of Hydrogeologists (IAH), Dubrovnik, Croatia.
- Żurek A, Różański K, Witczak S (2017) Lagtime of river systems to changes in pollutant load on the catchment: a regional scale assessment (2017) EGU European Geosciences Union General Assembly, Vienna, Austria.
- Wachniew P, Bar-Michalczyk D, Kania J, Malina G, Michalczyk T, Różański K, Witczak S, Zieba D, Żurek A, (2017) Two dimensions of nitrate pollution management in an agricultural catchment. EGU European Geosciences Union General Assembly, Vienna, Austria.
- Iversen BV, Kjærgaard C, Petersen RJ, Christensen S, Rasmussen KR (2016) Predicting tile drainage discharge. ASA, CSSA, SSSA 2016 Annual Meeting - Arizona, USA.
- Wachniew P, Kania J, Szklarczyk T, Witczak S, Michalczyk T,Różański K, Duliński M. Calibration of transient transport model for fissured-karstic aquifer in southern Poland with the aid of tritium data. 43rd IAH Congress, Montpellier, 25-29.09. 2016.
- Stelljes N, McGlade, K (2016) Reducing nutrient loadings from agricultural soils to the Baltic Sea via groundwater and streams (Soils2Sea).ECSA 56: Coastal systems in transition: From a 'natural' to an 'anthropogenically-modified' state, Bremen, September 2016.
- Domnin D, Chubarenko B, Capell R (2016) Mathematical modeling of nutrient loading from small catchments of the Vistula Lagoon. Abstracts book of EMECS'11 – Sea Coasts XXVI Joint Conference (22-27 August, St-Petersburg). St-Petersburg: RSHU, 2016. P. 215
- Bar-Michalczyk B, Duliński M, Kania J, Malina G, Różański K, Szklarczyk T, Wachniew P, Witczak S, Zięba D, Żurek A (2016) Groundwater transit time distribution and transfer of nitrates from soils to river network*,* EGU General Assembly 2016, Vienna, Austria, 17-22 April 2016.
- Zięba D, Wachniew P, Bar-Michalczyk D, Kania J, Malina G, Różański K, Michalczyk T, Różański K, Witczak S, Żurek A (2016) Downstream changes of water quality in a lowland river due to groundwater inflows*.,* EGU General Assembly 2016, Vienna, Austria, 17-22 April 2016.
- Åkesson A, Wörman A, Riml J, Seibert J (2015) Temporal Change in Discharge Response in Unregulated Swedish Catchments - Quantifying Potential Effects of Anthropogenic Modifications in Stream Network Properties on Flow Time Distributions. Paper No. H43E-1552, America Geophysical Union Fall Meeting, San Francisco, 14 - 18 December 2015.
- Pilipchuk V, Domnin D, Karmanov K (2015) Assessment of nutrient concentrations in the Pregolya River catchment by monitoring 2014-2015. Proc of the "IX All-Russian scientific-practical conference of young scientists on water ecosystem problems «Pontus Euxinus 2015», Kovalevskii;s Institute of Marine Biological Researches , Sebastopol, 17-20 November, 2015. Sebastopol, DigitPrint, 2015. P. 119-121.
- Bar D, Nędzka M, Sroka K, Zięba D, Michalczyk T, Kania J, Malina G, Różański K, Wachniew P, Witczak S, Żurek A (2015) Nitrogen and phosphorus in the sediments and waters in rivers of Kocinka catchment. Solving societal challenges; working with sediments : 9th International SedNet conference. 23–26 September 2015, Krakow, Poland.
- Refsgaard JC (2015) Reducing nutrient loadings from agricultural soils to the Baltic Sea via groundwater and streams (Soils2Sea). 10th Baltic Sea Science Congress, Riga, 16-19 June, 2015.

BONUS SOILS2SEA has received funding from BONUS (Art 185) funded jointly from the European Union's Seventh Programme for research, technological development and demonstration, and from Baltic Sea national funding institutions.

- Gorbunova J, Domnin D, Chubarenko B (2015) Analysis of scenarios for socio-economic development and climat chnges of the Pregolya River catchment as a determining factor in the nutrient load. 10th Baltic Sea Science Congress BSSC 2015, Riga, 15-19 June, 2015.
- Stelljes N, Reid A (2015) Reducing nutrient loadings from agricultural soils to the Baltic Sea via groundwater and streams (Soils2Sea). European Climate Change Adaptation Conference (ECCA2015), Copenhagen, May 2015.
- Vendelbo AL, de Jonge H, Rozemeijer J, de Jonge, LW (2015) Continuous Passive Sampling from Agricultural Subsurface Drainage Tubes. Geophysical Research Abstracts Vol. 17, EGU2015-14310, 2015 EGU General Assembly.
- Hinsby K, Refsgaard JC (2015) Groundwater and stream threshold values for targeted and differentiated output based regulation of nutrient loadings to ecosystems. Geophysical Research Abstracts, 17, EGU2015-9225. Poster at the Annual General Assembly of the European Geosciences Union, 12-17 April, 2015.
- Capell R, Hansen AL, Donnelly C, Refsgaard JC, Arheimer B (2015) Modelling nutrient reduction targets – model structure complexity vs. data availability, EGU General Assembly 2015, Vienna, Session HS5.1, EGU2015-10149
- Riml J, Wörman A (2014) Decomposition of solute dispersion in watersheds across a spectrum of spatio-temporal scales. Presentation no: H33G-0925 at the Fall Meeting of the American Geophysical Union, San Francisco, 15-19 December, 2014.
- Żurek A, Wachniew P, Różański K, Witczak S, Kania J (2014) Isotope methods as a tool to characterize nitrate origin and transport in Kocinka catchment (central Poland): preliminary results. EGU General Assembly, 27 April – 2 May 2014, Vienna, Austria.

Other activities (chronological order)

- Refsgaard JC (2017) Participant in workshop ”Clear Waters – Added value of cooperating in project platforms”. Workshop organised by Interreg Baltic Sea Reguion Secretariat with participation of HELCOM and BONUS. Berlin, 28 March 2017.
- Hinsby K (2015) BONUS Soils2Sea presented at the 28th Working Group Groundwater plenary meeting14-15 april 2015 under the Common Implementation Strategy of the Water Framework Directive, European Commission.
- Martinez G (2015) Hosting of a world-café table at the workshop ‘Soils and Seas in the Nexus - Linking Sustainable Land Management and the Coastal and Marine Environments’ that was held as part of the Global Soils Week in Berlin, April 2015 (http://globalsoilweek.org/global-soil-week/gsw-2015)
- Matinez G, Stelljes N (2014) Presentation of BONUS Soils2Sea at an information booth hosted by the Federal Ministry of Education and Research (BMBF). POLEKO exhibition of advanced environmental protection in Eastern Europe, POLEKO, 14-17 September 2014, Poznan, Poland.
- Martinez G (2014) Participating in a panel discussion on “Successful cooperation: research, development, innovation”. 5th Annual Forum of the EU Strategy for the Baltic Sea Region (EUSBSR) jointly with the 16th Baltic Development Forum Summit, 3-4 June 2014, Turku, Finland.

Presentations at BONUS events

- Refsgaard JC (2017) BONUS 10 year Jubilee and Project Coordinators Forum. Helsinki, 3-4 May 2017.
- Refsgaard JC (2016) Participating in a panel discussion on ”uses of scenarios in research and policy support”. BONUS PILOT WORKSHOP ON SCENARIOS; Helsinki, 6.-7.4.2016
- Refsgaard JC (2015) Reducing nutrient loadings from agricultural soils to the Baltic Sea via groundwater and streams (Soils2Sea). BONUS Information event, 2 December 2015, Brussels.

BONUS SOILS2SEA has received funding from BONUS (Art 185) funded jointly from the European Union’s Seventh Programme for research, technological development and demonstration, and from Baltic Sea national funding institutions.

- Refsgaard JC (2014) Reducing nutrient loadings from agricultural soils to the Baltic Sea via groundwater and streams (Soils2Sea). Oral presentation at COCOA kick-off meeting, Jyllinge, 10 March, 2014.
- Refsgaard JC (2014) Reducing nutrient loadings from agricultural soils to the Baltic Sea via groundwater and streams (Soils2Sea). Oral presentation at "Kick-off meeting of the BONUS projects starting in 2014", Riga, 26-27 August, 2014.

Contributions to development and implementation of regulations, policies and management practices (performance statistics # 1)

- Refsgaard JC (2017) Preliminary key results and policy recommendations from BONUS SOILS2SEA. HELCOM workshop, Stockholm, 6. November 2017.
- Bartosova A (2017) oral presentation and participation at HELCOM – BONUS BALTICAPP regional workshop on the use of ecological-economic research to support and improve marine policy implementation in the Baltic Sea region, Stockholm, 29-30 March 2017
- Chubarenko B, Domnin D (2016) Invited lecture "Problems of nutrient pollution of the Baltic Sea: from local to international level" at the Inception Workshop in Kaliningrad in the frame of the ICLD Program on cooperation between municipal and regional authorities of self-governmental level of Sweden and Russia, 08 November, 2016, Kaliningrad
- Hinsby K (2014-2015-2016) Leading the preparation of Technical Report "Groundwater associated aquatic ecosystems" (including examples of the derivation of groundwater threshold values based on good status objectives for associated aquatic ecosystems) prepared by CIS Working Group on Groundwater supporting the implementation of the Groundwater Directive and the Water Framework Directive. The Report was published in October 2015 (European Commission, 2015)

Suggestions for designing, implementing and evaluating the efficacy of public policies and governance (performance statistics # 2)

- Refsgaard JC (2017) Perspectives with spatially targeted measures and regulation (In Danish). Workshop with stakeholders and government representatives. Thyregod, Denmark, 12 June, 2017.
- Chubarenko B. (October 30, 2017). Presentation of proposal on organisation of Working Group on Adaptation to Climate Changes at the meeting of Public Council on Nature Use and Ecology of the Ministry of Environment of the Government of the Kaliningrad Oblast
- De Jonge H (2014) Presentation and debate of Sorbisense environmental monitoring concept to the Danish minister of Environment, Mrs. Kirsten Brosbøl
- De Jonge H (2014) Presentation and debate meeting with Danish farmer organization "Bæredygtig Landbrug", with more than 400 participants
- De Jonge H (2014) Debate and panel meeting organized by trade organization "Dansk Miljøteknologi", with delegates of the Danish Ministry of Environment
- Morén I, Riml J, Wörman A (2015) A paper has been produced that contains a methodology for evaluating the quantitative effect of local remediation actions in streams on hyporheic exchange, such as from riffle structures, bed substrate and meanders

BONUS SOILS2SEA has received funding from BONUS (Art 185) funded jointly from the European Union's Seventh Programme for research, technological development and demonstration, and from Baltic Sea national funding institutions.

Members or observers in stakeholder committees e.g. in EC or HELCOM

(performance statistics # 3)

- Chubarenko B. (2018) Member of the Public Ecological Council at the Ministry of Environment of the Government of the Kaliningrad Oblast
- Domnin D (2017) Expert of the Water Users Partnership of Gurjevsk Municipality, Kaliningrad Oblast
- Chubarenko B (2016-2018) Member of Regional Public Council on Coastal Protection, Ministry of Construction, the Government of the Kaliningrad Oblast
- Chubarenko B (2015) Member of HELCOM-VASAB MSP working group *(Boris Chubarenko, ABIORAS)*
- Hinsby K (2014-2016) Member of European Working Group on Groundwater under the Common Implementation Strategy (CIS) for the Water Framework Directive
- Hinsby K (2014-2016) Member of stakeholder committee in the project "Future land use in Denmark" executed by the Danish Board of Technology and Aalborg University - http://www.tekno.dk/article/danmarks-areal-i-fremtiden/
- Refsgaard JC (2014-2018) Member of Scientific Technological Board, Joint Programming Initiative Water (Water JPI)
- Olesen JE (2017-) Member of the Scientific Advisory Board of Joint Programming Initiative Agriculture Food Security and Climate Change (FACCE JPI)
- Chubarenko B (2014) Member of the Public Council at ROSPRIRODNADZOR (environmental control) authority)

International, national and regional stakeholder events organised by Soils2Sea (performance statistics # 4)

- 3rd BONUS Symposium "Sustainable Ecosystem Governance under Changing Climate and Land Use in the Baltic Sea Region" Gdansk 14-16 March 2018, organised jointly with BONUS GO4BALTIC, BONUS BALTICAPP and BONUS MIRACLE. Among the more than 120 attending participants, were 19 BONUS SOILS2SEA scientists plus eight stakeholders and 2 keynote speakers invited and sponsored by BONUS SOILS2SEA.
- First Governance Up-Scaling Workshop, Berlin, Germany May 2017
- Second Governance Up-Scaling Workshop, Gothenburg, Sweden, October 2017
- Third Governance Up-Scaling Workshop, Olstyn, Poland, November 2017
- Film-screening and discussion of the Soils2Sea documentary in Berlin (December 2016)
- 2nd Stakeholder workshop in Norsminde catchment organised jointly by GEUS and Ecologic in collaboration with SEGES and Norsminde Catchment Council, 24 November 2016.
- 2nd Stakeholder workshop in Tullstorps Brook catchment organized jointly by KTH, SMHI and Ecologic, 15-16 November 2016.
- 2nd Stakeholder workshop in Kocinka catchment organised jointly by AGH and Ecologic, 13-14 October 2016.
- Stakeholder workshop in Norsminde catchment organised jointly by GEUS, AU and Ecologic in collaboration with SEGES and Norsminde Catchment Council, 11 December 2014.
- Stakeholder workshop in Kocinka catchment organised jointly by AGH and Ecologic, 11 December 2014.
- Stakeholder workshop in Tullstorps Brook catchment organized jointly by KTH, SMHI and Ecologic, 22 November 2014.
- Soils2Sea Advisory Panel meeting in Berlin 17-19 May 2017.
- Soils2Sea Advisory Panel meeting in Krakow 30 September – 2 October 2015.
- Soils2Sea Advisory Panel meeting in Stockholm 8-9 September 2014.

BONUS SOILS2SEA has received funding from BONUS (Art 185) funded jointly from the European Union's Seventh Programme for research, technological development and demonstration, and from Baltic Sea national funding institutions.

Joint events/co-operation activities/partnerships with non-Baltic research actors (performance statistics # 5)

- SMHI (Alena Bartosova, Berit Arheimer) has participated in an IAHS-driven initiative to identify "23 Unsolved Problems in Hydrology " (2017-2018)
- GEUS (Jens Christian Refsgaard, Anker L Højberg, Emilia Ptak) and Ecologic (Grit Martinez, Nico Stelljes) participated in a writing-workshop in Copenhagen, 28-29 November 2016 to prepare a common scientific paper on international comparison of water co-governance examples.
- KTH has cooperated with Utah State University and Indiana State University, U.S.A., which has resulted in a common scientific paper (Water Resources Research) on how to delineate spatially variable parameters in streams.
- GEUS (Klaus Hinsby) is on behalf of the EuroGeoSurveys (European Geological Surveys) developing a framework for collaboration with the Joint Research Centre of the European commission within areas of groundwater and integrated hydrological modelling of river basins etc. (2014-2015).
- GEUS (Klaus Hinsby) is on behalf of the EuroGeoSurveys (European Geological Surveys) developing a framework for a new ERA-Network for Applied Geoscience with topics including integrated catchment modelling and nutrients – inspired by Soils2Sea (2016).
- SMHI (Alena Bartosova) has participated in International Workshop on Estimation of nitrogen loads to the marine environment around the time of the year 1900 and presented on evolution of landscape processes and hydrology with respect to nitrogen concentrations (2016)
- SMHI has contributed with their knowledge of the availability of pan-Baltic discharge and nutrient data to the European EMODnet project, Baltic Sea Checkpoint (2015).
- SMHI has contributed with their knowledge of the availability of pan-Baltic discharge and nutrient data to the European EMODnet project, Baltic Sea Checkpoint (2015).
- SMHI has initiated a collaborative experiment using the SWITCHON platform (http://www.water-switch-on.eu) with a research partner in the UK (JBA consulting) on "Estimating riverine nutrient concentrations in agricultural catchments". (2014)
- KTH has participated in an international collaboration in terms of a writing project that resulted in an extensive review paper on biogeochemical processes in the hyporheic zone of streams and which is recently published in Reviews of Geophysics. The collaboration has been a joint effort between Northwestern University and USGS in U.S.A., Politecnico di Torino and University of Padua in Italy and the Royal Institute of Technology. (2014)
- AGH has cooperated with Laboratoire de glaciologie et géophysique de l'environnement (LGGE) in Grenoble, France on analyses of stable isotope composition of nitrates in water samples collected in the Kocinka catchment (2016)

Entries to openly accessible common databases, storing original data from the entire Baltic Sea Basin system or larger geographical area (performance statistics # 9)

- Download of data from CORINE LAND COVER (*ABIORAS*)
- Download of climate projections from the CORDEX data base (*ABIORAS*).
- Results from scenario simulations at the Baltic Sea scale are available to public from HYPEweb, http://hypeweb.smhi.se/soils2sea/ (SMHI)
- SMHI has added the E-HYPE v3.1 nutrient modelling results for all of Europe (created with a focus on the Baltic Sea basin as part of S2S) onto hypeweb for free online visualisation and download: http://hypeweb.smhi.se/europehype/long-term-means/ (SMHI)

BONUS SOILS2SEA has received funding from BONUS (Art 185) funded jointly from the European Union's Seventh Programme for research, technological development and demonstration, and from Baltic Sea national funding institutions.

Popular Science Journal Papers (performance statistics # 10)

- Olesen JE (2016). Tragedien om kvælstof. Landbrugsavisen. Nr. 10, s. 6.
- Olesen JE (2016). Er landbrug bæredygtigt. Landbrugsavisen. Nr. 18, s. 6.
- Olesen JE (2016). Kvælstofudfordringen: Hvad indebærer målrettede indsatser og målrettet regulering i kvælstofindsatsen? Momentum. Nr. 2, s. 14-16.
- Olesen JE (2015) Landmænd skal producere mere og grise mindre. Teknik og Miljø, Stads- og Havneingeniøren 5, 21.
- Olesen JE (2015) Faldende proteinindhold i korn. Grovvarenyt 26, 10-11.
- Olesen JE (2016) Gode løsninger skabes sammen. Landbrugsavisen. Nr. 38, s. 6.
- Olesen JE (2017) Lær at elske efterafgrøderne. Landbrugsavisen. Nr. 3., s. 6.

Interviews to media (performance statistics # 11)

- Videnskab.dk. https://videnskab.dk/naturvidenskab/det-er-slemt-forskere-stimler-sammen-for-at-redde-oestersoeen. 16.03.2018 (GEUS, 2018)
- Videnskab.dk. https://videnskab.dk/naturvidenskab/oestersoeen-lider-behov-for-indgreb-der-goer-ondt-paa-landbruget. 22.03.2018 (GEUS, 2018)
- Fiskeforum. http://www.fiskerforum.dk/erhvervsnyt/a/forskere-var-samlet-i-gdansk-for-at-redde-oestersoen-22032018. 22.03.2018 (GEUS, 2018)
- Danish Radio. https://www.dr.dk/nyheder/regionale/bornholm/forsker-oestersoeen-er-udfordret-landmaend-skal-tage-affaere. 23.03.2018 (GEUS, 2018)
- Danish Radio. :HTTPS://WWW.DR.DK/RADIO/P1/ORIENTERING/ORIENTERING-2018-03-23/00:39:27 (GEUS, 2018)
- Science Nordic. http://sciencenordic.com/baltic-sea-needs-intervention. 14.04.2018 (GEUS,2018)
- SMHI News page: https://www.smhi.se/forskning/forskningsnyheter/klimatforandring-och-samhallets-utveckling-paverkar-naringstillforseln-till-ostersjon-1.131916 (SMHI, 2018)
- Polish Press Agency: http://www.pap.pl/aktualnosci/news,1235098,dr-wachniew-polskie-wody-beda-zanieczyszczone-jeszcze-przez-kilkadziesiat-lat.html /(AGH, 2018)
- Polish Radio Kraków: http://www.radiokrakow.pl/wiadomosci/aktualnosci/polskie-wody-beda-zanieczyszczone-jeszcze-przez-kilkadziesiat-lat/ / (AGH, 2018)
- Fakt: http://www.fakt.pl/pieniadze/finanse/do-baltyku-trafiaja-zwiazki-azotu-z-nawozow/gs2cqdz /(AGH, 2018)
- Polish TV Kraków: https://krakow.tvp.pl/35720568/23012018-1830 /(AGH, 2018)
- Polish TV Bydgoszcz http://bydgoszcz.tvp.pl/35689410/20012018 /(AGH, 2018)
- Polish Radio: https://www.polskieradio.pl/13/2772/Artykul/1733436 /(AGH, 2017)
- A Soils2Sea scientist participated in public round table discussion on coastal protection and protection of environment in Kaliningrad Oblast, TV Kaliningrad, January 2017 (ABIORAS, 2017)
- Many interview with Danish media on new nitrogen regulations in Denmark, examplified by this in JyllandsPosten: http://jyllands-posten.dk/politik/ECE8448471/klimaforsker-justerer-sin-kritik-landbrugspakken-er-fornuftig/ / (AU, 2016)
- Interview in Swedish national radio - P3 Nyheter - regarding floods in China, 2016-08-02.
- Intervju for Inrikes Magasin No.10 2016. http://inrikesmagasin.se/2016/11/17/kraften-i-sveriges-vatten-och-vindar/
- KTH News page: https://www.kth.se/forskning/artiklar/forandringar-i-landskapet-okar-risken-for-oversvamningar-1.602098 *(KTH)*
- Swedish Radio: http://sverigesradio.se/sida/artikel.aspx?programid=110&artikel=6302712 *(KTH, 2015)*
- Miljömagasinet: http://www.miljomagasinet.se/artiklar/151111-oversvamningarnas-orsaker.html *(KTH, 2015)*

BONUS SOILS2SEA has received funding from BONUS (Art 185) funded jointly from the European Union's Seventh Programme for research, technological development and demonstration, and from Baltic Sea national funding institutions.

- Forskning.se: http://www.forskning.se/2013/03/13/risken-for-oversvamningar-i-sverige-har-okat/ *(KTH, 2015)*
- Interview to the Lodz regional branch of Polish TV on the project activities in the Kocinka catchment, June 2015 *(AGH, 2015)*
- FoodCulture: http://www.foodculture.dk/Miljoe_og_Klima/Klima/2015/Joergen_E_Olesen_-_Goer_Danmark_til_et_groent_teknologicenter.aspx#.VtPu9k1IhaQ / (*AU, 2015*)
- Danish Radio: https://www.dr.dk/nyheder/politik/faktatjek-advarsel-om-kaempe-co2-svineri-var-overdrevet / (*AU, 2015*)
- Landbrugsavisen: http://landbrugsavisen.dk/%C3%B8kologer-%C3%B8nsker-ikke-krav-om-biogas / (*AU, 2015*)

Multi-media products and TV episodes produced (performance statistics # 12)

- Releas of the documentary film "Soils2Sea: Reducing nutrient loadings into the Baltic Sea" in October 2016.

Other international, national and regional communication, dissemination and public outreach initiatives (contribute to performance statistics # 13 together with papers, conference contribution, BONUS events and other activities)

- Hansen AL (2018) Shallow groundwater dynamics and the effect of tile drainage in a Danish till area. Presentation at TReNDS meeting, 4. Apr 2018, Aarhus, Denmark
- Refsgaard JC (2018) 3rd BONUS Symposium Gdansk 14-16 March 2018. Presentation at TReNDS meeting, 4. Apr 2018, Aarhus, Denmark
- Refsgaard JC (2018) SSPs and scenarios in BONUS projects. Presentation at TReNDS meeting, 4. Apr 2018, Aarhus, Denmark
- BONUS Soils2Sea Newsletter – Issue 3, October 2017
- Bartosova A (2017) Source to Sea Activities at SMHI. Source to Sea Platform Meeting in connection to World Water Week. Stockholm, Sweden, 23 August 2017.
- Martinez G (2017) Screening of SOILS2SEA movie and discussion with participants at community centre “Paul Gustavo“ in Altenburg (Mecklenburg-Vorpommern, Germany) (January 2017)
- Martinez G (2017) Screening of SOILS2SEA movie and discussion with participants at Advisory Council for Regional Planning in Greifswald (Mecklenburg-Vorpommern, Germany) (March 2017)
- Martinez G(2017): Participation in BONUS Miracle governance workshop (Uppsala, December 2017)
- Hansen AL, Ernstsen V (2017) Omsætning af nitrat i undergrunden. Presentation at TReNDS project midway seminar, 28. Feb. 2017
- Hansen AL, Refsgaard JC, Olesen JE, Børgesen CD (2017) Potential benefits of a spatially targeted regulation based on detailed N-reduction maps. Danish Water Forum Annual Meeting, 30. Jan 2017, Copenhagen, Denmark.
- Bar-Michalczyk D (2016) Report from the visit of Polish stakeholders in Sweden and their participation in stakeholder workshop published in the Newsletter of the Mykanow Commune (Dec 2016)
- Hansen AL (2016) Soils2Streams - Nitrogen transport and reduction in groundwater and subsurface drainage. Presentation at TReNDS meeting, 13. Oct 2016, Odder, Denmark
- BONUS Soils2Sea Newsletter – Issue 2, October 2016 and update and translation of BONUS Soils2Sea flyer
- Hansen AL (2016) Estimation of small scale heterogeneity in groundwater nitrate reduction – A modelling study. Presentation at Soils2Sea workshop on Groundwater N-reduction, 14. March 2016, Copenhagen, Denmark

BONUS SOILS2SEA has received funding from BONUS (Art 185) funded jointly from the European Union’s Seventh Programme for research, technological development and demonstration, and from Baltic Sea national funding institutions.

- Hansen AL (2016) Uncertainty assessment of groundwater nitrate reduction maps using multiple geological models. Danish Water Forum Annual Meeting, Copenhagen, 28. Jan 2016,
- SSM:s forskningsdagar 2015. conference organised by Strålsäkerhetsmyndigheten. Presentation: Utströmningsmönster för grundvatten och radioisotoper i ytvatten, Stockholm 19 November 2015.
- BONUS Soils2Sea Newsletter – Issue 1, September 2015
- SVC-dagarna 2015. Organiser of session "Workshop Vattenkrafthydrologi". Presentation "Klimatdrivna fluktuationer i avrinning – Betydelse för regleringsbegränsningar. 20-21 October 2015 *(KTH)*
- BONUS Soils2Sea flyer, June 2014
- Hydrologidagarna 2014, Stockholm University, 18 March 2014. Change in the runoff periodicity and energy potential of surface water in Sweden. *(KTH)*

Postgraduate courses (performance statistics # 14)

- A PhD course was organized as part of a Marie Currie ITN project HypoTRAIN and with input from Soils2Sea, 28 – 30 November 2015. It had 12 participants, including Soils2Sea participants, and provided the scientific basis of the hyporheic zone and how it relates to remediation actions in streams aimed at reducing nutrient export.

BONUS SOILS2SEA has received funding from BONUS (Art 185) funded jointly from the European Union's Seventh Programme for research, technological development and demonstration, and from Baltic Sea national funding institutions.