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Volume of Abstracts

Compiled by Dico Fraters and Karel Kovar

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The abstracts in this volume were selected and evaluated by members of the Scientific Advisory Committee, resulting in the allocation in the oral presentations (platform presentation) and poster presentations. This volume contains only those abstracts that are expected to be actually presented at the conference.

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PREFACE

Agriculture provides food, fibre, energy, and, last but not least, it provides a living for many people around the world. The potential drawback of agricultural production is pollution of the terrestrial and aquatic environment by nutrients, pesticides, trace elements, anti-biotics, natural and synthetic hormones, and newly arising problem substances such as plastics and PFAS. Growth in agricultural production, as it has occurred in Europe and North America since 1950s, and more recently in many other parts of the world, threatens the quality of groundwater and surface waters or has already led to deterioration of the quality of these waters. Typical hotspot areas with problems occur in Denmark, the Netherlands, northern Italy, Germany, France, China, USA and New Zealand.

Policies to abate deterioration of water quality have been developed and programmes of measures to improve water quality have been implemented. For example, the European Union has adopted directives that should result in a good quality of all waters by 2027 (Nitrates Directive in 1991, Water Framework Directive in 2000). Experiences of the last 15 to 25 years indicate that it will be a great challenge to realise these objectives in the remaining years. Nevertheless, the European Commission monitors compliance with these directives and several Member States have been forced through the European Court of Justice to amend their national legislation, for example the Netherlands in 2003, France in 2013/2014 and, more recently, Germany in 2018. In other parts of the world, e.g. in New Zealand, the government has initiated a national science challenge to improve land and water quality. Recently, California and other USA states have also implemented laws that should control water pollution, amongst others, by agriculture. Nevertheless it is has become clear that realisation of the objectives of these policies gets more difficult, not only since the easy, low cost measures already have been implemented, but also because there is a pressure to increase agricultural production. For example, the government of New Zealand strives to increase agricultural production and at the same time improve water quality. Is such a twin aim a realistic one? In addition, other policies, for example to abate climate change, may affect land use and thereby water quality. Are we aware of potential conflicting policies? Countries use different approaches to implement measures, which approach works best? Should measures be enforced by law (top down) or implemented on a voluntary basis (bottom up)? Experiences show that the latter means a long term investment in building relation, gaining trust and raising awareness. Do we have time? These are some of the issues that are addressed at LuWQ2022.

This prepublished volume contains the selected abstracts as they were received. The Abstract Numbers in the TABLE OF CONTENTS are identification numbers, assigned as part of the submission process. **These abstract identification numbers are referred to from the Conference Programme, both for oral and poster presentations.** For example, "*(abstract #221)*" in the Conference Programme relates to "Abstract number–221 Pitfalls and new solutions in water quantity and quality monitoring" in this Volume of Abstracts.

We wish you a fruitful and enjoyable stay in Maastricht.

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Abstract number–000 Agriculture and the Environment – How to further improve water quality. An introduction to the LuWQ2022 conference

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In many countries around the world, action plans have been introduced to tackle the agriculture related emissions of nutrients, pesticides and other substances to groundwater and surface waters. In many cases, reduction measures have been implemented successfully and there are numerous reports documenting water quality improvement. However, many reports show that after a major improvement of the quality of groundwater and/or surface water in the early years of the action plans, in later years, further improvements were minimal or even absent, while the water quality goals were not yet met.

The measures in the early years of the action plans regarded the easy gains or 'low hanging fruit' such as better use of N in different types of animal manure, closed periods for application of slurry, and cover crops. Often, it was not only interesting to realise these measures from an environmental point of view, but also from an economic point of view, for example substituting chemical fertiliser use by improved use of N in animal manure. To further improve water quality, measures have to be taken that often are more complex and/or more expensive and require more knowledge and skills from the farmer. These measures might sometimes require actions that go against their intuitions or what they have always been told and done to optimise production. An example is limitation of nitrogen fertilisation to a value below the calculated economic fertilisation requirement in nitrate-polluted areas.

The LuWQ conferences provide a platform for exchange of experiences and knowledge that may help us to take the next steps in reducing agricultural emissions and improving water quality. This presentation discusses lessons learned at the so far four held conferences.

Before discussing water quality improvement, it should be clear that water quality is complex as 'water' concerns many different types of water and waters are connected, for example, groundwater-surface water interactions and interactions between river and lake and river and estuary. Each system has its own limit for each of the, large number of, chemical

substances and physical conditions. Combined toxicity and interactions between chemical, physical and biological agents is not making assessments easier. Furthermore, agriculture is not the only source of pollutants. Especially for larger waters it may be difficult to determine the exact impact of agriculture due to delay in response time, biogeochemical processes, background losses and other sources, such as industry and sewage treatment plants.

Studies presented at previous conferences showed that improving water quality is a cyclic process that depends heavily on having access to water quality information (monitoring data and model underpinned interpretation) as a control for trends. Moreover, improving water quality needs a very long haul and the involvement of all concerned. Investing in a common objective and gathering and sharing relevant information is key for success, but it takes time. It is without discussion that there are many challenges to overcome. At the regional and national level, there is also a need for 'trusted' monitoring and model systems that can assist in showcasing status, trends and not least where measures should optimally be implemented – such as N-retention maps.

On the policy level, examples have shown that non agri-environmental laws and regulations may have a significant impact on the emissions by agriculture to waters. In addition, an abrupt change in agri-environmental policy – due to a change in government or enforced by international law – can greatly delay the improvement of water quality.

At implementation level, examples made clear that it is often difficult to find resources for building a long lasting relationship with farmers and other relevant parties – such as suppliers (concentrates, fertilisers, etc.), veterinarians, and advisors – and to find the right balance between voluntary measures, regulations, and incentives to reach together the water quality goals. It is a track with ups-and-downs, and it will be trial and error for a while. Although this is a slow and a labour intensive approach, it may be the most and, perhaps, the only successful approach.

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R.J.H.M. van der Veeren, S.A.M. Damen, P.H.J. Goorhuis, A.C.C. Plette

Abstract number–3 Ten years of experience with agricultural water management in the Netherlands: Co-operation and knowledge sharing between farmers and regional water authorities to achieve environmental objectives

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After World War II, which confronted the Netherlands with big starvation, agricultural policies in the Netherlands were focused on producing enough food for the Dutch population. These

policies, in combination with favorable natural conditions and infrastructure, resulted in a highly productive and efficient agriculture. However, this intensive agriculture also caused serious pressures on the environment, such as widespread eutrophication by nitrogen and phosphorus, and toxic stress due to emissions of plant protection products (PPP) to the surface waters. Therefore, ever since the 80's of last century, the Netherlands have tried to reduce those pressures by implementing general policies for all farmers. Ever since, soil surpluses of N and P have been reduced significantly, and emissions of PPP have been reduced. Nevertheless, circa 60 % of the fresh water bodies is still prone to eutrophication, and toxicity still hampers reaching good ecological quality in surface waters.

Even in a small country such as the Netherlands, there are large differences in regional circumstances, which, beyond a certain point, make further restrictions in general policies less efficient. Therefore, the Netherlands have been looking for more tailor made solutions and policies. This resulted in the Dutch 'Task force Agricultural Water management' (DAW), which now celebrates its 10th anniversary. This paper presents some illustrative examples of how this voluntary tailor made approach is used to improve the co-operation between farmers and water authorities to achieve environmental objectives, such as the European Nitrate Directive and the European Water Framework Directive. It describes the most important struggles, achievements, lessons learned and things to do.

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Abstract number–6 Assessment of agricultural nitrogen pressures and legacies in Denmark

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The links between nitrate-nitrogen (N) leaching from agricultural fields in catchments in Denmark and N in streams can in general terms be divided into two pathways: i) groundwater; ii) a more surface-near transport (e.g. tile drains). Therefore, catchments with quick hydrologic pathways respond also quickly on programme of measures for N, when analyzing trends in data from river monitoring stations. On the other hand, catchments having bot high N-attenuation or longer N time lags makes it complicated for managers and policy makers as the response of the implemented programme of measures might both be dampened and at first turn out at monitoring stations several decades after farmers adopted the measures. As River Basin Management Plans (RBMPs) under the Water Framework Directive (WFD) runs in 6 years periods – time lags might end up with an overdosing of measures. Therefore, biogeochemical attenuations and time lags for N needs to be mapped as they have major effects on the expected level of reduction of N loadings to water bodies from implementation of RBMPs and the expected legacy for water quality. The aim of this study is to improve our understanding of N time lags being mapped based on more than 30 years of N data from more than 160 Danish stream monitoring stations.

A national wide screening for trends in annual flow-weighted total nitrogen (TN) concentrations at 163 river monitoring stations shows in most cases a downward trend (average: 30% ± 17%) during the last 30 years 1990-2019). The N-surplus has been reduced (farm gate: -44%; field: -45%) during the same period. Diffuse N-sources and mostly agriculture contributed the most to TN in streams (93% ±8%) during the period 1990-2019). The reduction in the diffuse N loadings are paralleling the development of the N surplus for most Danish streams. However, in certain parts of Denmark several river monitoring stations shows a much different response, which in some cases is no response at all. Such a pattern can only be explained by N-flows in the catchments to be delayed in groundwater aquifers. Using long term data for national N-surplus a simple lag-time analysis shows that the time lags for N are long for 21 catchments (up to 20 years), medium long for N in 62 catchments and with nearly no delay for N in 80 catchments. Moreover, all the stream stations experiencing long time lags are situated in the chalk and partly karstic landscapes of Denmark from the Danien period. The catchments having long delays for N shows in most cases also a very low attenuation of N in groundwater as measured N-concentrations are substantially higher than found in the streams having nearly no time lags. Therefore, we conclude that incorporation of biogeochemical and hydrologic time lag principles into water quality regulations will be necessary for providing managers and regulators with realistic expectations when implementing new policies for N.

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van den Brink C.
C. van den Brink

Abstract number–7 Dutch approach to meet the nitrate objectives in vulnerable groundwater protection areas reviewed

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Agricultural practices cause diffuse water pollution issues, which is a policy concern across the globe. Especially in groundwater protection areas (GWPAs) at elevated sandy soils, this agricultural heritage and actual agricultural land use causes exceedances of nitrate objectives in shallow groundwater and impacts the quality of abstracted groundwater used for drinking water. Since 2011, a governance approach based on a mutual gains approach (MGA) using voluntary measures only was developed in 6 GWPs in Overijssel to reduce nitrate leaching from the rootzone as additional regulation was not possible as result of a socio-economic balancing of interests. This approach is used in a national agreement as part of the 6th Nitrate Action Programme to meet the nityrate objectives in 34 vulnerable GWPA in 5 Dutch provinces, adding a time-bound deadline to the existing nitrate standard. In 2021 the results in the 34 GWPA is reviewed and in case objectives were not yet met, the 5 provinces were asked to make an assessment whether the objectives will be met in 2025. The effectiveness was studied by analyzing the engagement process qualitatively and by analyzing the impact of measures at farm scale as quantitative indicators. For nutrients, the effectiveness is expressed in the N-surplus at farm scale and the realization of groundwater

quality objectives in GWPA. In addition, the participation rate of farmers within the GWPA was assessed. The results indicate that the engagement process based on voluntariness creates a platform for meaningful engagement, adds to the economics of the farm and reduces the agricultural impact on groundwater quality. However, the nitrate objectives of the Water Framework Directive (WFD) are not met at the level of GWPAs in 12 out of 34 GWPA, while in 10 GWPA the realization of the objectives depends on climatic conditions and 1 GWPA no assessment of the future status could be made. Due to the voluntariness of the approach, the participation rate relies on the farmers' expectation of the costs and benefits of the process, and diminishing economic returns prevent the further improvement of efficient nutrient use. These results are the basis for further discussion and consideration on how to the meet the objectives in 2025.

Wolters T., Kunkel R., Venohr M., Wendland F.
T. Wolters, R. Kunkel, M. Venohr, F. Wendland

Abstract number–10 Compliance checking for modelled nitrate concentrations in leachate and gap analysis for reaching WFD targets for groundwater

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Modelled nitrate concentrations in the leachate are an important indicator for the designation of nitrate-polluted areas in Germany and for the development of scenarios for the long-term achievement of the groundwater quality target according to the specific requirements of the EU Water Framework Directive. In the project AGRUM-DE the mean long-term nitrate concentration in leachate was modelled German-wide based on the model system RAUMIS-mGROWA-DENUZ. This contribution focuses on the validity of the modelled values based on a method developed by Wolters et al. (2021). For this purpose, monitoring stations with oxidizing properties from aquifers filtered near to the surface and shallow springs were preselected based on which mean nitrate concentrations were calculated. For comparison, the means of modelled nitrate concentrations in the leachate were averaged for the hydrological catchment area for each of these monitoring stations. Evaluations have been carried out for all major land use classes (arable land, forest, grassland and urban areas). In the presentation both, the agreement and deviations between modelled nitrate concentrations in the leachate and measured nitrate concentrations in groundwater will be discussed. In a wider sense, the compliance checking approach has contributed to assess if the model system RAUMIS-mGROWA-DENUZ is able to reliably represent interrelationships and influencing factors that determine simulated nitrate concentrations in the leachate based on observed nitrate concentrations in groundwater.
Wolters, T.; Cremer, N.; Eisele, M.; Herrmann, F.; Kreins, P.; Kunkel, R.; Wendland, F. Checking the Plausibility of Modelled Nitrate Concentrations in the Leachate on Federal State Scale in Germany. Water 2021, 13, 226. https://doi.org/10.3390/w13020226

Clement T.V., Bielders C.L., Degré A., Manssens G., Foucart G., Pigeon O., Blondel A., Huyghebaert B.
T.V. Clement, C.L. Bielders, A. Degré, G. Manssens, G. Foucart, O. Pigeon, A. Blondel, B. Huyghebaert

Abstract number–13 Effectiveness of undersown crops and strip tillage at reducing erosion and pesticide transfer in maize crops: Results of field trials

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Soils of the European loess belt are intensively used for industrial cropping and are known to be prone to surface crusting and erosion. Subsequent runoff and sediment transfer from cropland result in various off-site impacts such as muddy floods and the contamination of surface waters by sediments, nutrients, and pesticides. As a result, there is increasing pressure on the agricultural community to adopt alternative cropping practices to alleviate their environmental impacts. To this end, as part of the Intell'eau project, we assessed the effectiveness of two conservation practices at mitigating water, sediment, and pesticide flows by means of erosion plots under natural rainfall during the 2021 cropping season in forage maize. A control treatment, representing conventional maize farming practices, was compared to 1) maize undersown crops (red fescue or white clover) sown in the inter-row at the same time as the maize and 2) strip-tillage, which consists in preparing the seedbed by tine-tilling the maize row only, leaving the inter-row surface undisturbed. All treatments were implemented in triplicate. Results from the undersown crop plots showed no statistically significant difference in seasonal runoff, soil and pesticide (sulcotrione) losses compared to the control practice (bare inter-row). Most soil and pesticide losses occurred in June, when the undersown crops and maize are still poorly developed (< 5% total vegetation cover). Total seasonal runoff, soil and sulcotrione losses were 15.7±4.4 mm, 13.6±7.1 t/ha and 0.19±0.05 g/ha for undersown crop plots, and 18.6±2.6 mm, 11.5±4.7 t/ha and 0.15±0.08 g/ha for control plots. Nevertheless, during the extreme rainfall events of 13-15 July 2021 (119 mm in three days at the trial site), the undersown crops reduced runoff by 83% (1 mm, versus 6 mm for control plot) and soil losses by 90% (0.03 t/ha, versus 0.3 t/ha for control). When strip tillage was performed after a winter cover crop (mustard), a statistically significant difference ($p = 0.1$) between strip-till and the conventional practice (rotary harrow)

was observed regarding seasonal runoff (-45%), soil (-70%) and pesticide (-66%) losses. When strip tillage was performed on soil left bare during winter, no differences were observed in terms of runoff, soil and pesticide losses. On the latter site, a particularly important development of rills was observed in the inter-row in the strip-till plots. Yield differences between conventional and conservation practices were always below 10%, and none were statistically significant. Further investigations (additional years and locations) are needed to better evaluate the effectiveness of these two techniques. In particular, the follow-up of the undersown crop in time must be considered, since benefits are expected from a well-established cover during the winter period, as well as from the supply of organic matter to the soil upon destruction before spring, with likely improvements in soil structure.

Hooijboer A.E.J., Tenner E.
A.E.J. Hooijboer, E. Tenner

Abstract number–14 Measuring water quality on farms in the Netherlands with sensors: Results of the four year WaterSNIP programme

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The effects of the manure policy in the Netherlands are monitored in the Manure Policy Monitoring Programme (LMM). On 450 farms in the Netherlands ground and surface water is monitored. Grab samples are taken one to seven times per year and analysed in the laboratory. Nutrients (P and N compounds) are the main parameters in the LMM. In the four year Water Sensor Nutrient Innovation Programme (WaterSNIP) is investigated whether it is possible to monitor the water quality in LMM continuously with sensors. As part of this programme we tested a nitrate sensor in combination with a multi parameter probe in a ditch at two LMM farm during four years.

Measurements with sensors have benefits in comparison with the traditional laboratory measurements. Firstly, it gives insight in the processes that lead to leaching of nutrients, as high frequent monitoring is possible and variation of water quality becomes visible. Secondly, a much more accurate average concentration can be calculated compared to the fewer grab samples on the same location. Thirdly, the results from sensor measurements can be send to the database by telemetry and are therefore real time available.

However, during our research it became clear, that is not possible to replace all laboratory analyses by sensor measurements. The main reason is that sensors are not available for all nutrient components that are measured in the LMM. It is possible to measure nitrate concentrations with sensors, but for phosphate and ammonium we found no sensor that is feasible for our purposes. For organic nitrogen and phosphorous compounds no sensors are available.

Another drawback is that the maintenance of a monitoring network with sensors is very time

consuming, despite the fact that measurement are taken automatically. Sensors need a lot of cleaning, reparation and calibration. It will just be impossible to measure concentrations with sensors on all 450 farms in our monitoring network.

However the results of high frequency nitrate measurement give many information about the pattern of nitrate leaching. At the moment we foresee a role for sensors in the future as a supplement of the traditional way and not as a substitution for laboratory analyses.

Glendell M., Gagkas Z., Richards S., Lilly A., Vinten A., Coull M., Stutter M.I.
M. Glendell, Z. Gagkas, S. Richards, A. Lilly, A. Vinten, M. Coull, M.I. Stutter

Abstract number–15 PhosphoRisk – a systems approach to modelling phosphorus pollution risk in Scottish rivers using a spatial Bayesian Belief Network

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Water pollution remains one of the main reasons for the failure of waterbodies to reach Good Ecological Status (GES) under the Water Framework Directive (WFD). Among the multiple pressures affecting water quality, phosphorus (P) pollution is a major cause of surface water quality failures. Reducing P pollution in agricultural catchments is challenging due to the complexity of biophysical drivers along the source-mobilisation-delivery-impact continuum that necessitate place-based interventions informed by evidence-based decision making.

Evidence supporting the likely effectiveness of land management mitigation measures and their spatial targeting is uncertain. We developed a decision-support tool (DST) using a hybrid spatial Bayesian Belief Network to integrate diverse information on the potential effects of water quality mitigation measures, including data and expert opinion, while accounting for uncertainties in both data and knowledge. The DST facilitates system-level thinking about phosphorus pollution and brings together academic and stakeholder communities to co-construct a model specific to the region of interest. The expert-based causal model simulates the probability of soluble reactive phosphorus (SRP) concentration falling into the WFD high/good-moderate/poor GES classes at the catchment outlet and the effectiveness of mitigation measures such as buffer strips and fertiliser application rates.

The DST integrates climatic, land use, soil, topographic and land management information and was applied to map critical source areas of pollution at 100m grid cell resolution in seven catchments representative of hydroclimatic and land use intensity gradients in Scotland. Sensitivity analysis revealed the importance of fertiliser inputs, soil Morgan P and

presence/absence of soil erosion for SRP losses from diffuse sources, while the presence/absence of septic tanks, farmyards and the design size of sewage treatment works were influential variables related to SRP losses from point sources. However, mean daily runoff was the most influential variable affecting the concentration of SRP at the catchment outlet. Reducing fertiliser inputs below optimal agronomic levels resulted in a 5% greater probability of high/good GES, while the implementation of riparian buffers had a smaller effect of just 1% increase in probability of high/good GES at the catchment outlet.

When compared to observed water quality, the DST simulated a plausible marginal probability of the high/good GES, with some differences between the study catchments (under-estimation in 4 and over-estimation in 3 of the study sites). In further work, the DST will be up-scaled to a regional level and down-scaling to farm level will be tested. The quantified uncertainties will inform further research and targeted future data collection.

Schmidt B., Fischer M., Krüger A., Trepel M.
B. Schmidt, M. Fischer, A. Krüger, M. Trepel

Abstract number–16 AGRUM-DE: A national project towards a common understanding between water management and agriculture in Germany with regard to nutrient inputs

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High nutrient inputs into groundwater and surface waters continues to be a Europe-wide issue. For implementing the EU Nitrates Directive, the EU Marine Strategy Framework Directive and the EU Water Framework Directive (WFD) effectively, it is necessary to know both, the areas contributing significantly to the total nutrient load in river basins and the corresponding nutrient input pathways. Additionally it is indispensable to assess the extent different reduction measures may help to reach the environmental targets.
For this purpose, national authorities for water management (LAWA) and for agriculture (Thünen Institute) initiated and funded the project AGRUM-DE in Germany. In AGRUM DE the Research Center Jülich (FZJ), the Institute for Freshwater Ecology and Inland Fisheries (IGB) and the cooperatively integrated Thünen Institute (TI) from Braunschweig are working in cooperation with authorities and public institutions of water management and agriculture on federal state level. With the AGRUM-DE project, we developed a nationwide model to determine nutrient inputs into groundwater and surface water, the need for action and possible action scenarios for all German river basin districts.
The initiation of the AGRUM-DE project in Germany has to be seen against the background

of the pilot case of the EU commission against Germany questioning the correct implementation of the WFD with regard to diffuse nutrient input to water bodies, deficit analyses and measure planning. Planning, implementing and reporting requires a sophisticated modelling approach for setting river basin specific nutrient management targets and develop effective programs of measures. In Germany, the responsibility for implementation lies with the 16 federal states. So far, these have each carried out their own, sometimes significantly different modelling. Therefore, one of the biggest challenges of AGRUM-DE was the coordination and balancing between the stakeholders in water management and agriculture from the 16 Länder and the federal government.
In the AGRUM-DE project, the coordination has organized more than eight workshops with stakeholders from water management and agriculture from the Länder together with the modelling experts with the aim to gain the best data for the model and raise acceptance for the approach. The coordination also represented the project to LAWA and reported on the progress. The final model results are used by German river basin district for WFD reporting for the third management period and for developing the program of measures.

Durand P.
P. Durand

Abstract number–18 Modelling nitrogen dynamics in farming landscapes: From system understanding to support to policies, 20 years of TNT2 model

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Brittany, Western France, is one of the regions most impacted by nitrogen pollution in Europe, due to intensive farming, high livestock density and highly sensitive environment. To understand better nitrogen transfers and transformations in farming catchments, we developed a detailed, fully distributed model coupling by adapting and coupling STICS crop model and Topmodel hydrological model. Within a few years, this model became a tool to assess, ex-ante and ex-post, the policies and regulations enforced to mitigate nitrate pollution of drinking waters and eutrophication of coastal areas. The model was applied to more than 20 catchments in the region for a large diversity of scenarios, from simple fertilisation rate adjustments to complex mixing of production system changes and landscape management. The model applications helped scientists and policy makers to strengthen their grasp of the nitrogen dynamics in shallow groundwater, temperate catchments, mainly in the following topics:
-response time and nitrogen legacy
-efficiency of landscape structures (riparian areas, hedgerow networks) and controlling mechanisms
-efficiency of EU regulations, best management practices and production system changes
-alternative solutions to reach more ambitious water quality targets, especially against coastal eutrophication
-impact of climate change on nitrogen pollution

These findings were sometimes counter-intuitive and policy-makers showed reluctance to accept them, e.g.: the response time being more than ten years even in shallow groundwater catchments with thin soils and precipitation over 1 m/year; the impossibility to reach low nitrate concentration by adjusting fertilisation only; the limited efficiency of buffer zones because of the major pathways of nitrate-rich waters. However, the assessment of 20 years of science – policy dialog based on these modelling results is mostly positive, showing progress in both how scientists can transmit their messages to the stakeholders and how stakeholders can make better use of these messages. Further developments of the TNT2 model include improving its applicability to larger catchments and to innovations in farming, and incorporating it into more comprehensive socio-ecosystem approaches.

Kronvang B., Larsen S.E., Windolf J., Tornbjerg H., Rolighed J.
B. Kronvang, S.E. Larsen, J. Windolf, H. Tornbjerg, J. Rolighed

Abstract number–20 A novel machine learning national model for diffuse source total phosphorus concentrations in streams

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Data on the diffuse source annual flow weighted total phosphorus (TP) concentrations from 349 Danish streams draining smaller catchments (< 50 km2) for the period 1990-2019 were used for developing a model in machine learning software (DataRobot version 6.2; DataRobot Inc. Boston MA, USA). The developed diffuse source TP-concentration model will substitute an older model that have been in place to calculate P-loadings to Danish estuaries from ungauged areas. A total of 207 streams with 3,144 annual observations of flow-weighted TP concentrations together with information on 19 explanatory variables was entered into the DataRobot software. DataRobot divides the input data into three layers: Training dataset (64%), validation dataset (16%) and hold out dataset (20%). Thereafter, DataRobot conducts a five-layer cross-validation and tests among 72 different model types before suggesting final best solutions.
In this case, the TP-concentration model was developed as an 'eXtreme Gradient Boosted Trees Regressor with early stopping' as suggested by the DataRobot software to be superior for modelling the annual flow-weighted TP concentration based on 13 explanatory variables. The most influencing explanatory variables in the final model are: 1) tile drainage in the catchments; 2) ; 3) period (two periods with different sampling regimes; 4) proportion of agricultural land; 5) importance of bank erosion; 6) deviation of annual runoff from long-term mean. The final TP-concentration model has a R2=0.69 for the training dataset, R2 = 0.71 for the validation dataset and R2 = 0.67 for the hold out dataset.
A validation of the new machine learning TP-concentration model on 142 independent streams with 1,261 annual observations was conducted to investigate the uncertainty of the

model simulations. The validation showed the TP-concentration model to have a high explanatory power (R2=0.60) and with a very good simulation performance in the nine Danish georegions, as well as for the 30 year long time series of data.
An application of the model for calculating flow-weighted TP-concentrations within nearly 3,200 catchment polygons (ID15's) covering the Danish land area showed that the new developed machine learning TP-model is a valuable tool both for calculation of TP-loadings from ungauged areas to lakes and coastal waters as well as for linking catchment pressures to stream ecological status.

Surdyk N., Klages S., Baran N., Farrow L., Glavan M., Hansen B., Heidecke C., Kim H., Laurencelle M., Williams J., Wright I., Velthof G.L.
N. Surdyk, S. Klages, N. Baran, L. Farrow, M. Glavan, B. Hansen, C. Heidecke, H. Kim, M. Laurencelle, J. Williams, I. Wright, G.L. Velthof

Abstract number–22 Challenges for linking agricultural pressure indicators with water quality state indicators: Examples from FAIRWAY project

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To effectively reduce the agricultural impact on aquatic environments, the cause-effect relationships between agricultural practices and groundwater or surface water quality should be well understood. In this context, environmental indicators are often used since they can display in rather simple terms some complex environmental phenomenon variation. Yet, the selection or the creation of the best indicator to explain a phenomenon can be challenging. In the FAIRWAY (Farm systems management and governance for producing good water quality for drinking water supplies) project, we focused on the identification of indicators in order to quantitatively and conceptually show the relationship between agricultural practices (driving forces and pressure indicators) and groundwater quality (state indicators) that could be used in the European Member States. Hence, our approach was not to create new indicators but to assess the link between existing indicators.
The objective of this study is to determine how indicators of pressure and of state i.e. water quality can be linked to assess the efficiency of mitigation measures using common

European indicators. First, we conducted a survey among the FAIRWAY case studies to identify indicators available and used. Second, statistical tests were performed between selected indicators of pressure and state for both nitrate and pesticide. We examined the link between indicators, and the relevance of some indicators, as statistical calculations give the mathematical expression of the link that exists between them. The use of this (statistical) method reveals two lessons.
-First, the lag time between contaminant emissions and environmental impacts should be assessed. Cross-correlation appears to be a promising method to tackle it, but this method is not applicable on every site generally because of the lack of adequate datasets.
-Second, the selection of informative indicators (that could be applied within Europe) is not trivial. Despite common regulatory drivers at the European scale, the calculation of indicators is highly variable across Europe. This variability appears during collection, storage or dissemination of input data from the Member States. Harmonized practices in term of data collection and interpretation is needed and once information is acquired it is essential that it is made available using FAIR (Findable, Accessible, Interoperable, Reusable) principles to all the potential users.
Today, as implementation of regulations has been country-specific, the uniform application of data-driven indicators of pressure and status indicators across Europe remains challenging.

Tenner E., Hooijboer A.E.J., Rozemeijer J.C.
E. Tenner, A.E.J. Hooijboer, J.C. Rozemeijer

Abstract number–23 Measurement campaign High-frequency Nitrate sensors in the Meuse River: Eight nitrate sensors compared, what are the differences?

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More and more water authorities are using sensors to determine water quality at high frequencies. There is little information on the reliability of sensor measurements and the differences between types of sensors. Moreover, there is no uniform way of using sensors. This makes it hard to compare sensor measurements with each other. In the Water Sensors Nutrients Innovation Programme (WaterSNIP), RIVM works together with other research institutes, water boards and suppliers of sensors to share knowledge, to set up projects and, ultimately, to develop a single measuring method using sensors.
In a measurement campaign that was initiated within WaterSNIP, eight different types of nitrate sensor were compared in the Meuse river near the Netherlands-Belgium border. During two months in Autumn the sensors measured the nitrate concentrations every 15 minutes in the Meuse, and grab samples were taken three times a week which were analysed in a laboratory. Furthermore, the influence of temperature and chloride were tested in an spike test.

The measurement campaign shows that if a nitrate sensor (UV method or auto-analyser) is properly calibrated, the measurement sequence is more accurate than the laboratory measurement. Moreover, the continuous determination allows much better determination of the change in nitrate concentration (the dynamics). This provides insight into the processes that lead to nitrate leaching, and thus a more accurate average of nitrate concentration can be determined.
Temperature, tested in a range between 6-12 ˚C, and chloride, tested from almost no chloride to moderately brackish water, have little influence on the measured nitrate concentration. The differences between the sensors are mainly determined by the initial calibration of the sensors. It is, therefore, impossible to say which sensor is 'best in the test'; all sensors tested can be used to measure variations in nitrate concentration.
The results of this test support the need to develop a uniform measuring method with sensors and a uniform way of calibration. Although laboratory measurements prove indispensable, high-frequency measurements provide a lot of additional information and insight.

Odeurs W., Vandervelpen D., Elsen A., Ruysschaert G., Vanden Nest T., D'Hose T., Verguts V., Vandendriessche H.
W. Odeurs, D. Vandervelpen, A. Elsen, G. Ruysschaert, T. Vanden Nest, T. D'Hose, V. Verguts, H. Vandendriessche

Abstract number–25 Monitoring of Flemish farms benefiting from derogation reveals determinant parameters for the nitrate-N residue

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In September 2015, the European Commission granted for the third time derogation to the region of Flanders pursuant to Council Directive 91/676/EEC. The derogation implies that farmers can deviate from the standard of 170 kg nitrogen per hectare for livestock manure under certain conditions. As required by the European Commission a network of about 160 farms was set up to monitor the impact of derogation on nitrogen and phosphorus losses from soil. The monitoring network was focused on sandy and sandy-loam soils cultivated with grass, maize or a mix of grass and clover, fifty-fifty with and without derogation. During a four-year period, in-depth information and data were gathered about 1920 parcels. The information concerned in first instance fertilisation (type of fertiliser, application date, application method, dose of N and P, etc.) and yield data, covered by the monitoring assignment. Nevertheless, the monitoring network offered the opportunity to explore also other parameters and evaluate them in relation to the nitrate-N residue. The additional parameters can be classified as climate parameters, parcel parameters, fertilisation

standards, farm parameters and farm nitrogen-indicators. The statistical analysis on the nitrate-N residue was performed for the period 2016-2018. In a first step, the individual effect on the nitrate-N residue was evaluated. Out of the 49 parameters, 39 were significantly correlated with the nitrate-N residue. Per parameter, 0.3 to 17 % of the variability of the residue was explained. Correlation tests were used to point out the correlated predictors. Of the correlated parameters, the least significant were excluded for further analysis. A multivariate analysis was started with 31 variables. Only 16 parameters appeared to be statistically significant if they were combined. They explained about 34 % of the variability of the nitrate-N residue. The amount of organic carbon, the time between the application of organic fertilisers and the sampling for the nitrate-N residue, the dose of mineral nitrogen applied and climate parameters appeared to be important. The most determinant parameters appeared not to be related to the derogation. This result corresponds with the observations in the derogation monitoring network 2016-2019 and the former Flemish derogation monitoring networks, where consistently no statistical difference in nitrate residue was found between parcels with and without derogation. Moreover, the revealed significant parameters agreed basically with the parameters pointed out in the statistical analysis of the nitrate-N residue of the period 2011-2016 instructed by the Flemish Land Agency.

Geranmayeh P., Speks A., Collentine D.
P. Geranmayeh, A. Speks, D. Collentine

Abstract number–26 Has regional targeting improved distribution of funds and construction of purpose driven wetlands in Sweden?

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In the past 30 years, the Swedish EU Rural Development Program (RDP) has included financing for wetland construction with two goals; mitigating eutrophication and supporting biodiversity. Implementation of the measures has led to the construction of over 1718 wetlands since 2007. However, the cost effectiveness of these wetlands has been difficult to assess because of the lack of defined targets associated with the measures. This has led to an increase both in the identification of goals for which an RDP financed wetland has received support and used as a key for the distribution of the national budget to regional (county) authorities that administer wetland construction programs.

The purpose of this paper is to investigate if the increase of this type of targeting has been effective for the regional distribution of funds and consequently, the construction of purpose driven wetlands. To assess the effectiveness of the targeting, wetland construction financed through the Swedish RDP for two periods at the regional (county) level was evaluated. The county determined targets for nutrient reduction and biodiversity were included in the period 2014-2020 and in our study the wetlands constructed during this period were compared with

an earlier period when there was no regional targeting (2007-2013).

Most of the counties had set higher action plan targets for nutrient retention than for biodiversity, yet more counties exceeded their target share for biodiversity rather than nutrient retention. Wetland construction area was significantly larger for both purposes in the later period 2014-2020, the mean area for nutrient retention doubled from 2.1 to 4.1 hectares. Construction costs were significantly higher for nutrient retention (mean approx. 225 000 SEK per ha) wetlands than for biodiversity (168 000 SEK per ha). However, from being lower, the cost covered by the RDP subsidy (%) for biodiversity increased to equal as for nutrient retention.

The results indicated that while targeting is a step in the right direction, because targets are not binding, the allocation of funds can be shifted at the county level to finance the construction of wetlands that do not meet the intended purpose for that region. We suggest that to increase purpose driven effectiveness, the distribution of national funds for wetland construction be divided between the two purposes identified at the regional level as shares and that shifting funds between the purposes only be permitted in accord with a redefinition of shares at the county level.

Venohr M., Nguyen H.H., Kunkel R., Tetzlaff B.
M. Venohr, H.H. Nguyen, R. Kunkel, B. Tetzlaff

Abstract number–27 Compliance checking for modelled N and P loads in surface waters and gap analysis for reaching MSFD and WFD targets in surface waters

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Based on the pathway specific spatially-differentiated modelling of Total Nitrogen (TN) and Total Phosphorus (TP) emissions via diffuse pathways as well as from urban systems and point sources, the total nutrient emissions to surface waters were quantified. For the subsequent modelling of in-water retention, the inputs were first aggregated at sub-catchment scale. The resulting loads were modelled using a routed watercourse network, taking into account surface water area distribution, runoff conditions and water temperature. The loads determined in this way were used to validate the overall model results for recent conditions as an average over the years 2010-2016. The derived loads show no significant bias and, at 19 % (TN) and 23 % (TP), a good agreement with the observed loads.
As a final step in the AGRUM-DE model chain, based on the recent conditions and an agricultural reduction scenario, we examined to which extent quality targets of the EU Marine

Strategy Framework Directive (MSFD, Directive 2008/56/EC, for TN) and the EU Water Framework Directive (WFD, 2000/60/EC, for TP) are achieved or exceeded. The TN reduction requirement was transferred from the coasts to the upstream catchments by backward modelling and specific target values were determined for TP for water body types. We found that for the recent conditions in Ems, Weser, Elbe and Oder as well as in most of the coastal direct catchments, a total TN reduction requirement of 53 kt/a (12 %) exists. For the reduction scenario, the MSFD targets were largely achieved and significantly reduced in the Ems and Schlei/Trave. For phosphorus, a clearly different spatial distribution of the reduction needs was found, which amounts to 5.5 kt/a (33 %) of the current emissions.
It can be concluded that measures currently targeted and depicted in the reduction scenario can lead to the fulfilment of the TN targets in a mid-term. For TP, a considerable input reduction has been achieved in recent decades through improved wastewater treatment. A further reduction by one third will only be possible by additional measures also addressing diffuse emissions. In addition, the calculation carried out here at sub-catchment scale potentially leads to an underestimation of the TP reduction needs.

Moore P.A.
P.A. Moore

Abstract number–28 Legacy effects of fertilizing with alum-treated poultry litter on phosphorus runoff

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Treating poultry litter with alum (Al2(SO4)3.14H2O) is a best management practice (BMP) that greatly reduces ammonia (NH3) volatilization, as well as phosphorus (P) runoff and leaching. Lower ammonia levels in poultry houses treated with alum result in faster growing birds with better feed conversion, lower mortality and results in much less propane being used during cooler months (which lowers carbon dioxide emissions) because of lower ventilation requirements due to less ammonia. Currently 40% of the broiler chickens in the USA (~3.4 billion chickens per year) are grown with alum, mainly due to improved poultry production and lower propane use because of lower NH3 levels in rearing facilities, although our original goal for developing this BMP was to reduce non-point source P pollution. The objectives of this study were to evaluate the long-term effects of alum-treated poultry litter and untreated litter on soil test P and P runoff from pastures being fertilized for 20 years and to evaluate the legacy effects after fertilization was ended. Litter (5.6 Mg/ha) was applied to paired watersheds each year in spring. During the period when the fields were fertilized, the average P runoff from untreated litter (1.96 kg P/ha) was 231% higher than alum-treated litter (0.85 kg P/ha). Mehlich III P (0-10 cm) values in soil after 20 years of application were higher where alum-treated had been used (468 mg P/kg) than with untreated litter (388 mg P/kg), due to less leaching and runoff. However, water extractable P (WEP) in soil was 159% higher where untreated litter had been applied (49.1 versus 30.9 mg P/kg), indicating

the use of alum-treated lowered soluble P in soil. Phosphorus concentrations and loads in runoff decreased dramatically after fertilization ended, even though Mehlich III soil test P levels were still high, indicating that poultry litter had been the dominant source of P in runoff while litter was being applied. During the six-year period after fertilization ended total P loads in runoff from the field which had been fertilized with untreated litter (0.71 kg P/ha) was 203% higher than P loads from the field that had been fertilized with alum-treated litter (0.35 kg P/ha). This study provides further evidence that treating poultry litter with alum is a sustainable BMP that provides both short-term and long-term improvements in water quality.

Warne M.S.J., Turner R.D.R., Davis A., Smith R., Huang A.
M.S.J. Warne, *R.D.R. Turner*, A. Davis, R. Smith, A. Huang

Abstract number–29 Temporal variation of imidacloprid concentration and risk in waterways discharging to the Great Barrier Reef and potential causes

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The widely used neonicotinoid insecticide imidacloprid has emerged as a significant risk to surface waters and the diverse aquatic and terrestrial fauna these ecosystems support. While herbicides have been the focus of research on pesticides in Australia's Great Barrier Reef catchment area, imidacloprid has been monitored in catchments across the region since 2009. This study assessed the spatial and temporal dynamics of imidacloprid in 14 waterways in Queensland, Australia over seven years in relation to land use and concentration trends. Imidacloprid could be quantified (i.e., concentrations were greater than the limit of reporting) in approximately 54% of all samples, but within individual waterways imidacloprid was quantified in 0 to 99.7% of samples. The percent of each catchment used to grow bananas, sugar cane and urban explained approximately 45% of the variation in imidacloprid concentrations and waterway discharge accounted for another 18%. In six waterways there were significant increases in imidacloprid concentrations and the frequency and magnitude of exceedances of aquatic ecosystem protection guidelines over time. Overall, the risk posed by imidacloprid was low with 74% of samples protecting at least 99% of species but it was estimated that upto 42% of aquatic species would experience harmful chronic effects. Potential explanations of the changes in imidacloprid were examined. Not surprisingly, the only plausible explanation of the increases was increased use of imidacloprid. While field-based measurement of the effects of imidacloprid are limited in the Great Barrier Reef Catchment Area (GBRCA) the risk assessment indicates that biological harm to aquatic organisms is highly likely. Action to reduce imidacloprid concentrations in

the GBRCA waterways is urgently required to reverse the current trends and mitigate environmental impacts.

Hitzfeld K.L., Müller A., Knillmann S., Pickl C., Liess M., Weisner O., Vormeier P., Liebmann L., Reemtsma T.
K.L. Hitzfeld, A. Müller, S. Knillmann, C. Pickl, M. Liess, O. Weisner, P. Vormeier, L. Liebmann, T. Reemtsma

Abstract number–31 Small streams, big problems – German event-driven monitoring reveals alarming pesticide pollution and regulatory deficiencies

Kristina Hitzfeld[1], Alexandra Müller[1], Saskia Knillmann[1], Christina Pickl[1], Matthias Liess[2], Oliver Weisner[2], Philipp Vormeier[2], Liana Liebmann[2], Thorsten Reemtsma[3]

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The German Environment Agency (UBA), together with the Helmholtz-Centre for Environmental Research (UFZ), conducted the 'Kleingewässermonitoring'. In 2018/2019 more than 100 representative small streams were monitored in the agricultural landscape across Germany for plant protection product (PPP) residues following run-off events. The aim of the monitoring program was to realistically assess the PPP exposure in small streams, which are currently mostly neglected within the Water Framework Directive (WFD, 200/60/EG). Catchments were selected with an area of < 30 km², agricultural streams were characterized by > 20 % arable land, and a distance of at least 3 km to wastewater treatment plants upstream of the sampling sites. In addition to common grab sampling and a biological monitoring of macroinvertebrates, automatic event-driven samplers were installed to capture peak exposure following rain events (1). The monitoring revealed that in more than 80 % of the agricultural stream sections pesticide concentrations exceeded regulatory acceptable tresholds (2,3). This result is alarming as PPP risk assessment and management are in place to ensure environmental concentrations below those thresholds, which is also the prerequisite for product authorization. Twenty active substances were responsible for over 90% of exceedances in all samples. Moreover, 30 % of samples showed exceedances of more than one substance (3) and the pesticide mixtures detected were on average 2.2 times more toxic than the most potent pesticide alone (4). The biological monitoring linked the effects on aquatic invertebrate communities to agricultural pesticide pressure (2). The German Environment Agency initiated the monitoring to gain a realistic view on the exposure in the field and to obtain data to revise assumptions and estimations used in the risk assessment of PPP. Now, with the results at hand, first national consequences are elaborated and regulatory deficiencies are identified. With regard to the PPP regulation at the European level, this presentation will raise ideas how stakeholders and authorities together could approach the observed discrepancy between actual pollution and protection

goal.
Kleingewässermonitoring
project: www.ufz.de/kgm
contact: kleingewaesser-monitoring@ufz.de

(1) Liess et al., Umsetzung des Nationalen Aktionsplans zur nachhaltigen Anwendung von Pflanzenschutzmitteln (NAP) – Pilotstudie zur Ermittlung der Belastung von Kleingewässern in der Agrarlandschaft mit Pflanzenschutzmittel-Rückständen; UBA Texte 07/2022
(2) Liess et al., Pesticides are the dominant stressors for vulnerable insects in lowland streams; Water Res. 201 (2021) 117262.
(3) Halbach et al., Small streams – large concentrations? Pesticide monitoring in small agricultural streams in Germany during dry weather and rainfall. Water Res. 203 (2021) 117535.
(4) Weisner et al., Risk from pesticide mixtures – The gap between risk assessment and reality; Sci.Tot. Environ. 796 (2021) 149017.

Ezzati G., Barron J., Kyllmar K.
G. Ezzati, J. Barron, *K. Kyllmar*

Abstract number–32 Catchment-specific best management practices to minimize nutrient losses

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Agricultural catchments are facing the challenge of nutrient fluxes leaving the farms and entering waterbodies. In order to control and mitigate the nutrient loads, best management practices (BMPs) are developed. Studying their effectiveness after implementation requires a long-term approach with precise monitoring of water quality, weather, and agricultural practices to enable detection of trends in nutrient loads. In Sweden, water quality monitoring programme of small agricultural catchments has been ongoing since 1980s.

This study looked at the impact of BMPs on total nitrogen (TN) and total phosphorus (P) annual loads from three catchments with contrasting soil types. The catchments' area sizes are from 182 to 1632 ha having over 70% of the area dedicated to arable land. Generalized additive model was applied to understand the link between various BMPs, suspended solids, runoff, rainfall, and temperature. The implemented BMPs that have been recorded for the previous two decades are: % land under plowing (seasonal), % land under manure application (seasonal), % land under cultivation measure (4 types), mineral/manure P and/or N based fertilisation, crop distribution (11 types).

The results showed that the impact of BMPs was not similar between catchments and single measure could not be related to losses. However, seasonality in plowing showed significant contribution to TP losses in sandy loam catchments, and to TN losses in clay-soil catchment.

Autumn oilseed was highly significant in relation to TP losses in one of the sandy-loam catchment. Meanwhile, fallow, legumes, and spring oilseed were all significant indicator of N losses in the clay catchment. The other factors were also showing varying degrees of significance and the significant impact of climate-related variables was more evident on TN loads. Runoff showed to have very significant impact on losses in all catchments. Consequently, suspended solid was a highly significant variable in defining the nutrient fluxes, mostly P.

The data analysis indicates that the impact of any measure highly depends on catchments' unique characteristics such as soil characteristics, climate conditions, and farming practices. Hence, understanding such complex system asks for a holistic approach to simultaneously consider the impact of multiple variables. Therefore, more tailored management practices are needed in view of the growing threat of more extreme weather events. Agricultural catchments in Sweden are close to maximum BMP actions, so the practises to manage both input and mobilisation of non-point diffuse loads need more research to support agricultural and land managers to further improve water quality.

Hankin B., Smith P., Strömqvist J., Wood N., Warren S., Shelton K., Burgess C., Pope L., Newton T.
B. Hankin, P. Smith, J. Strömqvist, N. Wood, S. Warren, K. Shelton, C. Burgess, L. Pope, T. Newton

Abstract number–33 The impact of climate change-driven water quality changes on long-term environmental planning

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[5]*Environment Agency, England*

The UK Government has a 25-year Environment Plan for recovering and managing land sustainably to secure future resilience and biodiversity. Such a long-term plan needs to be informed by an understanding of potential future policy change and a detailed understanding of the likely impacts of changing flows and temperatures on water quality processes in a changing climate. This study has used a rainfall-runoff and water quality process-based HYPE model that has been well calibrated across England (Hankin et al., 2019) encompassing a range of process complexity, and recently updated to include the influence of the major groundwater aquifers. It is driven by high resolution (2) HadUK daily precipitation and temperate timeseries reflecting the spatial and temporal heterogeneity in UK climate.

For estimating future impacts the model has now been driven based on the UKCP18 RCP8.5 high-resolution precipitation and temperature future timeseries for 12 ensembles which attempt to capture future rapid changes including more localised convective events. Monthly uplift factors at the sub-basin scale (~ 20km2) made from comparing the UKCP18 projections for 2020-2040 with 1980-2000 were derived and applied to the HadUK dataset.

The HYPE model was then simulated for each ensemble for a future baseline scenario encompassing farming emissions compatible with 2015 that include on-farm mitigation measures implemented through Catchment Sensitive Farming (CSF). CSF is an advice-led initiative, in England, that enables farmers to take action to reduce water and air pollution.

The future inter-quartile ranges of flow and water quality predictions for nutrients, suspended sediment and FIOs across different percentiles have been generated and visualised against the baseline. Maps, flow and concentration duration curves have then been generated showing the future percentage changes for the 3 policy scenarios and the implications for the 25 year plan are considered. The initial analysis shows, for the climate change signature of increasing winter rainfall, the potentially competing influence of increased dilution leading to reduced concentration, but faster runoff processes resulting in reduced travel-time with less time for decay and increased concentrations. The presentation will explore these narratives in more detail with reference to predicted changes to different runoff processes in specific catchments.

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de Jonge M., Rietra R.P.J.J.
M. de Jonge, *R.P.J.J. Rietra*

Abstract number–34 Exploring nitrate in shallow groundwater on the basis of soil types: Possible role of denitrification capacity in subsoil

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Nitrate concentrations in shallow groundwater in drinking water abstraction areas with agricultural land use vary between 0 and 200 mg/ nitrate while the average concentration is areas is often above 50 mg/l. Nitrate is responsible for additional cost for water treatment, either to remove nitrate or decrease water hardness. Finding the fields with high and low nitrate concentrations is necessary to decrease nitrate in an efficient manner. High groundwater levels in the Netherlands are responsible for denitrification of approximately 30% of the leached nitrate. Cover crops and strong leaching of DOC, can increase denitrification capacity of subsoils. While effects of groundwater levels on nitrate are known and detailed groundwater maps are available, the knowledge of other determining factors on denitrification of leached nitrate are much less known.

In this study we explore simple soil characteristics on pairs of locations with similar soil types and groundwater levels but different nitrate concentrations in shallow groundwater. The measured soil characteristics are related to denitrification: potentially denitrification capacity, soil organic matter (SOM), dissolved organic carbon in soil solution (DOC), and water-extractable organic carbon (WEOC), groundwater level. The goal is to find a simple indicator or measurement to predict denitrification.
On each location samples were taken from soil layers with different positions towards the groundwater table.
We do find a relation between nitrate in shallow groundwater and the potential denitrification capacity of subsoil, but do not find any relation between potential denitrification capacity of subsoil and SOM, DOC or WEOC. This is in strong contrast to results found in literature for the top soil layer. In soils with deep inversion we did find relevant denitrification capacities in soil layers in contact with shallow groundwater.

Altés V., Merlin O., Pascual M., Villar J.M., Laluet P.
V. Altés, O. Merlin, M. Pascual, J.M. Villar, P. Laluet

Abstract number–35 Nitrate and salt exportations monitoring at irrigation district level

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Implementation of irrigation in rainfed areas provide high yields, economic benefit, and rural development. Nitrate pollution is a common problem in these areas with impacts in downstream ecosystems when high levels are reached. This pollution is also an extra cost for the farmers. Provide information that enables farmers to fertilize more efficiently can be a good tool to lower these loses. The aim of this study was to determine the amount of nitrate and salts exported yearly at irrigation district scale (6200 ha, Spain). To do so, we used the modernized drainage network in the irrigation district not only to know the amount of water exported in the basin but also the nitrate and salt concentration. Four drainage basins were monitored using modern sensors as CTD (MeterGroup INC, USA), which measures water level, electroconductivity and temperature. This allowed us to establish the water flow during the irrigation campaign. The use of Nitrachek 404 (KPG Products LTD, UK) to measure the nitrate concentration in the drainage water periodically provided us enough data to establish a first approximation to the exportations of nitrate. In addition, complete laboratory analyses were carried on specifying the salt composition of the drainage water. The results showed an average loss of 37 kg/ha of nitrogen and an average salt exportation of 3.457 kg/ha, that indicates the leaching of the soil during the irrigation period. Implementing irrigation can be a great tool to enhance the development of a region, however, it has to be complemented with great water and fertilization management to lower its environmental impact.

Zinnbauer M., Eysholdt M., Kreins P.
M. Zinnbauer, M. Eysholdt, P. Kreins

Abstract number–36 Regional agricultural N surpluses and potential impacts of the revised Fertilizer Ordinance in Germany

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Agricultural nitrogen (N) emissions are a main cause for missing European water quality standards in Germany. Recently, the European Commission has requested Germany to implement a national monitoring system to surveil the effectiveness of the 2020 revised Fertilizer Ordinance, which is the national implementation of the Nitrates Directive's action program, with respect to its capabilities of reducing nutrient pollution of ground- and surface waters. In this context, the model network AGRUM-DE aims at providing a holistic understanding of sources, pathways and fates of nutrient emissions to waters.
We contribute by modelling nationwide agricultural N soil surface budgets at municipality-level with the regional agro-environmental model RAUMIS. We quantify spatial agricultural N inputs, removals, and surpluses utilizing data from the Integrated Administration and Control System (IACS), combined with other statistical data and expert knowledge. The IACS dataset allows to model N budgets using nationwide field-level data for crop farming, and nationwide farm-level data for cattle husbandry. In a scenario analysis we perform an ex-ante impact assessment of the German Fertilizer Ordinance with respect to its potential to reduce regional agricultural N surpluses.
Our results allow to identify regional emission hot-spots as well as areas with low pollution levels. About 90 % of municipalities exhibit surpluses between 20 and 100 kg N / ha. The overall N surplus amounts to 58 kg N / ha for the base year. Mineral fertilizer accounts for more than half of the total N application, followed by animal manure (25 %) and biogas digestate (15 %). The revised Fertilizer Ordinance is estimated to reduce the overall N surplus by 18 % to 38 %, compared to the baseline scenario.
Our results serve as basis for subsequent modelling N fluxes in soil, ground- and surface waters, and marginal seas in the model network.

Zhuang Y., Silvasy T., McIntyre T., Lester W., Daughtery J., Marek A., Freeman T., Momol T.M.
Y. Zhuang, *T. Silvasy*, T. McIntyre, W. Lester, J. Daughtery, A. Marek, T. Freeman, T.M. Momol

Abstract number–37 Florida-Friendly Landscaping™ education in central Florida results in measurable water conservation

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As in many places in the world, Florida, U.S. is facing critical water scarcity and quality issues due to climate change and population growth. Public water supply is projected to increase 573.3 million gallons per day (2.6 million cubic meters per day) by 2040, approximately 60% of which is residential water use (Florida Department of Environmental Protection, 2019). The home landscape is a place where there is great opportunity for people to adopt water conservation practices (Hurd, 2006). The primary barrier for water conservation is inadequate information about available strategies to conserve and the associated benefits (Warner et al., 2018). Therefore, a Florida-Friendly Landscaping™ (FFL) activity checklist was developed to predict the environmental and economic impacts of implementing water conservation measures (Boyer & Dukes, 2015). Extension Agents incorporated this checklist into their programs using a multidimensional approach. Urban water conservation Extension programs were expanded from county-based in-person classes to multi-county outreach and online teaching. In 2021, the FFL program in six Central Florida counties educated over 7,000 urban residents about sustainable landscape practices. Based on client self-reported follow-up surveys (n=262), the annual water savings due to adoption of FFL practices was approximately 37.5 million gallons (0.14 million cubic meters). It saved homeowners $161,729.66 in utility bills. The most adopted practices included calibrating sprinkler systems to deliver ½ inch (12.7 mm) to ¾ inch (19.05 mm) of water instead of 1 inch (25.4 mm), reducing irrigation frequency during summer, and reducing irrigation frequency during winter, which contributed to 67% of the total water savings. Adoption is lower for water conservation practices that require installing soil moisture sensors and converting or installing irrigation spray heads. Impacts of changes in household water use multiply when life cycle assessment of a water supply system is considered. The reduction of 34 million gallons of residential water use resulted in saving 129,459 kWh of energy (Copeland & Carter, 2014) and $97,563.13 (Borisova et al., 2021) in treating and delivering water to the end users, reducing 92 metric tons of carbon dioxide equivalent of greenhouse gas emissions (U.S. EPA, 2022), deferring the need for $319,331.64 investment in alternative water supply infrastructure (Borisova et al., 2021), and

potentially reducing stormwater runoff and avoiding water quality deterioration. Impacts of these educational water conservation efforts are expected to be greater than what was reported here based on the total program attendance. It remains imperative to document the value of water conservation. Effective outreach such as FFL implemented by Extension Agents results in measurable reductions in water use that allows families and communities to conserve and protect Florida's water resources.

Darr S.G., Ross D., Malcolm D.T., Barker M.
S.G. Darr, D. Ross, D.T. Malcolm, M. Barker

Abstract number–38 Enhanced estimates of gully erosion to improve modelled estimates of progress towards water quality targets for the Great Barrier Reef, Australia

Shawn Darr[1], David Ross[1], Donald Malcolm[1], Margaret Barker[1]

[1]*Queensland Department of Resources*

The Australian and Queensland governments have developed the Reef 2050 Water Quality Improvement Plan (Reef Plan) to protect the Great Barrier Reef (GBR) from the impacts of reduced water quality from sediment sources including gully erosion. To measure and report on progress towards the water quality targets the Paddock to Reef Integrated Monitoring, Modelling and Reporting Program was established. Modelling is an essential component used to report on progress towards targets.
Gully erosion from grazing lands is a major source of fine sediment, contributing approximately half the fine sediment load delivered to Australia's world heritage listed GBR. Modelling the fine-sediment contribution from gully erosion and assessing the potential water quality improvement due to gully remediation projects within GBR catchments, is reliant on accurate maps of gully density and information on gully geometry and activity rates. Prior to this project, the distribution and activity rates of gully erosion across the entire GBR catchment area was poorly understood. Only a small number of datasets with limited geographic extent or broadscale modelled estimates of gully densities were available.
To improve model inputs for gully erosion, a novel low-cost approach to mapping gully erosion was developed. Using custom-built geographic information system (GIS) tools, aerial photography, uniform grids and a team of mostly volunteer team members, the presence or absence of gully erosion within 100 m2 cells was mapped for the 428 186 km2 catchment area of the GBR. Combining the desk top analysis with targeted field work, improved delineation of gully hotspots was achieved. The field work also achieved significant improvements to generic estimates of gully geometry and activity rates previously applied to the models.
Whilst the preferred option would be to capture lidar data across the entire GBR catchment area, this low-cost approach provided improved gully erosion data across all GBR catchments. This led to improved model estimates of fine sediment loads flowing to the GBR and more reliable estimates of progress towards Reef Plan targets. The gully density maps have also been useful for prioritising lidar capture for detailed mapping of gully erosion in

high priority catchments. The improved model estimates also provide a valuable tool for assisting the prioritisation of remediation projects.
This approach provides a low-cost approach to mapping gully erosion at various scales.

Kronvang B., van't Veen S.G., Zak D.H., Henriksen E.S., Ovesen N.B.
B. Kronvang, S.G. van't Veen, D.H. Zak, E.S. Henriksen, N.B. Ovesen

Abstract number–39 Advancing understanding of the importance of surface runoff for delivery of water, sediment, nutrients and pesticides to streams within agricultural catchments

Brian Kronvang[1], Sofie van't Veen[2], Dominik Zak[3], Emil Henriksen[3], Niels Ovesen[3]

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Explicit knowledge of the dynamics and spatial distribution of surface runoff, leaching and preferential flow paths and source areas in landscapes and their connections with surface water is critical for protecting the aquatic environment for inputs of sediment, nutrients, pesticides and other harmful substances. Therefore, there is a need for quantifying off-site surface runoff and the resulting transport of sediment, nutrients and pesticides to surface waters at the field scale combined with simultaneous measurements in receiving watercourses to increase our knowledge about the linkages between source areas, transport pathways and the resulting impacts on water quality in receiving water bodies. The importance of surface runoff for transport of sediment, nutrients and pesticides to surface waters have only been limited studied in Denmark even though forecasts of climate change predicts that extreme weather conditions with more intense precipitation events will increase in the future with a risk of having more frequent incidents with surface runoff from agricultural land.
The influence of surface runoff for transport of sediment, nutrients and pesticides to streams is measured in three carefully selected agricultural micro-catchments showing high risks for having surface runoff in the national model. Within each catchment, an edge of field monitoring site and a stream monitoring station has been established. The edge of field monitoring site consists of a flow chamber collecting surface runoff from the neighbouring field and an automatic sampler initiated at the onset of surface runoff. The edge of field surface runoff sampling station is established with communication to the stream station for starting an automatic sampler at the onset time of surface runoff on the field. Selected water samples collected at the edge of field and stream station is analysed for sediment, nutrients and pesticides. A first pilot study from one of the small catchments during the winter of 2015-2016 showed that surface runoff from the field amounted to 48 mm. the loss of suspended sediment, total nitrogen and total phosphorus, respectively, 56 kg sediment ha-1, 0.29 kg N ha-1 and 0.30 kg P ha-1). The new edge of field and stream monitoring setup in three agricultural catchments was established during autumn and winter of 2019-2020. The first results from the winter of 2019-2020 with the full monitoring programme in the three

catchments have shown frequent surface runoff events and relatively high concentrations of a number of pesticides both in edge of field and in stream samples.

Strömqvist J., Bartosova A., Brendel C.
J. Strömqvist, A. Bartosova, C. Brendel

Abstract number–40 National-scale modelling of silica and assessment of riverine contribution to potential coastal eutrophication

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Beside nitrogen (N) and phosphorus (P), usually the main nutrients of concern in surface water management, silica may also have a significant impact on coastal and marine aquatic systems. The ratios between nitrogen and phosphorus to dissolved silica (DSi) impact not only primary production, but also the quality and succession of algal species and potentially whole coastal food web structures.
We present the newly developed silica simulation routines in the Hydrological Predictions for the Environment (HYPE) model capable of simulating hydrology and water quality. The new routines include simulation of 1) weathering, the primary source of DSi in the aquatic environment, as a function of e.g. soil type and soil temperature, 2) processes affecting the amount and speciation of silica in surface waters (production, mineralisation and sedimentation of algal silica), and 3) transport processes through the rivers and lakes to coastal zone.
The new routines were applied to the high-resolution national hydrology and water quality HYPE model set-up of Sweden, complementing the existing calculations of N and P fate and transport in the country. The combined simulated riverine loading of N, P and DSi to the Swedish coast was used to calculate the Indicator for Coastal Eutrophication Potential (ICEP) for all Swedish rivers, thus providing a mechanism for assessing the role rivers and lakes may have for the status of coastal zone water bodies. The indicator represents the new production of nonsiliceous algal biomass (possibly causing harmful algal blooms) potentially sustained in the receiving coastal water body by either N or P delivered in excess over silica .

Dupas R., Casquin A., Viaud V., Durand P.
R. Dupas, A. Casquin, V. Viaud, P. Durand

Abstract number–41 The influence of landscape organized heterogeneity on riverine nitrate dynamics

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Landscape organized (or structured) heterogeneity is often assumed to influence hydrological and biogeochemical patterns across space and time. Here, we quantified landscape organized heterogeneity with two indices describing the spatial configuration of nitrogen sources or sinks regarding 1) their hydrological distance to the nearest stream (i.e. upslope/downslope heterogeneity: in the lateral dimension) and 2) their hydrological distance to the outlet in the river network (i.e. upstream/downstream heterogeneity: in the longitudinal dimension). The nitrogen sources considered are agricultural fields and the sinks are riparian wetland. Using public nitrate concentration and discharge data from 180 catchments in western France (5-150km²), we tested whether landscape organized heterogeneity influenced riverine nitrate concentration and dynamics. The metrics computed to characterize nitrate concentration and dynamics were the flow-weighted concentration (FWNO3), the slope of the log(C)-log(Q) relationship (slope b) and the ratio of the coefficients of variation of concentration and discharge (CVratio). Results showed a high positive correlation between slope b and the CVratio, but no correlation between the later and FWNO3. 43% of the catchment exhibited a positive b slope, indicating maximum nitrate during the winter high flow period and 17% exhibited a negative b slope, indicating maximum nitrate during the summer/fall low flow period; the remaining 40% exhibited a near-zero slope. Landscape organized heterogeneity was larger in the lateral dimension for both nitrogen source and sinks than in the longitudinal dimension. In the lateral dimension, nitrogen sources were primarily located upslope and nitrate sinks downslope. In the longitudinal dimension, no general trend was observed for nitrogen sources and nitrate sinks were rather located upstream. Heterogeneity in the lateral dimension was highly variable among catchments for the smaller catchments and less variable for the larger ones. Heterogeneity in the longitudinal dimension did not exhibit a visible relationship with catchment size. No relationship was found between indices of landscape heterogeneity and FWNO3, arguably because other primary factors (such as the nitrogen surplus or runoff) control most of the regional variability in FWNO3. We found non-linear relationships between our indices of nitrogen sink organization and the b-slope or the CVratio, both in the lateral and longitudinal dimensions. The catchments with a negative b-slope (maximum nitrate during low-flow season) had their wetlands located more upstream and/or more upslope than the average. The relationship with nitrogen sources were opposite by construction (agricultural fields are often located outside wetland areas) but less clear.

Trepel M., Kreins P., Venohr M., Wendland F., Zinnbauer M.
M. Trepel, P. Kreins, M. Venohr, F. Wendland, M. Zinnbauer

Abstract number–42 Nutrient modelling in the national monitoring programme for implementation of the Nitrate Directive in Germany

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In Germany, nitrate concentrations in groundwater bodies, nutrient concentrations in surface waters and nutrient loads are still too high for reaching the environmental targets set by the European Water Frame Work Directive (WFD) and the Marine Strategy Framework Directive (MSFD). Agriculture is the main driver for pressures from non-point source pollution. The German Fertilizer Ordinance regulates agricultural practice and controls nutrient input into groundwater and surface water. However, there is some time delay until changes in agricultural practice are measurable in groundwater and surface waters. Effective policy, however, needs information about the expectable effects of adapted regulations at an earlier stage. In this regard, nutrient modelling can predict the effects of agricultural measures on nutrient inputs intro groundwater and surface waters before implementation.
Based on the results from the national AGRUM-DE modelling project, nutrient modelling with the AGRUM-DE approach is included into the recently developed national monitoring program for implementation of the Nitrate Directive in Germany. The future national nutrient model will use highly accurate and latest agricultural data from farm and Länder level for calculating nutrient balances with a high spatial resolution. For this purpose, the national law is adapted, so that in future, the administration can collect the required agricultural data on a legal basis. The resulting nutrient balances will have a high spatial resolution. Accordingly, improved agricultural input data for the geohydrological modelling will be available.
In parallel, the modules in the geohydrological modelling approach will be adapted to higher spatially resolute input data. Especially, the sensitive input data on soils and substrate will be adapted to a scale of 1:50.000. The modelling concept does not focus only on diffuse nutrient inputs from agricultural exclusively. Additionally, point sources as well as riverine retention processes are accounted for in the modeling approach, because full implementation of the Nitrates Directive requires a wider view on nutrient pollution including nutrient load reduction for the marine environment.

Barcala M.V., Jansen S., Rozemeijer J.C., Bisschops B., Goosens M., Weert J.
M.V. Barcala, *S. Jansen*, J.C. Rozemeijer, B. Bisschops, M. Goosens, J. Weert

Abstract number–43 How to optimize phosphate removal by iron-coated sand filters in agriculture

Victoria Barcala[1], Stefan Jansen[2], Joachim Rozemeijer[2], Bob Bisschops[3], Martin Goosens[4], Jasperien Weert[4]

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[3]*Delphy*
[4]*Rijnland*

High phosphate concentrations may lead to eutrophication. Diffuse emissions from agriculture is one of the main sources of phosphate in surface waters. Phosphate retention measures can be effective, but they should use little or no valuable arable land to be readily accepted by farmers. Iron-coated sand (ICS) can be placed enveloping tile drains or in a subsurface or edge-of-field reactors to remove phosphate, thus taking no extra space. ICS is a by-product from the drinking water industry and is available in large quantities at a low price. To apply this measure at a regional scale, a detailed understanding of the phosphate retention mechanisms is needed. This study focused on the effect of flow velocity and submerged (reducing) conditions on ICS phosphate removal efficiency in the laboratory and in the field.
Laboratory column experiments demonstrate that phosphate adsorption on ICS is a kinetic process and high flow velocities limit the phosphate adsorption rate. The lifespan of the filter is determined by the diffusion of phosphate inside the iron coating which is a slow adsorption process. Therefore, we advise using ICS filters in slow-flow systems to optimize phosphate adsorption. In addition, ICS has a high hydraulic conductivity that allows rapid drainage if needed. Laboratory batch experiments showed that ICS phosphate removal efficiency does not significantly decrease if the filter is exposed to reducing conditions. Phosphate was not released from the ICS under reducing conditions because there were enough adsorption sites available. However, reducing conditions caused manganese and iron dissolution from ICS which after a prolonged exposure time might affect phosphate adsorption.
Second, we will present the results from on-going field experiments. Four drains enveloped with ICS and four in-between control drains enveloped with sea shells were constructed in September 2021. The water from the drains enveloped with ICS and the control drains is collected in separate pumping stations. A water pressure sensor was placed on each pumping station to measure the flow velocity. Weekly samples are taken from the drains enveloped with ICS and from the control drains to monitor dissolved phosphate, iron, and manganese. This is the first-time field experiments monitor flow velocities on ICS and control drains in the same field. This research contributes to an optimal design, operation, and management of drain filters with ICS.

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van Duijnen R., de Jong C., Lukács S., Brussée T.J.
R. van Duijnen, C. de Jong, S. Lukács, T.J. Brussée

Abstract number–44 Impact of crop type on nitrate concentrations in tile drain water in the Clay region of the Netherlands using monitoring data

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The installation of drainage systems on agricultural parcels helps to control the groundwater level, subsequently improving cultivability of the land and plant growth, and thus increasing crop production. However, the application of drainage systems can also lead to losses of nitrogen to surface waters. The crop type grown previous to the drainage season in winter

plays an important role in the amount of nitrogen that is available to be lost.
We used 12 years (2009-2020) of nitrate monitoring data from the Dutch Minerals Policy Monitoring Network (LMM) to determine the influence of crop type on nitrate concentrations in tile drain water of commercial farms in the Clay region. The monitoring setup of the LMM includes taking annual drain water samples in the winter half-year. Either three or four sampling rounds were performed per year at roughly 80 farms and at 16 tile drains per farm. We linked drain measurement results with information on crop type cultivated in the relevant parcel in the previous growing season. The latter was obtained from a national database called the Registration of Agricultural Parcels (BRP). Because of the nature of our monitoring data, this was done only for crops where enough data was available for analysis. As a consequence, the major crop types grown in the Netherlands were included. Furthermore, each parcel that is included in the sampling often contains only one sampling point and the measurement is met with high variability due to other factors. However, due to the large number of measurements per crop type per year (ranging from 100 up to 4,000), and the large number of monitoring years, this limitation can be largely dealt with.
Preliminary results show that crop types can be classified roughly into very susceptible to nitrate losses (leaf and stem vegetables), moderately susceptible (potato, maize, onion), intermediately susceptible (flower bulbs, wheat, barley, sugar beet) and low susceptibility (grassland).
This information can be used by both farmers and policy makers to determine the most effective measures per crop type to reduce nitrate concentrations of drain water, and ultimately surface waters, in order to comply with the water quality standards as set by the EU Water Framework Directive and Nitrate Directive.

Wichman T.A., Momol E., Rainey D., Unruh B., Barber L., Celestin M., Peralta C., Bain C., Bossart J.
T.A. Wichman, E. Momol, D. Rainey, B. Unruh, L. Barber, M. Celestin, C. Peralta, C. Bain, J. Bossart

Abstract number–45 Florida's Green Industries Best Management Practices training promotes sustainable urban landscapes

Tom Wichman[1], Esen Momol[2], Don Rainey[3], Bryan Unruh[4], Lynn Barber[5], Marc Celestin[6], Cesar Peralta[6], Cathy Bain[6], John Bossart[6]

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Florida enjoys an abundance of lakes, rivers and coastal waters, many with densely populated urbanized watersheds. Urban landscaping practices, including water, fertilizer and pesticide use, contribute to nonpoint source pollutant loading to surface and ground waters. Landscaping and lawn care are major businesses in Florida, employing tens of thousands of green industry professionals. To help minimize the potential nonpoint source loading from inappropriate landscaping practices, the UF/IFAS Extension Florida-Friendly Landscaping Program, in partnership with the Florida Department of Environmental Protection (FDEP), trains thousands of landscaping professionals statewide through the Green Industries Best Management Practices (GI-BMP) Training Program. State of Florida statutes require this training for all landscaping professionals who apply fertilizers. The training program has four main program goals: reducing off-site transport of sediment, nutrients, and pesticides to surface water or groundwater; promoting appropriate site design and plant selection; using appropriate rates and methods for irrigation and fertilizer application; and promoting integrated pest management (IPM) practices. The GI-BMP training includes six learning modules covering efficient use of water and fertilizer, integrated pest management, fertilizer application, and water pollution-minimizing lawn and landscape cultural practices. Course delivery is available through several formats, including in-person classes, distance Zoom trainings or self-paced options available online or through a DVD. Courses are available in English and Spanish, with Haitian Creole coming soon. Those persons successfully completing the training and a written exam receive a GI-BMP certificate. Since the program's start in 2006, over 71,906 persons received training, with 60,457 of these trainees receiving their GI-BMP certificate. Surveys conducted 6 months after each training class assess the extent to which trainees have changed their landscaping behaviors and practices to conserve water and reduce pollutants. For 2021, these surveys found that, post-training, 92-98% of the attendees used the GI-BMPs on a regular basis, with substantial improvements shown in those who always use the following practices: apply no more than 0.5-0.75 inches (1.27-1.91 cm) water per irrigation event (for water savings of 25-50%); reset irrigation controls/timers seasonally; reduce fertilizer application; and use integrated pest management. Further, the post-training surveys documented adoption of new technologies, specifically an increase of 22% in those who use soil tests to determine fertilizer needs and an increase of 33% in those who use integrative pest management practices prior to use of pesticides.

Lukács S., Fraters D.
S. Lukács, D. Fraters

Abstract number–46 Effects of drought: Extreme weather conditions provide insight in leaching process

Saskia Lukács[1], Dico Fraters[1]

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Long term dry weather conditions can have a severe impact on the concentration of nutrients in water leaching from agricultural soils. Data from the Dutch Mineral Policy Monitoring Programme (LMM) show that many years of decreasing nitrate concentrations were related to decreased nitrogen soil surpluses. However, after a couple of years of drought in the Netherlands, from 2017 till 2019, nitrate concentrations have been rising again. Extreme weather conditions like the exceptional dry summer and fall of 2018 can give us some insight in the process of nitrate leaching over the years.

In 2006, a special research programme has been set up in the Sand Region to monitor water quality at farms that are artificially drained by tile drains and ditches. This programme includes 60 farms where we sample water from tile drains, ditch water and the upper metre of groundwater during winter. In summer we sample ditch water and the upper groundwater. In accordance with the standard LMM monitoring, information on agricultural practices is also gathered for these farms. Data from this research programme for the 2006-2021 period show that the various water types have different responses to dry weather conditions with regard to the level of increase in nitrate concentrations and response time.

Due to drought, crop uptake of nitrogen and crop yields may be reduced. In such a case, the nitrogen soil surplus will increase, which can lead to more nitrate leaching. The amount of leaching and the concentration in the leachate will depend on the rainfall in fall and winter. As a response to the extreme drought of 2018, the nitrate concentration in drain water showed an extreme increase, whereas the rise in concentration in the upper metre groundwater was much less severe. In the subsequent years the nitrate concentration in the drain water decreased again, while the concentration in the upper groundwater increased only further.

These different patterns in the change in concentrations between the monitored water types may be a reflection of what happens in the soil. In our presentation we will discuss a/o the potential effect of accumulated nitrogen, due to reduced crop yields, on nitrate leaching in relation to the precipitations surplus.

Koroša A., Mali N.
A. Koroša, N. Mali

Abstract number–47 Modelling transport of nitrate in a gravel unsaturated zone

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The transport and dynamics of pollutants are among the most important processes in the aquifer, however many times they are not so well known. The transport of water and pollution in aquifer depends, among others, on the characteristics of the unsaturated zone. The unsaturated zone of an aquifer serves as a water reservoir which discharges water and

potential pollution to the saturated zone for a relatively long time. Nitrate pollution in groundwater, originating mainly from agricultural activities, remains a worldwide issue. Determining the transport characteristics of pollutants including nitrate in a gravel unsaturated zone is particularly difficult. Understanding the mechanisms and rates of movement of nitrate in the unsaturated zone is an important issue in the process of groundwater protection. One of the most valuable ways of investigating the characteristics, groundwater flow and solute transport in the unsaturated zone is by conducting experimental research, tracing experiments. Water and nitrate transport processes in unsaturated zone have been studied with combined tracing experiment using a lysimeter facility in the Selniška Dobrava. The tracing experiment lasted over a time period of approximately one year and a half. Due to its conservative behaviour, deuterated water was used as the conservative tracer and NO3-N was used as a nitrate tracer in the unsaturated zone. The δ2H and NO3-N values in unsaturated zone water were measured monthly. All together 36 sampling campaigns were performed. For the evaluation of flow and transport parameters the HYDRUS 1-D software was used. Water flow in the unsaturated zone was simulated by numerically solving the Richards equation. The Mualem - van Genuchten model was applied for the parametrization of water retention (θ) and unsaturated hydraulic conductivity (K). δ2H and nitrate transport was calculated using the advection-dispersion equation, which assumes a single porous medium and is the most widely used model to predict solute transport in soils under field conditions. In the conference contribution, modelling and estimation of hydraulic properties of the soil and nitrate within a coarse gravel unsaturated zone will be presented. The results were used to estimate the water and nitrate transport parameters in the coarse gravel aquifer in Selniška dobrava.

Mali N., Koroša A., Auersperger P., Kozjek M., Kovač Viršek M.
N. Mali, A. Koroša, P. Auersperger, M. Kozjek, M. Kovač Viršek

Abstract number–49 Microplastics as emerging contaminants in groundwater

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Microplastics (MPs) have received considerable attention as a new emerging pollutant. In addition to emerging organic pollutants (EOCs), they are recognised as one of the important factors in environmental pollution. MPs are tiny plastic particles that vary in material, shape, colour, and size. Most commonly MPs are labelled as plastic particles smaller than 5 mm and are of heterogeneous forms (fragments, foams, pellets, grains, films, fibers). Plastic pieces smaller than 1 μm are labelled as nanoplastics. MPs as EOCs enter the environment and also in groundwater (GW) as a consequence of different urban and agricultural activities.
In Slovenia 98% of drinking water demands are covered by GW resources. A considerable number of GW resources are polluted by pollutants originating from anthropogenic sources,

probably including MPs. The aim of the presented study was to investigate the presence of MPs and EOCs in karst and fissured aquifers of Dolenjski kras groundwater body. Special emphasis has been given to the assessment of land use and anthropogenic activities in the recharge area of each sampling site in connection with the occurrence of MPs and EOCs in groundwater. Microplastics in GW was sampled at 10 locations and filtered in laboratory through 10 µm nylon net membrane. The membranes were analysed for MPs with stereomicroscopes (10 - 120x magnification) and digital microscopes (100 - 5000x magnification). MPs were present in low quantities at 5 locations (< 0.13 particles/L). The presence of EOCs was assessed by means of passive sampling with active carbon fibres (ACF). Passive samples were analysed by gas chromatography mass spectrometry (GC-MS). For the interpretation of chromatograms, the AMDIS deconvolution was used. The deconvolution was covered by the GC-MS library with retention times for 921 organic contaminants from Agilent USA, as well as by the NIST 2008 library of mass spectra. Based on the results, a comparison of the presence of MPs and EOCs in GW and an analysis of the possible impact of the recharge area will be made.

Christiaens L., Goderniaux P., Orban P., Brouyère S.
L. Christiaens, P. Goderniaux, P. Orban, S. Brouyère

Abstract number–50 Characterisation of nitrate contamination through hydrochemical and isotopic analyses – application to the chalk aquifer of the Mons Basin (Belgium)

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Discriminating the different sources responsible for nitrate contamination of groundwater is a complex task. Indeed, the excessive presence of this pollutant can be the result of a combination of several elements (poor assimilation of inorganic fertilisers, decomposition of manure, losses in drainage systems). An excess of nitrate represents a danger both for the quality of drinking water supplies and for the health of ecosystems. Therefore, identifying the causes of this contamination is an important step in establishing an appropriate mitigation policy.

Largely exploited for public water production (50 million m³/year), the Mesozoic chalk aquifer of the Mons basin (Belgium), covers an area of over 400km². As a substantial water reserve for Belgium, the quality of this resource is continuously monitored. Over the last years, an increase in nitrate concentration has been observed in several monitoring wells and is progressively threatening the sustainability of some production sites. The land-uses in the area are various including fields, pastures, urban areas and industrial sites. It is, therefore, difficult to identify the origin of nitrate and mitigate the pollution.

Commissioned by the SPGE (Société de Protection et de Gestion de l'Eau, Belgium) and

conducted by the universities of Mons and Liège, the characterisation of the pollution and associated nitrate sources is carried out through multiple sampling campaigns covering the different land use zones and confined/unconfined areas. Classical hydrochemical analyses are performed to define the extent of the nitrate pollution, to locate potential denitrification zones and to highlight correlations with other major ions. In parallel, analyses of the stable isotopes of nitrate (δ15N and δ 18O) and boron (δ 11B) are carried out. These isotopes allow to differentiate different sources of nitrate, including mineral or organic fertilisers, household waste degradation in landfills and possible leakage from sewer systems in urban areas and also to highlight denitrification processes.

The results of the sampling campaigns are interpreted using a combination of classical tools (maps of the ions spatial distribution, Piper diagrams, binary graphs) associated with multi-criteria analysis algorithms (PCA, T-SNE, SOM'S). These methods, combined with isotopic measurements, make it possible to delimit multiple sub-zones in the basin according to suspected nitrate sources. Finally, the presence of a denitrification front along the interface between confined and unconfined aquifer is also highlighted.

Siksnane I., Lagzdins A.
I. Siksnane, A. Lagzdins

Abstract number–53 Analysis of the impacts of meteorological and hydrological variability on quality of agricultural runoff in Latvia

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Changing patterns in meteorological and hydrological conditions along with implemented agricultural management practices affect nutrient losses from agricultural lands. Sustainable management of surface water resources is one of the most important environmental issues to manage in order to meet the requirements set by the Water Framework Directive (2000/60/EC) and implemented in the national legislation of Latvia. Agricultural runoff monitoring is particularly important to investigate long-term changes in water quality as agriculture has been identified as the main cause of nutrient losses to surface waters and the Baltic Sea, especially if subsurface and surface drainage systems are installed. Nutrient enrichment may cause eutrophication and lead to undesirable consequences such as excess plant and algal growth, reduced light penetration and oxygen depletion in downstream water bodies.
Long-term data (1995 – 2020) as collected within the Agricultural Runoff Monitoring Programme at three monitoring sites Berze, Mellupite, and Vienziemite were summarized and analyzed to determine seasonal and annual changes of patterns in nutrient losses from small agricultural catchments and subsurface drainage fields. Hydrological pathways are of great importance not only for transportation of nitrogen but also for nitrogen transformation in soils and buffering capacities of the catchment area.

The study results indicate high variability in total annual precipitation and mean annual air temperature when the data measured over the time period of twenty years (1958-1978, 1979-1999, and 2000-2020) were compared indicating for evidences of climate change. The mean annual air temperature increased by 8 to 15% at all study sites, increase in air temperatures was observed also seasonally. For example, in the Mellupite catchment, the correlation between seasonal precipitation and runoff of 0.67 in winter, 0.33 in spring, 0.61 in summer, and 0.85 in autumn was detected.
As affected by the hydrological behavior losses (kg ha -1) of total nitrogen (TN) and total phosphorus (TP) in agricultural catchments had large variations depending on catchment characteristics, e.g. intensity of agricultural production and site location with respect to agro-climatic regions in Latvia: 33-48% for TN and 22-40% for TP in winter, 25-46% and 23-48% in spring, 2-6% and 5-19% in summer, and 14-25% and 18-31% in autumn, respectively.
The ongoing and foreseen changes in seasonal and annual patterns in meteorological and hydrological conditions may increase the risks of nitrogen and phosphorus losses from agricultural catchments in the future thus increasing challenges to fulfill the obligations set out in the Water Framework Directive (2000/60/EC).

Thorling L., Gourcy L., Broers H.P., Hinsby K.
L. Thorling, L. Gourcy, H.P. Broers, K. Hinsby

Abstract number–54 Redox conditions in European groundwater and nitrate pollution potential

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Nitrate leaching to groundwater is a general problem in cultivated areas in most of the world and is in EU regulated through actions plans as stipulated by the Nitrates and the Water Framework Directive. Nitrate is the contaminant most often resulting in poor chemical status of EU groundwater bodies not meeting the good status objectives of the WFD. As nitrate is only present in oxic groundwater the redox conditions in groundwater are an important parameter to know for adequate and efficient management and assessment of groundwater vulnerability towards nitrate. The redox condition is also relevant for the migration and fate of other contaminants from both diffuse and point sources, and hence it has large implications for the chemical status of groundwater bodies.
Comparison of monitoring results, impact of pressures and action plans across EU are qualified by knowledge on the geographical distribution of redox conditions. When the redox conditions are seen in relation to travel times through both the unsaturated and saturated

zone (HOVER 2022) this gives invaluable support for trend assessment and predictions of the response or lag times of remediation measures of current action plans. This improves management and assessing the history and fate of pollutants in the subsurface that threatens drinking water wells as well as dependent terrestrial and associated aquatic ecosystems across Europe.
The redox conditions are highly variable in space and time, and dependent on local hydrogeology. The EU GEOERA HOVER project aimed at making an EU overview through a common methodology with a simplified approach and making the results publicly available on the EGDI platform https://www.europe-geology.eu/.
A simple approach was selected for the determination of the transition of redox state from nitrate containing to reducing nitrate free water, which was relatively easy to harmonize and implement in contrast to a stricter delineation of denitrification status, due to the need for a practical method, which could initiate the development a pan European overview using data available in various countries.
Based on the existing data in each of the participating countries and previous experiences in mapping nitrate reduction a decision tree was proposed using a minimum number of parameters. The classification tree is based on nitrate concentration, presence at defined concentrations of Mn, Fe, O2 and NH4. After being tested in some pilot areas, the method was applied at national scale in France, Denmark, UK, Latvia, Spain, Ireland, Cyprus, Slovenia and pilot areas of Netherland/Flanders and Croatia.
After collecting data at sampling point the information was extended at lithological units for specialization purposes. Mapping challenges were considering depth and spatial variability.

This project is part of the GeoERA program and has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731166.

Brussée T.J., Wolbink G., Baumann B.
T.J. Brussée, G. Wolbink, B. Baumann

Abstract number–56 Strategy to reduce consequence for monitoring in case of change in laboratory

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A challenging moment in a monitoring networks history arises when chemical analyses are outsourced to a new laboratory. An unwanted, but possible structural change in water quality trend is on the lure. Changes are unavoidable as result influencing variables as the laboratory environment, analyzing staff, equipment and procedures vary between laboratories. There are a/o technological innovations, changes in resource availability and changes in legal obligations. How can one minimize the consequence for monitoring trends?

The Dutch National Minerals Policy Monitoring Network changed laboratory partner in 2018. The main aim of this presentation is to reflect on the steps taken, on the problems encountered, on the gains of the set up double measuring trajectory and on future recommendations in order to improve the strategy to reduce consequence for monitoring in case of change in laboratory.

We developed a strategy to reduce the effects of potential changes in laboratory analysis on results in advance. Before official analyses could be carried out by the new laboratory terms were set including a/o accreditation on specified topics, specified minimal detection limits, comparable measuring results to the former laboratory and maintenance of these quality standards during the contract period. In a double measuring trajectory field water sample measuring results were compared between the old and new partner laboratory. In this unique trajectory the new laboratory was supported by the former laboratory. The boundary conditions on the double measuring trajectory were derived from interlaboratory comparison results representative for each matrix and component. A statistical test was developed that evaluated whether boundary conditions were met incorporating variance and systematic differences. In the preliminary stages of the laboratory transition the new laboratory got the chance to set up equipment, train the staff and calibrate the equipment to approach the former laboratories technique of analysis. The trajectory involved several evaluation points and go-no-go moments per matrices and component supported by the statistical test results. Not all components surpassed the boundary conditions, therefore requiring research on possible causes and an advice for improvement for these components. Transparent communication and an open-minded attitude from all parties involved resulted in fruitful discussions about the results and eventually in a satisfactory improvement in laboratory analyses.

Soedarso J.A.R., Sutton N.B., Rijnaarts H.H.M.
J.A.R. Soedarso, N.B. Sutton, H.H.M. Rijnaarts

Abstract number–57 The fate of contaminants of emerging concern in sandy soils by irrigating with (in)direct treated municipal effluent

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In periods, with limited precipitation the indirect reuse of treated municipal effluent via surface water is inescapable. This is especially the case in the higher sandy soil region of the Netherlands, and in the agricultural areas that are close to the discharge of municipal sewage treatment plants. The fate of the brought in contaminants of emerging concern (CEC's) by irrigation is relatively unknown. This study is towards understanding the chemical and physical interaction between CEC's and sandy soil, to predict potential risk of CEC's build-up in the soil, leaching to the ground water and plant uptake.

The interaction between CEC's towards organic matter, iron and aluminum oxides and clay fractions in sandy soils was studied first. The interaction of CEC's toward the different fractions was researched with batch bottle experiments. The batch bottles were filled with different sand sample, which were selected to have varying fractions of organic matter, Fe- and Al- oxides and clay. Then the bottles were spiked with a fixed concentrations of CEC's found in municipal treated effluent. By frequently sampling the liquid phase of the batch bottles isotherms were made and the sorption capacity of CEC's were linked to the fractions. The existing ORCHESTRA model made by Meeussen (2003) for fate of metals was adjusted to model the fate of CEC's. The CEC's sorption capacity information was used to model the fate of the CEC's in sandy soil. The predicted fates of CEC's are used as a first impression of CEC's that could potential be a risk by accumulation in soil, leaching to groundwater or uptake by plants. In future, research we want to compare the predicted fates of CEC's with saturated and unsaturated column experiments and field pilot with direct reuse of treated effluent.

Brouyère S., Balzani L., Orban P.
S. Brouyère, L. Balzani, P. Orban

Abstract number–59 The CASPER project – an integrated approach for pollution risk assessment in peri-urban groundwater catchment areas

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In 2020, the European Union has established a recast of the 1998 EU Directive on the quality of water intended for human consumption, hereafter called Drinking Water Directive - DWD. One of the most significant evolutions in this recast is the introduction, through articles 7 of 'a complete risk-based approach to water safety, covering the whole supply chain from the catchment area, abstraction, treatment, storage and distribution to the point of compliance'. In practice, a 3-level risk assessment and risk management is expected: (1) at the level of the catchment area (article 8), (2) at the level of the water supply systems (article 9) and (3) at the level of the domestic distribution system (article 10). In this context, the CASPER project, funded by SPGE in the Walloon Region of Belgium, aims at developing an integrated approach for the evaluation and management of pollution risks for peri-urban groundwater catchments. The approach, which fully complies with the requirements of the DWD recast, consists of several key components. First, point and diffuse pollution sources are identified in the groundwater catchment area based on a mapping of hazardous activities combined with a specific groundwater monitoring survey aiming at identifying specific tracers of such sources of pollution. In a second step, risks associated to each of the identified source of pollution is estimated based on the measurement of pollutant mass fluxes and mass discharges downgradient these sources. Finally, a groundwater flow and transport model is developed at the scale of the groundwater catchment area, with the aim of evaluating the cumulative effect of the multiple sources on groundwater quality deterioration

in the catchment and at the abstraction points. The objective here is to describe the CASPER approach and to illustrate it using ongoing investigations in a peri-urban groundwater catchment exploiting groundwater from a chalk aquifer in Western Belgium.

Coppens J., Laethem R.
J. Coppens, R. Laethem

Abstract number–60 The use of the nutrient emission model NEMO for evaluating policy scenarios related to nutrient emissions from agriculture to surface waters in Flanders

Jan Coppens[1], Rob Laethem[1]

[1]*Flanders Environment Agency*

In order to quantify the nitrogen (N) and phosphorus (P) loads from agricultural lands to surface waters the Flanders Environment Agency (VMM) commissioned the development of the NEMO (Nutrient Emission MOdel) for the Flemish Region in Belgium. The aim of the model is to substantiate the agricultural measures for the Nitrate Directive action programs and WFD river basin management plans on a regional scale.
NEMO is a mechanistic model and currently operates with a 50m x 50m spatial resolution. Each raster cell is divided in an unsaturated zone and a saturated groundwater zone. In the unsaturated zone infiltration, percolation, mineralization, denitrification, P-sorption/desorption and plant uptake are simulated for the different soil compartments. In the unsaturated zone there is no interaction with neighbouring cells, all processes are only modelled in the vertical direction (1D). Groundwater flow in the saturated zone and erosion processes are described with a 2D model. Timesteps of calculations vary between one day and one month depending on the process.
NEMO was used to calculate the nutrient losses from agriculture in Flanders for 2010 to 2020. The results show the influence of precipitation on emissions and a spatial link with catchments with intense agriculture and high fertilizer use. The output of the model is used as input for the water quality model PEGASE which simulates nutrient concentrations in surface waters based on the loads of agriculture, industry and households. Emission reduction targets to reach good water quality status were then calculated for each sector. In preparation for the 2022-2027 river basin management plans and in support of the evaluation of the 6th Nitrate Directive action program for Flanders, different scenarios were simulated using NEMO to evaluate the impact of policy measures. These scenarios included a business-as-usual scenario, a scenario with the proposed measures and a maximal scenario with strengthened measures. Results of the different scenarios show that reduction of fertilisation and increased usage of catch crops contribute to closing the gap to a good water quality status. In certain catchments the measures are sufficient to reach short term, intermediate goals. But in several catchments a significant gap remains to the long term goals for good water quality status and further measures will be required in the next phase of policy planning.

McIntyre T.
T. McIntyre

Abstract number–61 Nitrogen reductions through behaviour change: A focus on fertilizer

Tina McIntyre[1]

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Seminole County, Florida, USA is home to numerous waterbodies, including the National Wild & Scenic Wekiva Springs River. This river, and many others, are legally impaired by Nitrogen (N). These water resources are economically and environmentally tied to the area through recreation, property values, wildlife support and aquifer recharge. Research on the Wekiva Springs Basin showed 26% of all nitrate entering the basin was from urban turfgrass fertilizer.

September 2018 – September 2021 the Agent taught Fertilizer Workshops, which targeted residents by offering a free bag of fertilizer and professionals by offering Continuing Educational Units (CEUs) for their state required license. Byway of 79 classes, 2,714 group learning participants were educated about fertilizer Best Management Practices (BMP's) for their landscapes.

In a 6 month follow up survey, 514 participants expressed that, as a result of the Fertilizer Workshop, they followed UF/IFAS recommendations and used at least 50% slow release nitrogen fertilizer. Based on best available leaching research, they reduced annual N leaching by 78.5 – 921.3 pounds and provided an economic benefit of $39,268 to $460,674.

We also calculated the N leaching reduction from participants complying with the Seminole County fertilizer restricted period ordinance, which runs annually June – Sept. One individual following the ordinance would reduce N leaching by 0.25 (well-vegetated) to 1.8 (bare soil) lbs. N/year. Based on the 434 individuals who, when surveyed, reported following the restricted period requirements, this equated to a total reduction of N leaching of 109.4 – 781.2 pounds, with a monetary value estimated at $54,684 to $390,600.

Combined, these two behaviors alone amount to 859.7 – 1,030.7 pounds N prevented or $93,952 - $851,274 in savings. The wide range in monetary savings is due to the wide range of possible scenarios that people might have in their home landscape. This approach assumes that typical residential landscape turfgrass is somewhere in-between the best (well-vegetated) and worst-case (bare soil) scenarios, therefore these estimates should be considered as upper and lower limits, rather than exact estimates.

These educational efforts resulted in data that shows significant behavior changes which reduced local levels of nitrogen and phosphorous, pollutants that lead to harmful algae blooms and impairments. Because of these workshops, participants better understand

sources of water contamination resulting from fertilizer misuse and acted to change those behaviors.

Lagzdins A., Siksnane I., Sudars R.
A. Lagzdins, I. Siksnane, R. Sudars

Abstract number–63 Targeted water quality monitoring for implementation of river basin management plans in Latvia: The approach of the LIFE GOODWATER IP project

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The overall aim of the LIFE GoodWater IP project is to improve the status of water bodies at risk in Latvia through targeted water quality monitoring and implementation of measures as described in the Daugava, Gauja, Lielupe and Venta River Basin Management Plans. Four water bodies at risk with previously identified pressures from agricultural sources were selected for detailed assessment including V046 Eda, V093 Slocene, G264 Age, L118 Auce. According to the Corine Land Cover 2018 database the share of agricultural land varies from 50% in G264 Age to 72% in V093 Slocene. Water quality monitoring activities were started in March, 2021 and will be continued until the end of the project in 2027. Water samples were collected using a grab sampling approach on monthly basis. Water samples were analyzed for concentrations of total nitrogen (TN), ammonium - nitrogen (NH4-N), and total phosphorus (TP). The locations of sampling points were selected using the same principles for all water bodies to target potential sources of nutrient losses including subsurface drainage systems, open ditches, main tributaries, before and after municipal wastewater treatment plants, before and after large livestock facilities, and outlets of the water bodies. The number of sampling points is similar for all water bodies, i.e., 13, 15, 14, and 15 for V046 Eda, V093 Slocene, G264 Age, and L118 Auce, respectively.
The monitoring results show pronounced differences among the selected water bodies at risk in terms of the specific character of nutrient losses that needs to be addressed. In V046 Eda, the mean concentration of TN in four sampling points exceed the threshold of good water quality. The increased concentrations of TN in two tributaries of the Eda River is likely to be related with agricultural activities, while in two cases with partially treated wastewater discharged from small municipal wastewater treatment plants. In V093 Slocene and L118 Auce, the mean concentration of NH4-N and TP rarely exceed the respective threshold values for good water quality, while TN concentrations are exceeded at all sampling sites indicating for a strong impact from agricultural activities. The water quality in G264 Age can be described as the most challenging from all water bodies selected for this study as all parameters nearly at all sampling sites exceed the respective threshold values for good water quality. This situation is caused by point source pollution leaving the slaughterhouse as completely untreated wastewater is discharged from this facility into the upstream part of the water body. Due to the project results operation of this slaughterhouse has been

stopped.
This work was supported by the integrated project “Implementation of River Basin Management Plans of Latvia towards good surface water status” (LIFE GOODWATER IP, LIFE18 IPE/LV/000014) financed by the LIFE Programme of the European Union and Administration of Latvian Environmental Protection Fund.

Lagzdins A., Veinbergs A., Grinberga L., Siksnane I., Sudars R., Abramenko K.
A. Lagzdins, *A. Veinbergs*, L. Grinberga, I. Siksnane, R. Sudars, K. Abramenko

Abstract number–64 The long-term results of the Agricultural Runoff Monitoring Programme in Latvia: Nitrate-nitrogen concentrations

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Latvia University of Life Sciences and Technologies has been responsible for implementation of the Agricultural Runoff Monitoring Programme in Latvia since 1995. Water quality and quantity monitoring activities are carried out in the areas with high share of agricultural land at multiple spatial scales including groundwater (20 wells), experimental plots (1 site with 16 plots), subsurface drainage fields (6 sites), small catchments (10 sites), small and medium size rivers (23 sites). The main objectives of the programme are to document and assess the current status and long-term changes in nutrient concentrations as affected by natural and anthropogenic factors. The results obtained within the programme are periodically reported to the European Commission regarding the implementation of the Water Framework Directive (2000/60/EC) and the Nitrates Directive (91/676/EEC) in Latvia. Water samples in the case of experimental plots, subsurface drainage fields, small catchments and rivers are collected on a monthly basis using a grab sampling approach or composite flow proportional sampling where discharge measurement structures and data loggers are installed. In the case of groundwater monitoring sites water samples are collected four times a year covering conditions with high and low groundwater level. Water samples are analyzed for three forms of nitrogen and two forms of phosphorus according to the national standards, in this presentation only the results on nitrate – nitrogen (NO3-N) concentrations are included.
The study results show a large variation in NO3-N concentrations among the spatial scales of monitoring with the lowest mean annual concentrations in groundwater (below 1.0 mg l-1) and the highest in the discharge from subsurface drainage fields and experimental plots (over 7.0 mg l-1). Overall, NO3-N concentrations follow the discharge patterns having the highest concentrations during high flow conditions in winter and spring, while the lowest concentrations during low or no flow conditions in summer and autumn. These patterns highlights the great importance of subsurface and surface drainage systems, which act as pathways for transport of excess water and soluble forms of nitrogen from agricultural fields to surface waters. At the river scale NO3-N concentrations tend to have a strong relationship

with the share of agricultural land in the catchment area indicating for a direct connection between agricultural activities and water quality. This determines the need for further implementation of measures targeted to reduce nitrogen losses from agricultural lands. Overall, it is essential to continue ongoing activities within the Agricultural Runoff Monitoring Programme also in the future, especially in the light of need to quantify changes in water quality as related to implementation of the Farm to Fork strategy aiming to reduce the use of fertilisers by at least 20% and nutrient losses by at least 50% by 2030.

Fölster J., Kyllmar K., von Brömssen C., Rakovic J.
J. Fölster, *K. Kyllmar*, C. von Brömssen, J. Rakovic

Abstract number–65 GAMM models on open data show improving water quality in agricultural streams

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Effects of measures in agriculture against eutrophication of surface water is often difficult to detect on a regional scale. The effects are often delayed by processes in the soil and in the stream and the natural variation of water quality is large. Data on water quality has earlier been scattered on local databases and has been difficult to compile for regional studies on the agricultural impact. Further, conventional statistical methods do not detect if a change has been gradual over time or happened only during a shorter time period and the results also depends on the delimitation of a time series. In this study on nutrient content for 30 years in 124 Swedish agricultural streams, we have overcome these obstacles. Since a few years, most of fresh water monitoring in Sweden data is reported to a national database with open access. From this we could download nutrient concentrations from around 1000 streams with a minimum of bimonthly data for 10 years. From these, we filtered out 124 agricultural streams by the land use criteria (> 15% agricultural land) and pressure criteria from source apportionment calculations for TotP (> 50% from agriculture, < 5% from sewage treatment plants, < 15% from scattered households, < 10% from urban storm flow). The sites represent the agricultural landscape in southern Sweden with catchments between 2 and 2 300 km2. The time series were analysed with GAMM models (Generalized Additive Mixed Models). The method fits a smoothed curve to data and test if the slope is significantly deviating from zero in each point. The results were visualized by newly developed tools (von Brömssen et al, 2021). The study shows that declining nutrient concentrations dominate over increasing, but with many streams without trends. Declines were most common 2000-2010. After 2015, some streams had increasing trends for nitrogen and nitrate, possibly due to drought. Similar trends were found for annual transports, but with less significant changes.

Our study shows that open access to monitoring data and appropriate statistical methods can reveal effects from measures against eutrophication on regional scale and be a useful support for water management.

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Skarbøvik E., van't Veen S.G., Atcheson K., Wenng H., Lannergård E., Kämäri M., Marttila H., Bieroza M., Stutter M., Mellander P.-E, Kaste Ø., Fölster J., Kronvang B., Lepistö A., Jordan P.
E. Skarbøvik, S.G. van't Veen, K. Atcheson, H. Wenng, E. Lannergård, M. Kämäri, H. Marttila, M. Bieroza, M. Stutter, P.-E Mellander, Ø. Kaste, J. Fölster, B. Kronvang, A. Lepistö, P. Jordan

Abstract number–66 Comparing the correlation between turbidity and suspended solid concentrations in rivers of different characteristics from six northern-European countries

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Turbidity sensors are often used as a substitute for suspended solids (SS) and particle bound substances in water. Such surrogate monitoring signals have enhanced utility when good correlations can be established between turbidity (Tu) as measured by sensors and SS concentrations determined from manual sampling across a range of flow conditions and then analysed in laboratories. Experience has shown that these correlations can range from excellent to rather poor and may also be unique, and therefore resource intensive for every sampling point. To shed more light on which conditions are needed to ensure an acceptable

Tu-SS correlation, we have used data from 35 different rivers in six Northern European countries: Denmark, Finland, Ireland, Norway, Sweden, and UK (Northern Ireland and Scotland). Our aim has been to find patterns in these correlations based on such river characteristics as mean and maximum turbidity, catchment area, hydrology, soil type, and topography.

We have also investigated how well the data for determining the Tu-SS relationship are representing the rivers' overall turbidity variations: in other words, how well do we manage to collect water samples for SS analyses up to the highest observed turbidity, allowing unbiased calibrations across the extremes of turbidity levels.

Also included in the study is an inventory of how the six countries use turbidity sensors for different purposes, including in national regular monitoring, their experiences with practical and technical constraints, and how they propose to solve these.

Mielenz H., Dieser M., Zieseniß S., Müller K., Greef J.-M., Stever-Schoo B.
H. Mielenz, M. Dieser, S. Zieseniß, K. Müller, J.-M. Greef, B. Stever-Schoo

Abstract number–68 Suitability of early indicators to assess nitrate leaching from agricultural fields

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An important contributing factor for regionally high nitrate concentrations in groundwater bodies is diffusive nitrogen (N) loss from agriculture. The development of nitrate pollution in groundwater and the evaluation of the effectiveness of corresponding water-protecting measures are monitored in Germany using a representative groundwater monitoring network. However, changes in nitrate loads, such as those expected as a result of the more recent amendments to fertiliser legislation, cannot be detected in the short term or in a cause-specific manner due to the often long transport routes. Therefore, different approaches to assess N leaching from agriculture directly were tested for their suitability to be used in a monitoring system. These early indicators comprised both, direct measurements in the field and calculated indicators, covering the field and the farm scale: field N balances (Nbal), farm N balances, soil mineral nitrogen contents (SMN), and mineral nitrogen concentrations in the subsoil (subMN, 120-300 cm). The indicators were applied in five test regions in Germany on 48 farms with a total of 576 test plots. The focus was placed on cash crop farms with low use of organic fertilisers. Data collection and measurements were conducted for four years from harvest 2017 to spring 2021. Thus a variety of soil types and weather conditions were covered. Generally, only weak quantitative correlations were observed between the individual indicators. We found a significant but very weak correlation between SMN in autumn and Nbal at plot scale. While we found no correlation between Nbal

and subMN of the subsequent year, SMN did show a correlation with subMN after the leaching period. The results show that for individual plots, the different indicators often provided inconsistent statements. This is due to the complex interactions of soil-climatic factors and agricultural management practices. While each indicator in itself contributes important aspects to the monitoring of nitrate leaching, the indicators do not provide sufficient information individually. Therefore, the simultaneous observation of several indicators is recommended to monitor nitrate leaching potential towards groundwater and to assess the influence of management and site factors.

Volk M., Amorsi N., Bokal S., van den Brink C., Natalja Čerkasova N., Farkas C., Fučík P., Glavan M., Honzak L., Krzeminska D.M., Lemann T., Monaco F., Nemes A., Nesheim I., Piniewski M., Schürz C., Strauch M., Toth (Szabo) B., Witing F.
M. Volk, N. Amorsi, S. Bokal, C. van den Brink, N. Natalja Čerkasova, C. Farkas, P. Fučík, M. Glavan, L. Honzak, D.M. Krzeminska, T. Lemann, F. Monaco, A. Nemes, I. Nesheim, M. Piniewski, C. Schürz, M. Strauch, B. Toth (Szabo), F. Witing

Abstract number–69 OPTAIN – Optimal strategies to retain and re-use water and nutrients in small agricultural catchments across different soil-climatic regions in Europe

Martin Volk[1], Natacha Amorsi[2], Sabina Bokal[3], Cors van den Brink[4], Natalja Natalja Čerkasova[5], Csilla Farkas[6], Petr Fučík[7], Matjaž Glavan[8], Luka Honzak[8], Dominika Krzeminska[9], Tatenda Lemann[10], Federica Monaco[11], Attila Nemes[6], Ingrid Nesheim[12], Mikołaj Piniewski[13], Christoph Schürz[1], Michael Strauch[1], Brigitta Toth (Szabo)[14], Felix Witing[1]

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The increasing number of droughts and heavy rainfall aggravates the existing conflicts among agricultural water uses and other human and environmental demands for water. Natural/Small Water Retention Measures (NSWRMs) can help mitigate such conflicts and serve a sound management of head watersheds, which could significantly contribute to an improved water quality, more resilient agriculture and society. Moreover, these measures the achievement of different Sustainable Development Goals and environmental targets formulated in several water- and agriculture-related policies of the European Union. Despite the existing comprehensive set of techniques to increase water and nutrient retention on both catchment and farm levels, knowledge is still lacking on the effectiveness of different scale- and region-specific measures across various soil climatic regions and agricultural systems, especially under changing climate conditions. The EU Horizon 2020 project OPTAIN aims to (i) identify efficient techniques for the retention and reuse of water and nutrients in small agricultural catchments across different biogeographical regions of Europe, and - in close cooperation with local actors - (ii) select NSWRMs at farm and catchment level and optimize their spatial allocation and combination, based on environmental and economic sustainability indicators. All gained knowledge will be translated into a Learning Environment allowing analysis of trade-offs and synergies between multiple values/goals in the management and design of NSWRMs.
The presentation will discuss the flow of the project that comprises of: a) establishment of Multi-Actor Reference Groups (MARG) in each case study, b) identifying and documenting NSWRMs and its potentials and constrains, c) modelling the environmental (SWAT+ for the catchment scale and SWAP for the field-scale) and socio-economic performance of NSWRMs in 14 case studies, d) multi-objective allocation and combination of NSWRMs, e) policy analysis and recommendations, and f) the establishment of the Learning Environment. Stakeholders in each case study will be involved during these steps to identify NSWRM practices considering both environmental and socio-economic indicators. We will present first results from these different steps, such as the actor-based identification of promising measures, including customized environmental and economic performance indicators. Furthermore we will provide an outlook focusing on the harmonized modelling and optimization approach across 14 case studies.

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van Herpen F.C.J., Vonk A.W., Rutjes H.A., van Gerven L.P.A., Verstraten J., Bartelds N., Rozemeijer J.C., van Loon A., Schipper P.
F.C.J. van Herpen, A.W. Vonk, H.A. Rutjes, L.P.A. van Gerven, J. Verstraten, N. Bartelds, J.C. Rozemeijer, A. van Loon, P. Schipper

Abstract number–70 Joint fact finding on options for nutrient loss reduction

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In 2018 the regional water authority Aa en Maas started a cooperative research project with 7 farmers in a small free draining catchment area (100 ha) on sandy soil in the south of the Netherlands. The objective was to investigate whether combining different monitoring techniques in for groundwater, surface water and soils can be used by farmers and water authorities to reduce the emission of nitrogen to the water system. This research is an example of a local approach, were water authority and farmers work together on interpretating monitoring data and finding solutions in local catchment areas.
The project consisted of 1) the design, installation, and operation of a surface water quality sensor network in a small catchment area and monitoring of the agricultural soils, 2) study groups with farmers to discuss the results, identify nutrient loss hot spots and hot moments and identify impacts of agricultural management activities on nutrient emissions, and 3) demonstration of agricultural best management practices in field experiments aimed at reduction of nutrient losses from the fields of the participating farmers, while maintaining production capacity.
The research showed that due to the large spatial heterogeneity, both at the catchment scale and also within the fields, it is difficult to find direct relations between agricultural activities and surface water quality. Weather conditions during the growing season have a large impact on both concentrations of nitrogen in surface water and in the soils. Good understanding of the nutrient uptake of crops in relation to timing of the use of fertilizers by farmers is essential in order to minimize unnecessary nutrient losses to ground an surface water, and maximize uptake by the crops. Discussions in our study group made it clear that it is easier for farmers and more in line with their agricultural practice to focus on minimizing the post-harvest nitrogen residues in the soil than on direct improvements of the surface water quality.
Our fact finding approach on a local catchment scale proved to be a suitable way for the regional water authority and farmers to discuss on hot spots, hot moments and mitigation of nutrient losses. This approach can help to select more tailor made mitigation measures on the level of individual plots and farms and prevent the introduction of more generic derived mitigation measures which are not likely to improve the water quality in a local catchment due to the characteristics of the area.

Hallberg L.V., Bieroza M.Z.
L.V. Hallberg, M.Z. Bieroza

Abstract number–71 The role of catchment controls for nitrogen and phosphorous removal in remediated agricultural ditches

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Combating eutrophication requires holistic mitigation measures aimed at reducing anthropogenic losses of nutrients, including nitrogen (N) and phosphorous (P) to aquatic ecosystems. This need will become critical in the future as increased flashiness, expected from changing climate and growing food demand, will further accelerate N and P pollution. To address these challenges, two-stage ditches have been implemented as a stream remediation measure with constructed floodplains, relying on hydrological and biogeochemical controls to reduce the export of N, P and other pollutants.

In this study, we investigated the potential for nitrate (NO3-) removal via denitrification and P sorption to sediments in 10 remediated ditches across two regions with differing catchment controls (soil texture, land use and hydrology) and design. Potential denitrification rates and nitrous oxide (N2O) yields were measured in channel and floodplain sediments between 2020-2021, using acetylene incubation assays. We also determined equilibrium phosphorous concentrations (EPC0) in floodplain sediments in spring 2021. Water and sediment chemistry were sampled monthly and flow discharge continuously.

Firstly, we found that denitrification was higher in stream channels and that floodplains contributed to 30% of total denitrification, controlled by the inundation regime and NO3 delivery. In floodplain sediments, net P sorption dominated and predicted higher P retention (mean 12.4 PO4-P µg L-1). Secondly, we found clear regional differences in NO3 removal rates: remediated ditches in the South promoted both higher denitrification rates and lower N2O yields in comparison to Central East. In contrast, we observed the opposite trend for P sorption in floodplains, with higher sorption capacities in Central East compared to South.

Statistical analysis showed that the observed differences in denitrification, N2O yields and P sorption were linked to differences in the soil type (South: loam, Central East: clay), agricultural land use (higher in the South) and floodplain height (lower in the South). Thirdly, despite the activity of denitrification and P sorption, the effect on reach-scale NO3 and P removal was insignificant, potentially due to additional inputs of nutrient-rich water e.g. from drains or subsurface flow pathways or insufficient nutrient residence time on floodplains.

These results shows that the effect of stream remediation on N and P removal and N2O emissions depends on the predominant catchment characteristics including soil texture and land use type but also the specific design of remediated ditches (floodplain elevation). Thus, the potential trade-offs in water quality management between NO3 removal and emissions of N2O, but also P, should be considered before choosing a design and location of remediated ditches.

Oduor B.O., Campo-Bescós M.A., Sarasibar J.C., Lana-Renault N.S.
B.O. Oduor, M.A. Campo-Bescós, J.C. Sarasibar, N.S. Lana-Renault

Abstract number–72 Modelling the impacts of climate change on streamflow and nitrates export in a Mediterranean agricultural watershed in Spain

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The increase in nitrate pollution in a watershed could generally be attributed to pollution from several factors including agriculture, livestock, and aquaculture. Nitrates pollution adversely affects water quality making it harmful for human consumption as well as resulting in increased eutrophication. Nitrate exportation in agricultural areas is inevitable. However, climate change introduces great uncertainty into an already very complex problem, thus an estimate of the effects of climate change on nitrate dynamics would greatly contribute to the management of the affected territories. This research aimed to predict the impacts of climate change on streamflow and nitrate exportation in a Mediterranean rainfed agricultural watershed using the Soil Water Assessment Tool (SWAT). The model was first evaluated for its suitability to simulate streamflow and nitrate loads under rainfed agricultural conditions in the 477 km2 Cidacos River Watershed located in Navarre, Spain. The model was then used to assess the climate change impacts using the RCP8.5 scenario to analyze the short-term (2011-2040), medium-term (2041-2070), and long-term (2071-2100) climate projections compared to a historical baseline period (1971-2000) while assuming that all other variables remain unchanged. The model performance was very good with satisfactory and acceptable results for both streamflow and nitrates. Streamflow had NSE values of 0.82 and 0.83 and R2 values of 0.83 and 0.84 during calibration and validation periods respectively, whereas the nitrate loads had NSE values of 0.71 and 0.68 and R2 values of 0.72 and 0.79 during calibration and validation periods respectively. The climate change scenario results indicated a significant decline in projected streamflow by 5.3%, 38.7%, and 72.0% in the short-term, medium-term, long-term projections respectively. This decline was mainly attributed to the projected decline in precipitation and increase in actual evapotranspiration as a result of increasing temperatures. Similarly, the projected nitrate load indicated a declining trend of 55.5%, 57.6%, and 78.0% in the short-term, medium-term, and long-term projections respectively. This decline was mainly as a result of the declining streamflow. The projected nitrate concentration rates also indicated a declining trend by 48.4%, 22.1%, and 20.1% in the short-term, medium-term, and long-term projections respectively. From the projections, the medium-term and long-term scenarios indicate very serious situations that would require drastic policy changes and management interventions to minimize the negative consequences. Therefore, there is need for better management practices that ensure sustainable water resources utilization and efficient nitrogen fertilizer application rates in the watershed to significantly reduce the pollution on streams.

Abstract number–73 Evaluating the impacts of agricultural transformation from rainfed to irrigation on streamflow and nitrates in a Mediterranean agricultural watershed in Spain

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Agriculture intensification, such as irrigation, creates a lot of pressure on the available water resources and the environment. This paper explored the water quality dynamics, specifically nitrates, before and after transformation from rainfed to irrigation agriculture within the Cidacos River Watershed in Navarra, Spain. The watershed occupies 477 km2, of which approximately 260 km2 have been traditionally rainfed cultivated, whereas 77 km2 were transformed from rainfed to pressurized irrigation between 2009 and 2011. The newly irrigated area is located in the watershed's lower region, close to the river's mouth. A previous baseline study by Merchán et al. (2020) showed an increase in the electrical conductivity and nitrate concentration in the river's lower reaches affected by irrigation. However, no information about the effect on streamflow, and nitrate loads resulting from the irrigation was explored. The aim of this study was, therefore, to fill this research gap by using the Soil Water Assessment Tool (SWAT) model, to recreate, simulate and understand the behavior of the Cidacos River in the irrigated area from 2017 to the present, assuming the transformation from rainfed to irrigation had not occurred; and then compare those simulated variables with the measured ones. The model was calibrated from 2000 to 2010 and validated from 2011 to 2020, and its sensitivity and uncertainties were analyzed for streamflow and nitrates at the Olite gauging station. The area of the watershed until Olite covers the region entirely under rainfed cultivation. The calibrated parameters were then used to simulate the entire watershed, up to Traibuenas, from 2017 to the present, considering all the territorial variables specific to each zone. The model evaluation results were satisfactory for both streamflow and nitrate loads, with streamflow having values of Nash Sutcliffe Efficiency (NSE) = 0.82/0.83 and R2 = 0.83/0.84 during calibration and validation periods, respectively. Similarly, the statistical evaluation values for nitrate loads were NSE = 0.71/0.68 and R2 = 0.72/0.79 during calibration and validation periods, respectively. Comparative analysis between the periods before and after the implementation of irrigation indicated a 6.6% and 43.2% increase in streamflow and nitrate loads, respectively, which subsequently increased the nitrate concentrations in the river. The results of this study could be particularly important and useful for land managers in Navarre

since thousands of hectares of land in this region are expected to be converted from rainfed to irrigated land in the coming years.

Andersen H.E., Heckrath G.
H.E. Andersen, G. Heckrath

Abstract number–74 Mapping of risk areas for diffuse phosphorus losses to the Danish aquatic environment

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While knowledge on the overall phosphorus (P) loading to the Danish aquatic environment is relatively well confounded, much more uncertainty surrounds the individual contributions and their spatial distribution. A targeted and therefore cost-effective reduction of P losses requires knowledge on the mechanisms behind the individual sources, their location, and size to enable the use of adequate mitigation measures. We report the results of a three-year study by scientists from Aarhus and Copenhagen universities on the mapping and quantification of sources to diffuse P losses. The study produced comprehensive new data supplementing existing data as well as developed a number of models. A series of maps was produced indicating risk areas for P loss to surface water across Denmark. In total, diffuse sources amount to 1327 t P yr-1 equivalent of ca. 66% of the overall P loading to the aquatic environment (2021 t P yr-1, average 2014-2018). The study demonstrated that erosion of stream banks is the most important diffuse P source (644 t P yr-1), followed by leaching from cultivated organic soils (326 t P yr-1), and leaching via macropores in minerogenic soils (162 t P yr-1). P losses which can be attributed to agriculture amounts to 683 t P yr-1 or 34%.

Bhogal A., Anthony S., Gooday R., Williams J.
A. Bhogal, S. Anthony, R. Gooday, *J. Williams*

Abstract number–75 Farming Rules for Water in England – Finding the balance

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The Farming Rules for Water (FRfW) were introduced in England in April 2018 to fulfil obligations on diffuse pollution under the Water Framework Directive, particularly in regard to

reducing phosphorus (P) losses to water from agriculture. The rules aim to ensure that 'all reasonable precautions' are taken to prevent diffuse pollution following the application of organic manures and manufactured fertilisers. In order to comply with the rules farmers must demonstrate they have planned nutrient applications to ensure they are applied in quantities that are sufficient to meet, and not exceed, the crop and soil requirements.

Recent clarification from the regulators has confirmed that farmers must demonstrate that the timing and quantity of organic manure applied is in accordance with crop and soil need at the time of application. This applies to all types of organic manure containing readily available N (RAN), and effectively rules out autumn and winter applications except to a crop that has a manufactured nitrogen fertiliser requirement in those seasons (e.g. winter oilseeds and grass to support late season growth in August and September). This interpretation is likely to have a significant impact on manure and nutrient management on all farms as in many circumstances it will not be practical to apply manure in spring. Moreover, changes in practice may also increase the risk of losses of pollutants other than nitrate (e.g. ammonia emissions to air, and P loss to water - so called 'pollution swapping'). This presentation summarises results from an impact assessment commissioned by the UK agricultural levy board (AHDB) to evaluate the impact of the Farming Rules for Water on farm practice and risks of diffuse air and water pollution and considers alternative options to autumn application timings for organic materials

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Cassidy R., Jordan P.
R. Cassidy, P. Jordan

Abstract number–76 Perspectives on water quality monitoring approaches from citizen science to enhanced and real-time solutions for delivering behavioural change

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A review of river water quality monitoring approaches assessed the feasibility and requirement for investment in real-time, high resolution water quality monitoring infrastructure, as part of a sustainable agricultural land management strategy for Northern Ireland (NI).

Based on evidence gathered during site visits to 11 locations in 7 countries in north-western Europe, options were identified and evaluated for suitability to deliver optimal and enhanced solutions to specific water quality monitoring objectives and with a focus on demonstrating a positive influence on stakeholder behaviour toward water quality issues.

A series of interviews and site visits were conducted with a selection of programmes with

comparable agricultural pressures to those in NI and with similarities in terms of landscape and climate. Monitoring programmes ranged from enhanced grab sampling and laboratory analysis to sub-hourly sampling of multiple parameters and nutrients in high-specification, bank-side or mobile laboratories. Just one programme had a primary objective to encourage farm practice change in an agricultural catchment. None of the other programmes visited could easily identify influences that had caused behavioural change among stakeholders and were largely focussed on policy surveillance or process research. However, it was clear that stakeholders were highly engaged with monitoring sites where data could be viewed in real-time for discussion on water quality issues.

This identifies a research space where water quality monitoring could be adapted for behavioural change investigations, and which is now being trialled across NI using mobile monitoring units.

Jarosiewicz P., Zagibajło K., Miszczak A., Zalewski M.
P. Jarosiewicz, K. Zagibajło, A. Miszczak, M. Zalewski

Abstract number–77 Spatial-temporal dynamics of pollutants in small rivers under the different pressure of orchards

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Small rivers, up to 3rd order (Strahler) are particularly vulnerable to pollution, and at the same time, they harbour a major proportion of freshwater biodiversity. Understanding of pollutants dynamics in headwaters, under different land cover pressure, is important to set a proper protection goal, implement best management practices and solutions, as also to adjust monitoring methodology. This study aimed to analyse the spatial-temporal occurrence of pesticides and nutrients, as also self-purification processes in river systems subjected to the agriculture pressure, in particular orchards.
To identify the temporal loads of pollutants, 4 rivers, with catchment areas ranging from 92,3 to 225,4 km2 (all Pilica River tributaries; central Poland) were selected and monitored (12 points) for 2 consecutive years (2018-2019). The total share of horticulture and arable land in the catchment was in a gradient from 57.3 to 80.6%, while in the orchard category itself from 0.1 to 62.9%. With applied methodology, 95 pesticides, inorganic nutrients, total forms of phosphorus and nitrogen (TP and TN), as also physicochemical parameters were monitored. Precipitation, river discharge and land cover were analysed to determine their impact on pollutants transfer.
A total of 30 pesticides were identified, being present in 89% of all collected samples (n = 144), with the highest impact detected in the upper part of the orchard-dominated catchment. Indeed, the spatial structure of the catchment in terms of the orchards presence

was the main factor determining the level of pollution, and yet the positive effect of riparian buffer zones, limiting maximum concentrations, was observed in one of the catchments. The temporal presence of pesticides was positively correlated with short-term rainfall (up to 3 days before the collection date), however, statistical significance was observed only for the most polluted river (orchard dominated catchment). No statistical difference was observed between seasons. The influence of orchards was also observed in the TP concentration in rivers, which was additionally correlated with precipitation. The efficiency of self-purification was related to the temperature, which confirms the significant role of biotic factors (river metabolism). A lower potential for self-purification was observed in winter.
Under climate change in central Europe, with wetter winters, and longer droughts interspersed with heavy rainfalls in the summer, we can expect a decrease in water quality in the orchard-dominated catchments. On the existing debate over the reliability of freshwater monitoring, obtained results may help to indicate the presence and dynamics of pollutants under different conditions for the sake of future optimization. Prevention methods (i.e. legislation, agriculture practices) as also Nature-based Solutions should emphasize the winter period when self-purification potential is low, but pollution levels can be still impactful.

Appels J.
J. Appels

Abstract number–78 No online sensor data possible without certified lab-data – how to optimize sensor data

Joep Appels[1]

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More and more water boards, water laboratories, municipalities and industrial companies are using online sensors to measure water quality. Logical, because that is fast, real-time and continuous. While manual random samples are time consuming, periodic and by themselves only random samples.
Sensoring, on the other hand, requires planning (how much/where), investment (purchase), management (maintenance/reagents) and analysis (data filtering, pre-processing of large amounts of data). That turns out to be specialist work.

Urban surface water has numerous functions, including water management, urban planning and ecological functions. Water quality has improved in recent decades and, partly under the influence of warmer summers and the corona crisis, citizens increasingly want to use urban surface water for recreation or simply to cool down.
The municipality of Breda also encourages the use of city water for activities such as city swims and other touristic events. The use of surface water for 'events' is also developing nationally. To this end, STOWA drew up a first guideline in 2019: 'Guide for events in, on, with, above and around water'.

The City of Breda uses since 2 years data from online (fecal)bacteria monitoring to have an

indication and if needed an alarm when the water quality in canals of the city is not suited for events. This is specially needed as lab results for bacteria testing can take up to 3 days which is when the event has taken place already. But lab data are still needed for legal reference and that's always a certified laboratory should be involved.

microLAN has with the BACTcontrol a single point online monitor to detect changes in the microbial water quality (within 1 hour) related to fecal contamination from for example overflows after rainfall events. Due to the climate change more and more severe storms are happening and the prediction of this is more difficult when and where they happen. microLAN is developing a cloud based platform to bring together online monitoring data with reference lab data in combination with rainfall, sewer information and storm water overflows. Through machine learning and modelling we want to improve our prediction capability in 2022 and better improve the information for the local government and the public.

Farrow L.G., Morton P.A., McRoberts C., Floyd S., Cassidy R., Jordan P., Doody D.
L.G. Farrow, P.A. Morton, C. McRoberts, S. Floyd, R. Cassidy, P. Jordan, D. Doody

Abstract number–79 Evaluation of Chemcatchers® for pesticide monitoring in agricultural grassland catchments

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Monitoring pesticide concentrations in surface waters requires the collection of a sequence of samples through time. However, this approach is labour intensive, costly, and often misses peaks in concentration, leading to average concentrations (i.e., time-weighted or flow-weighted mean concentrations; TWMC and FWMC, respectively) not being representative. As such, passive samplers are becoming increasingly widely used as they offer a low-cost, low-tech solution for both short and long-term monitoring of trends in contaminant concentration, but their performance in hydrologically dynamic rivers has not been widely explored.

On the island of Ireland, the highly soluble herbicide MCPA (4-methyl-2-chlorophenoxyacetic acid) is often found in surface water bodies which are abstracted and treated for drinking. Whilst herbicides can be removed from the water by treatment, the amounts of MCPA in the rivers mean that concentrations in treated water can occasionally exceed the drinking water standard of 0.1 ug/L for a single pesticide. River monitoring to identify hotspots to target with mitigation measures is an effective way of reducing MCPA concentrations in abstracted water and thus drinking water. Therefore, this study investigated the performance of Chemcatcher® passive sampling (PS) devices, compared to high-frequency sampling (HFS - 7-hourly to daily) in two dynamic rivers in the Irish border region over 16 months, focussing on MCPA and three other acid herbicides (mecoprop-P, fluroxypyr and triclopyr). River flow

and chemical parameters were explored to determine whether these affected Chemcatcher® performance.

MCPA concentrations spanned three orders of magnitude in both catchments, whilst the three other herbicides spanned two. Mixed effects modelling was used to compare the TWMC and FWMC values calculated from HFS with TWMCs from the PS Chemcatchers®. HFS produced higher pesticide concentrations regardless of whether TWMC or FWMC was used and PS TWMCs were more similar to HFS TWMCs than HFS FWMCs. HFS and PS TWMCs were not significantly different for MCPA but were for the other herbicides. Whilst there was a small indication that agreement between the two sampling methods may have been more comparable at lower flows, this was only apparent for MCPA and there appeared to be few relationships with flow or chemical river metrics. Results will be discussed in the context of improving water quality monitoring costs and effectiveness.

Dieser M., Zieseniß S., Mielenz H., Müller K., Greef J.-M., Stever-Schoo B.
M. Dieser, S. Zieseniß, H. Mielenz, K. Müller, J.-M. Greef, B. Stever-Schoo

Abstract number–82 Identifying most relevant factors on soil mineral nitrogen contents in autumn on agricultural soils in Germany using Random Forest

Mona Dieser[1], Steffen Zieseniß[2], Henrike Mielenz[2], Karolin Müller[2], Jörg-Michael Greef[2], Burkhard Stever-Schoo[2]

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To examine the effectiveness of the measures of the German nitrates action programme as early as possible, the Demonstration Project “Indicators for the early detection of nitrate loads in soil under crop production” was initiated. A total of 576 testing sites on 48 farms in five federal states were established on which, among others, soil mineral nitrogen content in autumn (Nmin) was measured from 2017 to 2020. Nmin is an important indicator for estimating the potential nitrate loads leaching towards the groundwater. The objective of this study was to determine the most important factors on the Nmin value in autumn and to analyse whether these are sufficiently addressed by the policy measures.
About 30 factors including nitrogen balance on field scale, measured Nmin in spring, precipitation, air temperature, humus content as well as management and site effects were classified with a random forest algorithm considering Nmin as target variable.
The results clearly show that, first of all, the main crop cultivated is decisive for the level of autumnal Nmin content in the soil. “Critical crops” are usually accompanied by i.e. fertilisation in autumn, high yield and quality expectations, intensive soil tillage and/or high proportions of nitrogen-rich crop residues. Other important factors on autumnal Nmin can be classified as site specific factors e.g. soil type and precipitation amount.
With the help of the extensive data set and the evaluation method used, it is possible for the

first time for Germany to assess the effectiveness of individual fertiliser prescriptions comprehensively and taking into account the entire farm management process as well as site specific impacts.

This work was financially supported by the German Federal Ministry of Food and Agriculture (BMEL) through the Federal Office for Agriculture and Food (BLE), grant number 2820ABS001.

Tetzlaff B., Kunkel R., Nguyen H., Venohr M., Wendland F., Wolters T.
B. Tetzlaff, R. Kunkel, H. Nguyen, M. Venohr, F. Wendland, T. Wolters

Abstract number–83 Modelling N- and P-input into surface waters in Germany

Björn Tetzlaff[1], Ralf Kunkel[1], Hong Han Nguyen[2], Markus Venohr[2], Frank Wendland[1], Tim Wolters[1]

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In the project AGRUM-DE a nutrient model system has been applied to quantify long-term N- and P inputs into groundwater and surface waters from both diffuse and point sources in Germany (358 000 km²). The nutrient model system consists of the FZJ-models DENUZ-WEKU and MEPhos focusing on diffuse sources and the MONERIS model (IGB) dealing with point source emissions and nutrient retention. The following input pathways have been considered: Water erosion, wash-off, artificial drainage, groundwater, interflow, atmospheric deposition, municipal waste water treatment plants, industry, rainwater sewers, combined sewers overflows, cesspits and exfiltration from leaky sewage pipes. Model results have been validated against monitoring data successfully.
Total model results show nitrogen emissions of about 494 000 tonnes per year, dominated by diffuse sources (77 % of the total emission). The input pathways groundwater and interflow are of highest significance regarding surface water pollution. Phosphorus emissions sum up to 23 000 tonnes per year, while diffuse and point sources are of equal importance. Here, water erosion and municipal waste water treatment plants are the most important pathways at the national scale. At sub-regional or local level the situation can differ greatly. The presentation will refer to the model results at greater detail and will outline selected model approaches.

Vaessen F.M.J.
F.M.J. Vaessen

Abstract number–84 The process by which a water supply company collaborates with farmers with the aim of avoiding investment costs for building a nitrate treatment plant

Frans Vaessen[1]

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Leaching of nitrate towards groundwater was (and is) a problem in the Netherlands, especially on the sandy and loamy soils (Loess) in the South. In 1997 the water supply company in the province of Limburg (WML) started a pilot to cooperate with farmers in one water extraction region with the primer goal to prevent investment costs for building a nitrate purification plan. Second goal should be to prevent leaching of nitrate and pesticides to groundwater. Those years nitrate levels increase that high WML made all the preparations to build a nitrate treatment plant soon. Despite this urgency, the nitrate problem was once again studied together with all WML experts. It soon became apparent WML only had desk studies and no data from farmers in the groundwater protection areas actually. Instead of starting to build that plant or an approach with stricter laws, WML started a pilot in collaboration with farmers.
From the beginning the approach of the project Sustainable Clean Groundwater (in dutch Duurzaam Schoon Grondwater (DSG)) was built on three cornerstones: Awareness (both for farmers and WML), Advice and Counselling and Stimulation. The approach turned out to be successful; the project has expanded from one water extraction region in 1997 upward to 13 groundwater protection regions in the province of Limburg in the present.
In return of getting advice, counselling and stimulation, the farmers were asked to deliver data on a.o. fertilization and yield. By combining these data and the results of soil nitrate analysis , WML was able to make better predictions of the expected nitrate levels in the groundwater to be extracted.
Now 25 years later, WML is still collaborating with farmers and no nitrate treatment plant has been built (yet)! The process by which WML developed a relationship of trust with farmers in groundwater protection areas out of hostility is described in detail in this presentation. The success and failure factors are also explained.

Kusters P.J.J.M.E., Crijns J.W.A.M.S.
P.J.J.M.E. Kusters, J.W.A.M.S. Crijns

Abstract number–85 Development and implementation of the Nitrate leaching Model South Limburg: Towards improvement of water quality in combination with sufficient fertilization of arable crops

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[2]*Delphy, Postbus 7001, 6700AA Wageningen, Netherlands*

Leaching of nitrate towards groundwater was (and is) a problem in the Netherlands, especially on the sandy and loamy soils (löss) in the South. In 1997 the water drinking company in Limburg (WML) started a cooperation with farmers in ground water protection areas with the goal to prevent the leaching of nitrate and pesticides. Profit should be two-sided: sustainable agriculture for the farmer with sound financial profit and prevent the building of nitrate treatment plants.

From the beginning the approach of the project Sustainable Clean Groundwater (in dutch Duurzaam Schoon Grondwater (DSG)) was build on three cornerstones: Awareness (both for farmers and WML), Advice and Counselling and Stimulation. The approach turned out to be successful; the project has expanded from one groundwater extraction area in 1997 to 13 groundwater protection areas nowadays in the province Limburg and no nitrate treatment plant had to be built until today.
In return of getting advice, counselling and stimulation, the farmers were asked to deliver data on a.o. fertilization and yield. By combining these data with the results of sampling and analysis on a depth of 2.5 meters and the input of knowledge on soil processes, behaviour of nitrate, common and practical agricultural knowledge we were able to develop the Nitrate leaching Model South Limburg for löss.
The first version was born in 2014. During the years it has been developed further and improved. Nowadays the Nitrate leaching model South Limburg for löss provides a prediction of the nitrate concentration in the soil moisture on 2.5 meter depth in 2 years. The model takes into account the succession of crops and typical characteristic of löss to “catch up” water with dissolved nitrate from greater depth. The succession of shallow and profound rooting crops is a very important tool for farmers to reduce nitrate leaching.
The Nitrate leaching model South Limburg was and is used in projects like DSG and Slim Bemesten (Smart Fertilizing). In the latest farmers could realize a surplus on the allowed nitrogen fertilization based on the model results without increasing the risk of nitrate leaching.

Zieseniß S., Dieser M., Mielenz H., Müller K., Greef J.-M., Stever-Schoo B.
S. Zieseniß, M. Dieser, H. Mielenz, K. Müller, J.-M. Greef, B. Stever-Schoo

Abstract number–86 Nitrogen use efficiency on arable farms in five regions in Germany at four scales – region, farm, crop and field

Steffen Zieseniß[1], Mona Dieser[1], Henrike Mielenz[1], Karolin Müller[1], Jörg-Michael Greef[1], Burkhard Stever-Schoo[1]

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Intensive use of nitrogen fertilizer in some regions of Germany led to nitrogen pollution of the ground water and therefore to negative environmental effects. In 2016, European Court of Justice condemned the Federal Republic of Germany for violating the European Nitrates Directive (91/676/EEC). In the course of this, a demonstration project with a set of early indicators was developed to monitor nitrate loads from agricultural land. The monitoring approach combines analytical and calculatory indicators and aims at determining the effects of political measures on agricultural nitrate loads. Here, we focus on calculatory indicators i.e. nitrogen balances at farm and field scale in five regions in Germany. These balances describe the total nitrogen loss potential. To further evaluate this potential, on-farm data from 48 farms is analysed with the concept of nitrogen use efficiency to compare arable farms at regional, farm, crop and field scale. Nitrogen output was used as indication for yield and a

target value of 80 kg N ha-1 a-1 was set as a desirable minimum output to ensure productivity. In order to account for unavoidable losses, the target value for the nitrogen surplus was set to 50 kg N ha-1 a-1. This evaluation shows differences between the farms and test areas regarding nitrogen use efficiency. In detail, the results show decreasing NUE with increasing amounts of organic fertilizer application. Likewise, excessive nitrogen fertilization in autumn reduces nitrogen use efficiency and thus increases nitrogen loss potential. This approach offers the possibility to identify potentials for the optimization of nitrogen use and thus to reduce nitrogen loads from arable farm land to ground and surface water.

Christel W., Friederich L.R., Ibsen-Jensen J., Machon J., Ejrnæs M.
W. Christel, L.R. Friederich, J. Ibsen-Jensen, J. Machon, M. Ejrnæs

Abstract number–87 Green transition of Agriculture – How Denmark plans to reduce aquatic N pollution and GHG emissions by transforming the sector and integrating N & C management at farm and landscape scale

Wibke Christel[1], Lukas Ringvad Friederich[1], Jakob Ibsen-Jensen[1], Johnny Machon[1], Morten Ejrnæs[1]

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In October 2021, the Danish government, parties supporting the government as well as several opposition parties entered into a broad political agreement. The "Agreement on a Green transition of the Danish Agricultural Sector" contains a binding target to reduce the greenhouse gas (GHG) emissions from the agriculture and forestry sector by between 55 and 65 % by 2030 compared to 1990 levels. This will deliver a substantial contribution to the overall national target, set by the Danish Climate Act, of a 70 % reduction by 2030. The agreement envisages the Danish agriculture sector as a world leader that sets an example of a successful green transition.
Besides the urgent need to reduce GHG emissions from agriculture, elevated nutrient loads to the sensitive aquatic environment in and around Denmark remain a challenge. Unlike the policies of the past, the political agreement takes a combined approach to the reduction of nutrient losses to the aquatic environment and of emissions to the atmosphere. In the future, the achievement of further reductions in an efficient way requires making use of the synergies that the intricate coupling of Carbon (C) and Nitrogen (N) cycles offer.
In order to address this combined challenge, the political agreement contains an ambitious research agenda. In 2022, a research program will be launched to develop the foundations for an integrated N and C accounting and management system at farm level. This system will underpin a new regulatory model for nitrogen emissions from 2026 and a future GHG regulation. At the same time, a separate research project will improve the mapping of nitrogen retention at landscape scale. These initiatives will enable a more targeted and cost-effective approach to regulation and strengthen incentives for farmers to participate in voluntary measures.
Other central initiatives in the agreement include e.g. restoration of peatlands, requirements

that reduce GHG emissions from the husbandry sector, more green areas and forests, initiatives to support enlarging the share of organic farmland and development of more plant-based food and feedstock. Moreover, the agreement seizes new opportunities for a greener agricultural production following the reform of the EU's Common Agricultural Policy (CAP). Furthermore, it secures support for research activities to identify and develop not yet fully mature technologies that can contribute to achieving the goals in the near future.
The presentation will introduce the most relevant elements in the political agreement and will highlight the importance of the close coupling of N and C cycles in a policy framework. Possible ways of implementing these complex relations in regulation and support schemes will be shown and discussed.

Bartosova A., Brendel C., Arheimer B.
A. Bartosova, C. Brendel, B. Arheimer

Abstract number–88 Evaluating sources and flows of riverine plastics with ensemble modelling

Alena Bartosova[1], Conrad Brendel[1], Berit Arheimer[1]

[1]*Swedish Meteorological and Hydrological Institute*

Plastic pollution is one of the major global water quality issues. Yet the lack of consistent data and standardized monitoring and assessment methods leads to a wide range of uncertainties in estimating the plastic load that is being delivered to marine environment. At the same time, continental and global dynamic hydrological models are becoming more available for large-scale estimation of time-dynamic water fluxes into sea basins. One such tool is a dynamic process-based rainfall-runoff and water quality model Hydrological Predictions for Environment (HYPE) and its global application, World-Wide HYPE (WWH, Arheimer et al., 2020). We present the first results simulating riverine plastic pollution using WWH.
WWH was amended to include the population living within different sanitation conditions. Sanitation service type and safely managed fraction were estimated for each catchment by combining country and regional sanitation data with human development index data (5 arc-min resolution) and high-resolution (1km grid) settlement type and population datasets. This information was then linked to plastic waste generation, both in terms of mismanaged waste production and microplastics associated with municipal point sources.
Data on plastic flows and concentrations were collected from published literature. Traditional model calibration techniques may not be appropriate in this case due to insufficient number of data points, large variability in plastic characteristics and sampling techniques, as well as large uncertainty and a lack of current knowledge of transport and transformation processes in water bodies. Thus, an ensemble of the models was developed by varying model parameters that affect generation, transformation, and transport of plastic from various land uses, sanitation categories, and in rivers. Collected data together with other global estimates were then used to evaluate the ensemble with a weight of evidence approach, highlighting sources and processes of major significance and focusing the ensemble towards a realistic

set. This set will be used to further develop modeling routines at a large scale and provide guidance in developing the full global model.

References:
Arheimer, B., Pimentel, R., Isberg, K., Crochemore, L., Andersson, J. C. M., Hasan, A., and Pineda, L., 2020. Global catchment modelling using World-Wide HYPE (WWH), open data and stepwise parameter estimation, Hydrol. Earth Syst. Sci. 24, 535–559, https://doi.org/10.5194/hess-24-535-2020

Turner R.D.R., Warne M.S.J., Neelamraju C., Orr D., Ferguson B., Mann R.
R.D.R. Turner, M.S.J. Warne, C. Neelamraju, D. Orr, B. Ferguson, R. Mann

Abstract number–89 Analysis of fifteen years of anthropogenic loads of sediment, nitrogen and phosphorus entering the Great Barrier Reef, Australia

Ryan Turner[1,2], Michael Warne[1], Catherine Neelamraju[2], David Orr[2], Ben Ferguson[2], Reinier Mann[2]

[1]*University of Queensland - School of Earth and Environmental Sciences*
[2]*Queensland Government Department of Environment and Science*

Like many receiving waters around the world, the Great Barrier Reef lagoon is being exposed to multiple stressors including climate change, extreme weather events, direct use and reduced water quality. The key factors causing the decline in water quality are suspended sediment (eroded soil), nutrients (nitrogen and phosphorus) and pesticides from catchment runoff to the GBR lagoon. The Australian and Queensland governments have been addressing the decline in water quality since 2003 through several iterations of the Reef Water Quality Improvement Plan (Reef Plan). One of the monitoring and evaluation components of Reef Plan is the Great Barrier Reef Catchment Loads Monitoring Program (GBRCLMP), which has been measuring water quality in the GBR catchments since 2006, at more than 56 monitoring locations. The GBRCLMP has calculated over 3500 annual loads for total suspended solids and nutrients (9 forms of nitrogen and phosphorus) which are a vital dataset used to validate and calibrate Source Catchment models that are used to predict progress being made towards reaching pollution reduction targets. They are also used directly in education programs and in determining if changes in land management practices are having measurable effects. This presentation will discuss measured annual average loads across all monitored basins compared to modelled ‘natural’ annual loads. Between 2006 and 2019 the annual loads, averaged over all sites, were 7.8 times larger than the modelled ‘natural’ sediment loads, 2.4 to 5.6 times larger for forms of nitrogen and 2.5 to 4.8 times larger for forms of phosphorus. When analysing the anthropogenic (caused by humans) load increases from various catchments, land use influences the magnitude of load compared to natural loads, with catchments dominated by grazing have markedly higher anthropogenic sediment loads while catchments with large amounts of cropping having markedly higher anthropogenic nutrient loads. This paper will also present other trends from this unique dataset and relate these to the aims of the Reef Plan.

Thorburn P.J., Webster A.J., Biggs J.S., Mooij M., Dungand B., Fitch P., Turner R.D.R., Davis A., Baker P., Fielke S.
P.J. Thorburn, A.J. Webster, J.S. Biggs, M. Mooij, B. Dungand, P. Fitch, *R.D.R. Turner*, A. Davis, P. Baker, S. Fielke

Abstract number–90 Increasing farmer awareness of the impact of agriculture on water quality with the 1622WQ app

Peter Thorburn[1], Tony Webster[2], Jody Biggs[1], Martijn Mooij[3], Bertrand Dungand[3], Peter Fitch[4], Ryan Turner[5], Aaron Davis[6], Peter Baker[4], Simon Fielke[7]

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[4]*CSIRO Land and Water, Canberra, Australia*
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[7]*CSIRO Land and Water, Brisbane, Australia*

In many regions of the world, farmers need to improve their management practices to reduce discharge of chemicals and nutrients to marine and aquatic ecosystems. However, they rarely appreciate the link between their practices and water quality, something which is necessary for them to engage in the process of improving management. There are extensive efforts in monitoring water quality in many regions, and the data collected in these programs are invaluable for characterising the water quality problem and tracking progress towards improvement. Yet the data and information from these programs are generally not readily available to farmers, despite the obvious role these data have in raising farmer awareness of local water quality and facilitating improved management. We developed a mobile web application, 1622WQ (https://wq.1622.farm/), using human centred design principles to provide farmers with real-time, high frequency information on nitrate concentration and other contextual variables in creeks and rivers draining into the Great Barrier Reef, Australia. 1622WQ is having impact. It attracted >1,000 users within a few months of being launched (Jan 2020), with that engagement subsequently being maintained. Surveys of farmers and other stakeholders have provided evidence that use of 1622WQ is changing farmers' attitudes about local water quality and their practices. While 1622WQ was designed for high frequency data, a version has been developed for "grab sample" data. This version is being used in pesticide monitoring activities. We think the 1622WQ app could be a valuable addition to many water quality monitoring programs.

Turner R.D.R., Warne M.S.J., McMahon J., Correa D., Mao Y., Phinn S.
R.D.R. Turner, M.S.J. Warne, J. McMahon, D. Correa, Y. Mao, S. Phinn

Abstract number–91 Reef Catchments Science Partnership: Enabling water quality improvements for the Great Barrier Reef

Ryan Turner[1,2], Michael Warne[1,2], Joseph McMahon[1], Diego Correa[1], Yongjing Mao[1], Stuart Phinn[1]

[1]*University of Queensland - School of Earth and Environmental Sciences*
[2]*Queensland Government Department of Environment and Science*

The Great Barrier Reef off the east coast of Australia (GBR) represents the world's most extensive coral reef ecosystem. Despite its enormous ecological and economic significance, it is being impacted by various stressors, including poor water quality entering the Reef lagoon—in particular, fine sediment and dissolved inorganic nitrogen derived from ongoing and expanding agricultural and industrial activities. The Queensland Government's Reef Protection Regulations (the Regulations) aim to address land-based sources (point and diffuse) to ensure there is no net increase in nutrient or sediment pollutant loads (total mass). Any new industrial and agricultural development, expansion or intensification must meet the no-net increase rule. To facilitate the implementation of the Regulations, the Reef Catchments Science Partnership (the Partnership) was established by the University of Queensland and the Queensland Government's Department of Environment and Science.

The Partnership will involve the development of GIS-based multi-criteria decision analysis using fuzzy logic and integer linear programming to provide environmental science tools that can be implemented to protect the GBR. These will be fit for purpose and provide government agencies with timely information to enable them to deliver education and engagement effectively and efficiently, prioritise activities and conduct proactive compliance. To assist with meeting the no net increase of sediment and nitrogen entering the Reef lagoon, the Partnership will also develop a series of tools to support water quality offsets (i.e. compensating for any gross increases). We will use publicly domain data including: Landsat and Sentinel satellite data, Lidar, real-time monitoring and existing high resolution mapping (e.g. land use, soil types, topography and gulley density). These remote sensing, modelling and machine learning tools may be coupled with in-situ monitoring to create a decision-making framework to support application of the Regulations. All tools and frameworks will be publicly released enabling potential application by other countries for their reefs. This presentation will demonstrate some of the proposed tools the Partnership will develop as well as discuss the stakeholder engagement that has occurred.

Mellander P.-E, Galloway J., Hawtree D., Jordan P.
P.-E Mellander, J. Galloway, D. Hawtree, P. Jordan

Abstract number–92 Phosphorus loss risk to water estimated from high frequency data: Quantifying the 'transfer continuum'

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[2]*School of Geography and Environmental Sciences, Ulster University, Coleraine, UK*

Long-term datasets of high frequency water quality parameters have created new possibilities to systematically explore and describe catchment scale processes of phosphorus (P) delivery to water. In a similar way to hydrologists using ratios of flow percentiles to describe river flow “flashiness”, or economists using income percentiles to assess economic inequality, we hypothesise that the ratios and trends of high and low percentiles of P concentrations and mass loads can be used to describe the dominating underlying process of P loss at a catchment scale. We interrogate a 10-year dataset of sub-hourly total P (TP), total reactive P (TRP) and particulate P + organic P (PP + org P, assuming equivalent to TP minus TRP) concentration and discharge from six (ca. 10 km2) river catchments in Ireland. The catchments span a range of physical conditions and are all dominated by typically intensive agricultural land (grass and arable). The objectives were to i) assess the seasonality and trends of high and low percentile concentrations and mass loads of P, ii) develop catchment scale indices of P mobilisation and delivery, in order to quantify the components of the nutrient transfer continuum, and iii) classify the dominating or potential risks for catchment P loss.
Three catchments had elevated P concentrations and a high probability of exceeding the environmental quality standard of TRP = 0.035mg/l (80.7%, 93.7% and 98.8%). In the other catchments the probability was low (0.1%, 22.5% and 29.0%). Catchments of different flow and P export regimes revealed different trends (Increasing/decreasing) for the 5th, 50th and 95th percentiles and for the different P fractions. The occurrence of the 95th percentile concentration was typically highest in the summer months and the mass loads in the winter months. However, there were variations in both magnitude and distribution of occurrence between the catchments and for different P fractions.
Catchments P mobilisation indices (ratios of concentration percentiles) and P delivery indices (ratios of mass load percentiles) matched the conceptual understanding of the catchments. There were both increasing and decreasing trends in the indices for some catchments and for different P fractions indicating changes of P loss risk. The mobilisation and delivery indices were combined with information on P source and impact to quantify the complete P transfer continuum in a simple model, to identify the specific or potential catchment type of P loss risk. Such information can be used to target suitable mitigation methods and further design these for scenarios of future weather conditions and land use.

Adams R., Doody D.
R. Adams, D. Doody

Abstract number–93 Meeting WFD Targets in the Blackwater Catchment in Northern Ireland: A simple modelling based approach to estimating phosphorus load reductions

Russell Adams[1], Donnacha Doody[2]

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[2]*AFBI, Belfast, UK*

Many of the Northern Irish catchments have consistently failed to meet Water Framework Directive targets especially due to high levels of dissolved nutrients and poor ecological status. A catchment based modelling study to address this issue is described here using the Catchment Runoff Flux Assessment Tool (CRAFT) water quality model to achieve this aim. The objectives of the study were (1) to identify the total phosphorus (P) load reductions required to attain soluble reactive P (SRP) concentrations required to achieve the WFD “Good” status levels in the 948 km^2 Blackwater Catchment; (2) to carry out model simulations to evaluate different mitigation scenarios that could achieve these reductions; and (3) to identify the most likely flow pathways for the transport of the diffuse component of the P export to the watercourses.
The observed SRP data were used to identify sub-catchments requiring significant load reductions and also to assess the load reduction required above the main Blackwater monitoring point itself. The CRAFT simulates runoff and P on a dynamic (daily) modelling scale from each sub-catchments and routes the flows and P loads to the monitoring point. The model is able to back-calculate nutrient loads associated with three major flow pathways. The model is then run again with a mitigation scenario where parameter values are modified, for example a reduction in P loading to the soil or trapping of sediments and nutrients transported in surface runoff.
The CRAFT evaluated, through simulation of daily runoff and P concentrations at the monitoring point, (1) the duration of any periods where the “Good” SRP status band is exceeded which reduced from 58.5% to 54.5%, and also (2) evaluated if the estimated P load reduction of 12.4 tonnes P/year is sufficiently large for the desired “Good” status mean concentration (0.069 mg P/L is the target) to be achieved. It was found that the mitigated area of the catchment which was 186.3 km^2 would need to be increased slightly to meet the target, even though the predicted load reduction from the modelling was slightly greater than the reduction calculated from the observed P data (9.7 tonnes P/year).

Rode M., Zhou X., Jomaa S., Yang X., Merz R., Wang Y.
M. Rode, X. Zhou, S. Jomaa, X. Yang, R. Merz, Y. Wang

Abstract number–94 Exploring the relations between sequential droughts and stream nitrogen dynamics in central Germany through catchment-scale mechanistic modelling

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[2]*eInstitute of Environmental Science and Geography, University of Potsdam, Potsdam-Golm, Germany*
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Like many other regions in central Europe, Germany experienced sequential summer droughts from 2015-2018. As one of the environmental consequences, river nitrate concentrations have exhibited significant changes in many catchments. However, catchment nitrate responses to the changing weather conditions have not yet been mechanistically explored. Thus, a fully distributed, process-based catchment Nitrate model (mHM-Nitrate) was used to reveal the causal relations in the Bode catchment, of which river nitrate concentrations have experienced contrasting trends from upstream to downstream reaches with special focus on nitrogen in-stream uptake processes. The model was evaluated using data from six high frequency gauging stations, reflecting different levels of runoff components and their associated nitrate-mixing from upstream to downstream. Results indicated that the mHM-Nitrate model reproduced dynamics of daily discharge and nitrate concentration well, with Nash-Sutcliffe Efficiency ≥ 0.73 for discharge and Kling-Gupta Efficiency ≥ 0.50 for nitrate concentration at most stations. Particularly, the spatially contrasting trends of nitrate concentration were successfully captured by the model. The decrease of nitrate concentration in the lowland area in drought years (2015-2018) was presumably due to (1) limited terrestrial export loading (ca. 40% lower than that of normal years 2004-2014), and (2) increased in-stream retention efficiency (20% higher in summer within the whole river network). In general in-stream nitrate retention was highest in summer with 35% of total nitrate load and amounted up to 13.5% on the yearly basis. In addition agricultural streams showed higher denitrification and assimilatory uptake amounts than more pristine forest dominated streams. From a mechanistic modeling perspective, this study provided insights into spatially heterogeneous flow and nitrate dynamics and effects of sequential droughts, which shed light on water-quality responses to future climate change, as droughts are projected to be more frequent.

Morton P.A., Hunter W.R., Cassidy R., Doody D., Atcheson K., Jordan P.
P.A. Morton, W.R. Hunter, R. Cassidy, D. Doody, K. Atcheson, P. Jordan

Abstract number–95 Walking trees and dark rivers: Impacts of a large-scale bogflow (peat slide) on water quality in the Derg catchment, NW Ireland

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Mass movements of peat have been recorded across Britain and Ireland for centuries. Whilst these events are natural and usually associated with heavy rainfall or erosion, certain anthropogenic land uses can make peat more vulnerable to failure. On 13th November 2020, a bogflow (i.e. a flow failure of blanket bog) occurred at Meenbog on the Irish border involving an estimated 20,000 cubic metres of peat complete with peat rafts carrying trees.

Although this was probably ultimately triggered by supersaturation of the peat, the surrounding land was partially drained, afforested and undergoing wind farm development. Despite the relative frequency of peat-related landslides, there is very little empirical evidence of their immediate impacts on water quality. Eyewitness accounts detail rivers turning black and fish kills but data on sediment loading and carbon transport is scarce. However, water from the River Derg, into which the Meenbog bogflow ran, was being collected by a refrigerated autosampler on a 7-hourly basis about 37 km downstream of the site of failure at a water treatment works abstraction point. This enabled collection of water samples for three days before and 25 days after the bogflow, which were all analysed for suspended sediment (SS), particulate organic carbon (POC) and dissolved organic carbon (DOC). These measurements were coupled with river flow data from 9 km upstream of the sampling point. Turbidity data were also collected at an hourly resolution before and after the bogflow at the same monitoring site.
The first three samples after the bogflow were black and completely opaque, with the highest concentrations measured (SS: 824.5 mg/L; POC: 346.1 mg C/L) in the first sample taken after the effects of the bogflow passed the sampling point. In comparison, the lowest concentrations of SS and POC were 1.9 mg/L and 0.85 mg C/L. SS and POC loads were both by far the highest on the day of the bogflow (SS: 215 t; POC: 90 t C), although greater flows the following day remobilised the peat and produced similarly high loads. The maximum turbidity peak on the day of the bogflow was 60 NTU, although turbidity continued to be influenced by remobilisation events, the highest of which was 119 NTU (minimum turbidity was 1.8 NTU). In contrast, DOC concentrations and loads appeared unaffected by the bogflow and were determined by river flow alone. Turbidity values returned to within previous ranges after approximately 12 days from the start of the bogflow, whilst SS and POC did after just 9 days. These results will be discussed in the context of impacts to drinking water treatment and carbon loss from vulnerable river catchments.

Buijs S., Rozemeijer J.C., Ouwerkerk K.
S. Buijs, J.C. Rozemeijer, K. Ouwerkerk

Abstract number–96 Impact of the 2018-2020 drought on nutrient concentrations in agricultural-dominated headwaters in the Netherlands

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High nutrient emissions to surface waters are a major drawback of the highly productive agricultural sector in The Netherlands. The resulting nutrient concentrations in water resources threaten their ecological, industrial, and recreational functions. To mitigate problems occurring with nutrients, legislation on manure and fertilizer application in agriculture was enforced in The Netherlands over four decades ago. The results of this legislation are evaluated periodically by assessing the water quality status and trends based

on a monitoring network consisting of 161 locations in agriculture dominated headwaters. The results of this monitoring network show that the water quality in agricultural dominated waters is improving, but that between 2017 and 2020, on average 53% of the monitoring locations do not yet meet the water quality standards for total nitrogen; and 54% for total phosphorus. We observed that nutrient concentrations are strongly influenced by weather-related variations.
In this presentation, we focus on the impact of three dry summers (2018 -2020) on the nutrient concentrations in agricultural headwaters. During drought, crops grow less and take up a smaller fraction of the available nitrogen and phosphorus in the soil. Also, less denitrification takes place, which means that more nitrate stays available for leaching to groundwater and surface water within the next wet period. Our monitoring results show that especially in the subsequent winter after a drought the nutrient concentrations are elevated. The high winter nutrient loads from agricultural catchments increase spring and summer nutrient concentrations in downstream water resources and enhance harmful algal blooms.

Bernhardt J.J.
J.J. Bernhardt

Abstract number–97 Modelling climate change impacts on regional agricultural irrigation demand – a case study in Bavaria (southern Germany)

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Climate change is causing an increase in average temperatures, changes in precipitation, and an increase in the frequency of extreme weather events worldwide. Related to the past 100 years in Germany, an increase in annual precipitation amounts can be seen. At the same time, a shift in precipitation times from the summer half-year to the winter months is becoming apparent. Climate simulations/models project a decreasing trend in water availability for plants and for agriculture during the vegetation period. Due to drought events, there is an increasing risk of agricultural production. There is a lack of statistical data about actual irrigation rates and especially their spatial distribution. For this reason, model approaches must increasingly be developed to support policymakers and planners in their decision-making. In the following study the ‚agricultural irrigation demand' (AID) was modelled. The parameter can be used to determine climate change impacts, in a regional and comparative manner. Moreover, the generated output data can fill the data lack and may be useful to estimate the impact of AID as one factor in upcoming water management conflicts.
The model approach is based on a spatial implementation of the ‚Geisenheimer irrigation control', a principle that extends the daily climatic water balance (CWB) by the plant-coefficient. For the spatial implementation area-wide geospatial data (potential evaporation, precipitation, soil characteristics and agricultural land use) is combined with plant-specific properties (plant-coefficient, root depth, optimum in soil moisture). By balancing daily CWB,

irrigation demands can be calculated and summed up to estimate AID per year and spatial unit (on a regional level). The climate change impact on AID is represented by using RCP 8.5 climate projections within the model simulation. Using regional climate projections derived from global scenarios comes with some uncertainties. To reduce possible misrepresentation of the data an ensemble-projection, containing six different regional projections, is used. To analyse long-time changes in AID a reference period (ex-post: 1991-2020) is compared with a future period (ex-ante: 2021-2050).
For the study area, the model predicts increase in AID by 22% from 2020 to 2050. In single drought years, the simulation shows even higher AID rates. The model results are highly sensitive to the input data. Trends in water quantity can be estimated by the consideration of agricultural land use and farmers irrigation decision making.

Severini E., Bartoli M., Pinardi M., Celico F.
E. Severini, M. Bartoli, M. Pinardi, F. Celico

Abstract number–98 Short-term effects of the EU Nitrate Directive reintroduction: Reduced N loads to river from an alluvial aquifer in northern Italy

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The Po Plain (northern Italy) is one of the largest aquifers in Europe and 67% of the utilized agricultural land in this area is classified as Nitrate Vulnerable Zone (NVZ). However, it hosts intensive agriculture and livestock farming. In a stretch of the Mincio River (a tributary of the Po River), hydraulic heads, physico-chemical parameters of river and groundwater were monitored for a hydrologic year (2020-2021), to evaluate the effects of manure fertilization and flooding irrigation on surface- and groundwater chemistry. From 2020 the Nitrate Directive's fertilization limit was reintroduced and a comparison has been performed comparing surface- and groundwater data from the 2019 fertilization period (before limit reintroduction) and 2020 (after). Results suggest that in 2021 the phreatic aquifer displayed elevated nitrate (NO3-) concentrations, exceeding 50 mg L-1, although average values were lower than those of 2019. Nitrate loads in the Mincio River reached 6670 kg NO3- d-1 and resulted from the overfertilization in the surrounding area and the quick transfer of nitrogen from groundwater to the river. Compared to 2019, the river loads decreased by 59%,

suggesting that the introduction of fertilization limits can produce measurable, short-term responses in alluvial aquifers.

Krzeminska D.M., Blankenberg A.G., Bechmann M., Deelstra J.
D.M. Krzeminska, A.G. Blankenberg, M. Bechmann, J. Deelstra

Abstract number–101 The effect of constructed wetlands under future climate conditions – 18 years of measurements in a small constructed wetland in Norway

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According to nationally scaled climate scenarios the annual average temperature in Norway will increase with 2.7 ºC from the period 1971-2000 to the period 2071-2100, and the increase will be more prominent during winter and less during summer. Increased annual precipitation and more frequent episodes with heavy precipitation are also expected.

The main pollution sources in rural areas are agricultural runoff and discharge from on-site wastewater treatment systems. Fresh water quality problems in Norway are largely caused by high phosphorus inputs from the catchments. Future climate change may influence runoff patterns, increase erosion and nutrient losses. The need for measures in the agricultural landscape, such as constructed wetlands, will increase.

This study presents 18 years of data from a typical Norwegian small rural catchment (Skuterud) and a constructed wetland established in the Gryteland stream. The catchment's total area was 450 ha with 61% agricultural land. The constructed wetland occupied 0.05% of the catchment area. Flow-proportional water samples were taken from the inlet and outlet since 2003 and
analyzed for sediments and nutrients. The main objective of this study has been to analyze how climatic factors (temperature, precipitation), influence the runoff from the catchment, and how these affects the retention of nutrients and sediments in the constructed wetland. We also evaluated the importance of removal of sediments trapped over time.

Results showed on average 47% and 25% retention of sediment and phosphorus, respectively, however there are large variations in the retention from year to year, and within each year. From the first analysis it seems that retention effect depends mostly on a combination of runoff level and sediment or phosphorus loads coming into the constructed wetland. Moreover, the maintenance work is important: when the constructed wetland is getting full the retention is increasing. However, it is important to notice that just after emptying the constructed wetland the whole system also need a time to reestablish good retention condition.

Nawara S., Willekens K., Janssens S., Degelin S.
S. Nawara, K. Willekens, S. Janssens, S. Degelin

Abstract number–102 Good practices focused on improving water and soil quality: The farmer as promoter and key actor for a right behaviour and broad use of appropriate techniques

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[4]*Project leader B3W, CVBB, Willem De Croylaan 48, 3001 Heverlee, Belgium*

In 2021 in Flanders (Belgium), an extension service for a better soil and water quality (B3W: Begeleidingsdienst voor Betere Bodem- en Waterkwaliteit) was set up. This service is funded by the Ministry of Environment through the Flemish Land Agency, responsible for the implementation of the Nitrates Directive. The goal of the service is not only to inform farmers on measures and techniques that reduce the risk of nutrient losses and/or enhance soil fertility, but also to guide farmers to change their behavior regarding practices. Key aspects of the service are:

- A consortium of 13 research and practice centers carry out the guidance task, each with their own expertise, domain (e.g., fruit, potatoes, vegetables, …) and projects, thereby functioning as a hub of knowledge exchange.
- The extension service consists of a back office, responsible for management and sharing of knowledge, and a front office with mentors going into the field, organizing extension activities and coaching individual farmers.
- The mentors of the coaching service do not just function as an instructor but more as a coach to stimulate collaboration and knowledge sharing between farmers.
- Farmers function as an ambassador, i.e., peer to peer learning between farmers is the core strategy of the service. This is established by:
  - Organizing thematic exchange moments (TUMs) where farmers who apply a sustainable/innovative technique share their knowledge with other farmers by explaining why and how they apply the technique, inclusive of indicating the advantages, disadvantages, economical costs, … . The farmers' experience is the key factor during this event. 'TUMs' are organized with a maximum of 30 persons to improve discussion and interaction.
  - Organizing focus groups in which 6-8 farmers are gathered together three times a year during two years in order to exchange knowledge on an innovative, not yet often applied, technique. In this period, they can test their innovative practices.
- The extension service also guides individual farmers to improve soil and water quality, focusing on farmers who are more difficult to reach at events and who are often a bit behind.
- Clear communication to reach the broad audience. The experiences, findings, points

of attention, … of the above mentioned events are communicated to the entire agricultural sector. This communication is sensitizing and practically minded. Various communication channels and formats are used for this, tailored to the target audience.

- The ultimate goal is to establish a change in practical behavior of farmers and the techniques used on their farms. A questionnaire after each event evaluates whether farmers consider to change or innovate their practices and the reasons behind it.

Every year specific working themes are defined, together with the Flemish Land Agency. That allows to shift the focus to sectors with the highest environmental issues and/or to new promising techniques.

Löw P., Osterburg B., Klages S.
P. Löw, B. Osterburg, S. Klages

Abstract number–103 Assessing the reliability and uncertainty of agri-environmental indicators in German nitrogen policy

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Crop need targeted and efficient nitrogen (N) fertilization is necessary for optimal nutritional plant supply and at the same time to reduce impacts on the environment, as loss of reactive N compounds threaten biodiversity, climate, and human health (Sutton & Bleeker 2013). The European Union (EU) Nitrates Directive (91/676/EEC), on which the nutrient policies of many EU-Member States (MS) are based, including Germany, aimed to reduce nitrate emissions from agricultural activities (European Commission, 1991). With the Farm to Fork Strategy, the Commission has proposed targets for 2030: the reduction of fertilizer use by at least 20 % and a reduction of nutrient losses by at least 50 % (European Commission, 2020). This would require immediate action.

The present study investigates the suitability of three different nitrogen (N) indicators as entry points for agricultural regulation for limiting N fertilizer inputs in Germany. The net soil surface balance (SoilB), gross farm-gate balance (FarmB) and an evened fertilization planning (FertP), indicators currently and recently applied in Germany and other EU-MS, were examined regarding design, data reliability and data uncertainty, and N reduction requirements.

Using Farm Accountancy Data Network (FADN) data of about 6,000 farms representing the agricultural sector with its different farm structures and regions in Germany, farm types were grouped according to the EU farm typology for a comparative study (Löw et al., 2021). Reliability and uncertainty were subject to the level of documentation and to the accuracy of determination of nutrient amounts. Results show (1) that design and purpose of the regulatory approaches differ whereby the required data basis is very similar, and (2) parameters used differ regarding reliability and uncertainty, both from FarmB (higher) to

FertP (lower). While FarmB is mainly based on verifiable documents such as receipts, FertP relies more on farm-internal data which are hardly verifiable. The limits for maximum input of N fertilizer at farm level vary with regard to approach and farm type, so that at the current state of implementation FertP is probably most limiting focusing on the agricultural sector (3). Further, the level of restriction differs depending on the farm type.

FarmB is acknowledged as an integer approach by scientific, consulting, and official institutions, albeit improvements are possible and necessary to make the indicator values more robust and justiciable. However, a discussion is ongoing in Germany on whether FertP as a mandatory performance indicator is sufficient and what FarmB will provide, apart from an additional bureaucratic burden. We argue that digital and receipt-based systematic documentation of nutrient flows along the value chain within FarmB can considerably improve data acquisition and reliability, and reduce data uncertainties.

Jordan P., Gaffney G.J., Johnston C.
P. Jordan, G.J. Gaffney, C. Johnston

Abstract number–104 Using short-rotation willow coppice to mitigate water quality impacts from point sources

Phil Jordan[1], Gabriel Gaffney[1], Chris Johnston[2]

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Waste-water treatment technologies sized between single house domestic septic tank systems and large-scale urban waste-water treatment works (WWTW) are small scale works that treat waste-water from small population equivalents (10s-100s PE). This has been a standard and regularly adopted solution in Irish rural landscapes where there is a dispersed population. However, small WWTW technologies range from modern package plants to basic solid separation systems—but where the final effluent is discharged to local water courses. Quantifying the water quality impacts of this point source discharge and providing further treatment prior to final discharge is a research priority to understand and prevent chronic pollution, particularly when rivers are vulnerable at low flows.
Nature based solutions to environmental pressures are increasingly used as they also offer multi-functional benefits. Here, short rotation willow coppice (SRC) was employed to treat the irrigated final effluent from two small rural WWTWs (PE 70 and 38) in Co. Donegal (Republic of Ireland) and Co. Tyrone (Northern Ireland) from European Union funding under INTERREG Va. The work was conducted in three stages. First, a baseline survey was undertaken in the streams receiving treated effluent at upstream and downstream points. Soluble reactive phosphorus (SRP) was measured as the pressure, and benthic algae were measured as the impact. SRP was measured during 24 hour campaigns over a low flow season, as single daily samples were found to be ineffective. Benthic algae were measured on the build-up of films on natural and artificial substrates over periods of several weeks. Second, mixed varieties of willow were planted and established in fields adjacent to the

small WWTWs and automated pump-irrigation systems constructed to deliver treated effluent to the willows. Third, a further water quality survey was undertaken to assess the ability of the SRC to reduce downstream pressures and impacts. The research followed a before-after-impact protocol.
Baseline surveys indicated a distinct SRP downstream pressure at both sites that followed a diurnal pattern and with concentrations above the threshold classes for polluted water. Algal surveys were less clear but most likely influenced by other factors such as shading and disturbance (during higher flows). Further results are discussed on the implementation of SRC irrigation and upstream-downstream water quality changes.

Spijker J., Fraters D., Vrijhoef A.
J. Spijker, D. Fraters, A. Vrijhoef

Abstract number–105 A machine learning based modelling framework to predict nutrient leaching from agricultural soils across the Netherlands

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Throughout recent decades, the excessive use of animal manure and fertiliser put a threat on the quality of ground and surface waters in main agricultural production areas in Europe and other parts of the world. Finding a balance between agricultural production and environmental protection is a prerequisite for sustainable development of ground and surface waters and soil quality. To protect groundwater quality, the European Commission has stipulated a limit value for NO3- of 50 mg L-1. Member states are obliged to monitor and regulate nitrate concentrations in groundwater. In the Netherlands, this monitoring is carried out by sampling nitrate concentrations in water leaching from the root zone at farm level within the national Minerals Policy Monitoring Programme. However, due to the costly procedure, only a limited number of about 450 farms can be sampled each year. While this is sufficient for providing a national overview of nitrate leaching, as a result of current and future challenges regarding the sustainable development of the agricultural system, Dutch policymakers need to gain insight into the spatial distribution of nitrate at smaller spatial scales. This study aimed to develop a predictive modelling framework to create annual maps with full national coverage of nitrate concentrations leaching from the root zone of Dutch agricultural soils, and to test this model for the year 2017. We used nitrate data from a national monitoring programme and combined them with a large set of auxiliary spatial data, such as soil types, groundwater levels and crop types. We used the Random Forest (RF) algorithm as a prediction and interpolation method. Using the model, we could explain 58% of variance, and statistical errors indicate that the interpolation and map visualisation is suitable for interpretation of the spatial variability of nitrate concentrations in the Netherlands. We used the variable importance from the RF and the partial dependency of the most important variables to get more insight into the major factors explaining the spatial variability. Our study also shows the caveats of data-driven algorithms such as RF. For some areas where no training data was available, the model's predictions are unexpected

and might indicate a model bias. The combination of visualisation of the spatial variability and the interpretation of variable importance and partial dependence results in understanding which areas are more vulnerable to NO3- leaching, in terms of land use and geomorphology. Our modelling framework can be used for different nutrients and to target specific areas. This framework can be used take more targeted regional policy measurements for the balance between agricultural production and protecting the environment.

Frederiksen R.R., Larsen S.E., Blicher-Mathiesen G., Kronvang B.
R.R. Frederiksen, S.E. Larsen, G. Blicher-Mathiesen, B. Kronvang

Abstract number–107 An empirical model for tile flow fraction in systematically tile-drained minerogenic soils

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Subsurface drainage systems (‘tiles’) are widely installed to maintain optimal soil moisture conditions for crops, increase soil temperature and allow for early field operations in spring. Tiles alter the connectivity between the land surface, groundwater and streams as drained areas experience a much faster hydrological response than undrained areas. Moreover, tile-drained areas account for a high part of the nitrate loading to streams as nitrate from drained areas is transported directly from the bottom of the root zone to streams, thereby escaping the natural nitrate retention under the deeper groundwater redox zone. Thus, it is important for catchment management that tile-drained areas are both mapped and considered when establishing nutrient budgets for catchments. However, measurements of tile flow are scarce and costly, and most process-based mechanistic models are challenged in incorporating a proper link for water transport between the root zone and the saturated zone. One of the main problems is to account for the tile-runoff to streams.
Here, we suggest an empirical modelling approach to obtain estimates of tile flow at field scale in systematically tile-drained minerogenic soils. Our hypothesis is that when annual tile flow (Q) is plotted versus accumulated drainage from the root zone (Db) or precipitation (P), Q starts after some lag time (Db or P has accumulated), and the relationship is expected to be linear between Q and Db or P. Furthermore, we hypothesise that the initial abstraction and slope of the line represent the potential water retention of the system.
We use measurements of tile flow from 38 single drainage areas representing agricultural fields with different soil types and morphological conditions to develop two linear regression models with Q as dependent variable and Db and P, respectively, as independent variables. The stations have different slopes related to their differences in soil type, topography, etc., but here we aim to estimate a common model that can be applied for prediction of the annual tile flow in ungauged fields in systematically tile-drained minerogenic soils. Furthermore, we investigate the station-to-station and year-to-year variance, and we explore whether geographical variables can explain part of the variance that is not explained by the univariate regression model.

Eventually, the empirical model is intended to improve process-based mechanistic catchment models being able to simulate realistic water and nitrogen transport and nitrate retention at field to catchment scale.

Farkas C., Engebretsen A., Skarbøvik E.
C. Farkas, A. Engebretsen, E. Skarbøvik

Abstract number–108 Water quality response to Nordic bioeconomy and climate change scenarios at catchment scale, a case study from S-E Norway

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Reducing the diffuse losses of nutrients to water bodies remains a major problem in the agricultural areas of the Nordic countries. Future transition towards bioeconomy raises new questions on how this will affect water quality and freshwater ecosystems.
The objective of our study was to evaluate the future changes in phosphorus and particle loads towards surface water bodies in an agricultural-forested catchment in S-E Norway. The INCA-P semi-distributed hydro-biochemical model was set up and adapted for a monitored pilot catchment, using measured discharge and water quality data as reference data for model calibration. The successful model calibration and validation gave an opportunity to test the reaction of the catchment on changing land use, soil management and climate conditions.
Five plausible Nordic Bioeconomy Pathways (NBPs) were quantified, ranging from a focus on sustainability to scenarios with less environmentally friendly land use. We selected proportion of land use (agriculture vs. forest), intensity of soil tillage and fertilization strategy as the main drivers. We executed scenario analyses by running the calibrated INCA-P model for different NBPs under the present and future climate conditions.

Suspended sediments and total P loads showed considerable increase under climate change conditions for all the NBPs, compared to the present climate, varying from 52% to 79% and from 12% to 32% for sediments and TP, respectively. Our results indicate that if the three selected in-field measures are implemented without other adaptation strategies, only the “sustainability first” NBP would ensure reaching the Water Framework Directive goals in the future. This indicates that also other mitigation measures (sedimentation ponds, buffer zones, grassed waterways, etc.) should be introduced to ensure good water quality in the study area in the future.

Kieboom N.A., Speed C.
N.A. Kieboom, C. Speed

Abstract number–109 National Sector Inventory and heat mapping of nitrogen loads to groundwater in England

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Nitrogen continues to be the most frequent reason for failure of groundwater body chemical status under the Water Environment Regulations in England. The impacts of excess nitrogen are not uniformly distributed. In general, nitrate concentrations in groundwater are greatest in the drier, arable-dominated southern and eastern areas of England. This coincides with where we are most dependent on groundwater for public water supply and base flow to rivers, lakes and wetlands. The need to limit nitrogen loads to habitats already in unfavorable condition due to nutrients is placing pressure on the permitting and planning systems to limit and offset the nitrogen from regulated activities and new developments, respectively. The need to manage nitrogen loads is therefore high on the political agenda.

To assess total nitrogen loads to groundwater a study is underway to produce a national inventory of nitrogen loads being applied to land throughout England from different sectors. This is using data from a variety of sources, including agricultural census, satellite land cover maps, publicly available national statistics, industry annual reports and published literature, to give greater confidence in the contribution of different sectors and improve estimates of the total nitrogen load. National heat maps showing variations in the spatial distribution of loads at a resolution of 5km2 will be produced for individual sectors and for the combined total load for England as a whole. This will enable a comparison to be made where the two methods of inventory and heat mapping have been undertaken separately for the same sector or type of material being applied to land, to understand uncertainties in the data.

This talk will present the findings from this work, including the validation of national data using higher resolution local data from selected catchments.

Coussement T., Tits M., Moermans S., Coppens J., Laethem R., Diels J., Elsen A.
T. Coussement, M. Tits, S. Moermans, J. Coppens, R. Laethem, J. Diels, A. Elsen

Abstract number–110 Further development of the modelling of nutrient processes in the unsaturated zone in the nutrient emission model NEMO

Tom Coussement[1], Mia Tits[1], Stijn Moermans[1], Jan Coppens[2], Rob Laethem[2], Jan Diels[3], Annemie Elsen[1]

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In order to better account for the effects of fertilisation, precipitation and temperature on nitrogen leaching to the groundwater on a catchment scale, the nutrient emission model NEMO, which was developed for the Flanders Environment Agency (VMM), was supplemented with a crop module. This module calculates the daily dry matter growth as a function of crop type, temperature, soil moisture content and nitrogen supply and links this to the daily calculation of the nitrogen uptake and the amount of crop residues added to the soil.
After calibration, the addition of the new crop module allowed the model to accurately predict crop growth, crop residues and nitrogen uptake at field level for field situations where detailed input information about soil, fertilisation and cultivation is available. The validation of the simulated effects of drought and fertilisation based on measurements in irrigation and fertilisation trials also gave acceptable results.
At the catchment scale, detailed information on agricultural practices is not available for each field. In addition, other sources of variation e.g. sowing and harvest time, crop varieties, soil cultivation, soil (structure) problems, infestations by pests and diseases, field history, etc., are not (yet) taken into account by the model. For calculations at a catchment scale, crop data (sowing and harvesting date) and fertilisation data were estimated per field based on average data and/or data available at farm level. In this way, the average N uptake and amount of crop residues was approximated well for most crops. However, although the correlation between simulated and observed residual nitrogen content in the soil after harvest showed a small improvement compared to the original model without crop module, it was not yet optimal for all crop types.
Nevertheless, the necessary mechanisms have now been added to the model in order to more correctly estimate the effects of drought, temperature, variation in fertilisation and catch crops. This also creates further possibilities for calculating scenarios regarding the effects of weather and climate, fertilisation and catch crops.

Holm H., Kolind Hvid S., Meldorf Deichmann M.
H. Holm, S. Kolind Hvid, M. Meldorf Deichmann

Abstract number–111 Development of a new and more differentiated nitrogen retention mapping to reduce nitrate leaching with a more targeted and cost-efficient N-mitigation strategy

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The current nitrogen regulation in Denmark does not consider the large variation in N-retention within catch-ments leading to nutrient losses and unfavorable agriculture practices.

The retention within a catchment can vary from <20% to 100% due to differences in drain transport, hydrological and geochemical conditions. The current retention mapping does not consider the differentiation in N-retention in the upper meters of the rootzone, because the processes in this zone isn't fully understood yet. Having to meet the reduction re-quirements within catchments with a high average retention will be associated with large economic conse-quences as lack of knowledge regarding spatial variation in N retention and spatio-temporal distributed drain flow fraction often means a general over-implementation of mitigation measures.

The purpose of the retention mapping is to achieve a cost-effective aquatic environment effort through an increased targeting of the N-mitigation strategy by knowledge of more detailed N-retention in the root zone and to distinguish the drain fraction.

The core of the project is 1) to further develop the Ejlskov redox probe to map the redox zone in the root zone, 2) use geophysical mapping methods to map the spatial geology and water saturation profile with drainage geometry to develop hydrological models that describe water level dynamics and drainage runoff, 3) develop an operational and scalable model for mapping spatially differentiated N-retention classes within catchments, and 4) demonstrate the environmental and economic effects of a differentiated targeted mitiga-tion measure effort with field and drainage mitigation measures.

The project will develop an operational model tool for differentiating N-retention classes within catchments to achieve a more environmentally efficient and cost-effective mitigation strategy. With the new highly de-tailed N-retention map, it will be possible to demonstrate the economic and environmental costs of various mitigation measures, both field measures and end off drainage measures, by considering the large variation in N-retention within the catchments.

Brandes E., Henseler M., Herrmann F., Kreins P., Shiravani G., Tetzlaff B., Wendland F., Wurpts A.
E. Brandes, M. Henseler, F. Herrmann, P. Kreins, G. Shiravani, B. Tetzlaff, F. Wendland, A. Wurpts

Abstract number–112 MOMENTUM – a model network to quantify microplastic sources and migration pathways throughout a river catchment

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Up to now, the relevance of the various terrestrial microplastic inputs into rivers and ultimately oceans remains largely unclear. Despite sparse data, plastic pollution of the terrestrial environment has gained considerable public attention. Particularly, farming activities such as the application of agricultural film, sewage sludge, and compost have been linked to microplastic contamination of soils. Partly due to the broad media coverage of this research topic, public calls for regulation are widespread. Besides implementing the precautionary principle, the environmental sciences should gain more systemic knowledge about current and expected future contamination to inform efficient policy action. This includes a model-based estimation of the microplastic inputs and contents in the different environmental compartments (air, soil, water) and the connecting transport pathways.
To tackle this knowledge gap, we developed MOMENTUM, a model network based on three independent models covering the microplastic inputs into agricultural soils (RAUMIS-MP), the diffuse and point sources into surface waters (mGROWA and TeMBa), and their transport/accumulation in the estuary (FSK-MPTM).
Using data on microplastic contents in biosolids from the literature combined with national and regional statistics on sewage sludge and organic waste production, as well as specialty crop areas, we estimated the spatial distributions of cumulative microplastic inputs into agricultural soils from 1960 to 2016. Then we used these regional microplastic pools to model diffuse emissions by water erosion into limnic ecosystems. We also estimated microplastic mass fluxes by diffuse atmospheric deposition and point sources (urban systems and wastewater treatment plants). The microplastic loads into the estuary served as input for the deterministic 3D microplastic transport model (FSK-MPTM). With the FSK-MPTM we were able to model the dispersion, transport, and accumulation of microplastic particles entering the tidal region in a mass consistent way, including the processes determining the interaction of small plastic particles with the fine sediment and biofouling effects.
By developing MOMENTUM, the microplastic sources, input pathways, and migration routes from the terrestrial via the limnic to the marine environment could be quantified for the first time in a river catchment. All involved models had in common that only very few input data were available and usable, causing high uncertainties in the current results, which are to be considered exemplary in large parts. The model network was designed in a way that it is transferable to other regions and that new data (e.g., measurement results, literature) can be easily integrated. The possibility of including all input sources, pathways, and transport processes into a model framework contributes - complementary to the sample analysis - to improving a systems understanding of microplastic pollution.

Hawtree D., Galloway J., Mellander P.-E
D. Hawtree, J. Galloway, P.-E Mellander

Abstract number–113 Application of a parsimonious phosphorus model (SimplyP) to two contrasting agricultural catchments in Ireland

Daniel Hawtree[1], Jason Galloway[1], Per-Erik Mellander[1]

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The Agricultural Catchment Program (ACP) has collected over a decade's worth of high frequency data for a number of hydrologic and chemical indicators at agricultural catchments around the Republic of Ireland. This dataset provides an excellent foundation for conducting robust modelling studies assessing long term hydrochemical dynamics in agricultural sites, within the context of EU regulations around the protection of water quality.

To examine the risks of phosphorus (P) export from agricultural catchment in this context, the parsimonious phosphorus model SimplyP was applied to two ACP study sites. These sites are in close proximity and are of similar size to each other but have contrasting physical characteristics and hydrochemical dynamics. Site "A" is dominated by grasslands with heavy soils and is P export risky, while site "B" is primarily arable land-use on lighter soils and has a lower risk of P export.

Using the SimplyP model, three contrasting agricultural deintensification scenarios were simulated in each site. The deintensification scenarios represent different agricultural management options which have contrasting scales of annual negative net P balances at the catchment scale. These scenarios are designed to assess what level of deintensification may be required to significantly alter the risk of P export, due to the accumulation of legacy P in areas with a long history of agricultural use.

The results of this modelling analysis are examined with respect to the contrasting dynamics at the two study sites, and the implications of the findings with respect to Ireland's obligations under EU water quality regulations.

Atcheson K.F., Mellander P.-E, Cassidy R., Cook S., Floyd S., McRoberts C., Morton P.A., Jordan P.
K.F. Atcheson, P.-E Mellander, R. Cassidy, S. Cook, S. Floyd, C. McRoberts, P.A. Morton, P. Jordan

Abstract number–114 MCPA exports and pathways at catchment scale: Insights from enhanced water quality data

Kevin Atcheson[1], Per-Erik Mellander[2], Rachel Cassidy[3], Sally Cook[1], Stewart Floyd[3], Colin McRoberts[3], Phoebe Morton[3], Phil Jordan[1]

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[3]*Agri-Food Biosciences Institute, Belfast, UK*

The acid herbicide MCPA is widely detected in water bodies, especially where there are frequent applications to grassland agriculture. However, there is an evidence gap relating to MCPA pathways between land use application/mobilisation and detection in water bodies. To address this, an enhanced water quality dataset was used to quantify exported MCPA loads in conceptual hydrological pathways using two separation techniques in the Irish cross-border River Derg (384km2), which is abstracted and treated for drinking water. The

Local Minimum Method (LMM) and Loadograph Recession Analysis (LRA) were adapted for use on MCPA load and discharge data collected every 7 hours over a 7 month period. This was augmented by storm event sampling at 1 hour resolution. The data indicated a very high total MCPA export of 85 kg over the seven months (0.355 µg L-1 flow weighted mean concentration). Specific pathway load contributions were quickflow (72 %), interflow (11 %), elevated baseflow (5 %) and deeper baseflow (12 %). The separations indicated an acute, storm dependent MCPA transport limited process during the application season in surface quickflow pathways that should be targeted for mitigation. Deeper MCPA transfers in baseflow indicated incomplete degradation with a more chronic presence. The high total MCPA exports were only possible to measure using an enhanced monitoring approach—providing estimates of pathway contributions and a framework for mitigation assessment, and research priorities for ecotoxicological studies.

Izydorczyk K., Frątczak W., Krauze K., Rychlicki T.
K. Izydorczyk, W. Frątczak, K. Krauze, T. Rychlicki

Abstract number–115 Multi-stakeholder local cooperation on water management in agricultural landscapes for increased water retention: Kutno County, Waterdrive case area

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The area of Kutno County is an important agricultural production area in Lodzkie Province (Poland), which was severely affected by drought in 2018 and 2019. The droughts affecting farmers and residents have turned water management from a theoretical research task into an important element affecting agricultural production.
The discussion about the possibilities of water retention in agricultural areas was the main topic of Local WATERDRIVE Meetings, which took place in 2020. The meetings were attended by farmers from Bedlno Commune (water company - voluntary association of farmers, who are owners of land through which a drainage system passes, community council), representatives of National Water Holding Wody Polskie (responsible for water resources management; from local, catchment, regional and national level), water companies and local authorities from Kutno County, regional authorities, agricultural advisors, and experts.
The collaboratively developed The Local Action programme for increased water retention in the Bedlno Commune is focused on two main elements: the modernisation of the drainage system towards controlled run-off, and the application of nature-based solutions (NBS).
The cycle of workshops carried within WATERDRIVE project enable stakeholders to identify the drainage system as a basic tool in the fight against drought. Renovation of the drainage system and switching to a controlled drainage allows water to be collected in open ditches

and underground pipes through damming facilities, and consequently raising the groundwater supplying soil with water. The result of the meetings was a joint action on the existing hydrotechnical infrastructure by the Bedlno Water Company and the Wody Polskie. Through weirs on the tributaries of the Bzura river, located in the Bedlno commune, water was dammed up by storing it in drainage systems and riverbeds. These activities triggered the national program "River channel retention" launched by Wody Polskie in April 2020. NBS measures under consideration consist of preservation / re-establishment of plant buffer strips, mid-field afforestation, restoration of wetlands or construction of artificial wetlands, restricted land development in areas being run-off generators and accumulators. This requires comprehensive top-down (commune local plans) and bottom up (at farm management level) actions. As NBS are established in particular locations, often involving private lands, and benefits are distributed broadly, beyond those locations, increase with time, and often not offer immediate gains, a prior effort should be done in awareness raising.

This study is an outcome of the Waterdrive project (#R094), which was supported by the Interreg Baltic Sea Region Programme.

Ouwerkerk K., Rozemeijer J.C., Buijs S., Kaandorp V., Hooijboer A.E.J., Lukács S., van Loon A.H., van der Grift B., Schipper P., Groenendijk P., van Herpen F.C.J., Oudendijk M.
K. Ouwerkerk, J.C. Rozemeijer, S. Buijs, V. Kaandorp, A.E.J. Hooijboer, S. Lukács, A.H. van Loon, B. van der Grift, P. Schipper, P. Groenendijk, F.C.J. van Herpen, M. Oudendijk

Abstract number–116 Hot-spots and hot-moments: High resolution monitoring in time and space to support a spatial targeting approach for nutrients in agricultural catchments

Kevin Ouwerkerk[1], Joachim Rozemeijer[1], Simon Buijs[1], Vince Kaandorp[1], Arno Hooijboer[2], Saskia Lukacs[2], Arnaut van Loon[3], Bas van der Grift[3], Peter Schipper[4], Piet Groenendijk[4], Frank van Herpen[5], Michiel Oudendijk[6]

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During the past thirty years, the water quality in Dutch agricultural areas has improved, but still not enough to meet the goals for the Nitrates Directive and the Water Framework Directive. The national government of The Netherlands currently makes a case for a spatial targeting approach for nutrients in problematic catchments. However, without a clear image of the hot-spots and hot-moments of nutrient losses within those catchments, it is not

possible to take focused and effective measures. Region-specific mitigation also requires region-specific monitoring.
The aim of this research is to explore the possibilities for supporting a spatial targeting approach for nutrients with new monitoring strategies. We designed and implemented detailed monitoring networks within two headwater catchments with intensive agricultural land use. The Vuursteentocht is a 13 km2 regulated polder catchment in the clay region. The Vinkenloop is a freely draining 7 km2 stream in the sand region.
In this presentation, we focus on (1) the results from a mobile laboratory equipped with sensors and auto-analyzers for Ptot, TRP, NO3, NH4, EC, pH, O2, and turbidity and (2) the results from routings for the spatial mapping of NO3, EC, and temperatures in the stream and connecting ditches. The continuous measurements produced valuable insights into hot-moments of nutrient losses. We registered the water quality responses to precipitation events, ditch and culvert maintenance, irrigation, weir level adjustments, and some unknown direct inputs. In combination with other monitoring data (e.g. discharge, precipitation, groundwater levels, conventional water quality sampling), the continuous data enabled closing the water and solute balance and the calculation of contributions of seepage and agricultural drainage to the total nutrient loads to the stream. The spatial routings revealed nutrient loss hot-spots, for example flower bulb fields and discharge from open solid manure storage. In addition, the spatially variable contribution of seepage water was revealed by the EC and temperature data.
The collected monitoring information unraveled the within-catchment nutrient sources and transport routes. We consider this to be a good starting point for selecting the right mitigation options at the right locations in discussion in discussion with farmers, the water boards, and other stakeholders.

Haghi R., Freitag S., Watson H., Robertson J., Stutter M., Glendell M.
R. Haghi, S. Freitag, H. Watson, J. Robertson, M. Stutter, *M. Glendell*

Abstract number–117 Evaluating the application of UV-Vis spectroscopy for simultaneous detection of nitrate, DOC and phosphorus and for chemical ‘water quality fingerprinting’

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Understanding of water quality based on data with low temporal resolution can greatly under-estimate pollutant concentrations and loads, hindering cost-effective targeting of mitigation measures and understanding of environmental change. Optical probes have been successfully deployed in catchment observatories and by the waste-water industry for high-resolution monitoring of nitrate and dissolved organic carbon (DOC). In this project, we test the application of this technology for the simultaneous detection of nitrate, DOC and phosphorus.
We develop new mathematical models to address the following questions:
1. Can we apply supervised chemometric approaches to monitor nitrate, DOC and

phosphorus simultaneously in order to enable accurate high temporal resolution data acquisition at lower cost?
2. Can we derive a 'chemical fingerprint' to characterize the spatial variability of water quality in river catchments, based on the full range of UV-Vis spectra, as an indicator of 'ecosystem health'?
3. Can we identify unusual changes in composition of environmental water samples and in ecosystem health due to changes in the integrated 'chemical fingerprint'?

An sc::an UV-Visible spectrometer was employed to acquire ~200 spectra of water samples, including laboratory mixtures and field samples, over the wavelength range of 200 to 800 nm with an optical pathlength of 35 mm. The samples were collected from various locations during several seasons to cover spatial and temporal variability in water quality. The predictive performance of two regression methods - Partial least square (PLS) and support vector regression (SVR) methods was investigated, alongside the impact of different pre-processing methods on accuracy of PLS and SVR models. We evaluate the performance of UV-Vis spectroscopy technique in combination with chemometric approaches for accurate estimation of nitrate, DOC and phosphorus simultaneously in environmental water samples at different turbidity levels. To assess the spatial variability in water quality in river catchments using the UV-vis spectra, we used principal component analysis (PCA) and Autoencoder (AE) to reduce the spectra dimension to generate a proper visualization of the experimental data. The UV-Vis spectrum of water samples from different catchments were recorded and the applicability of UV-Vis combined with PCA and AE to detect water contamination events was investigated.

Erlandsson Lampa A.M., Petersson J.F., Smith D.J.P., Bång L.M., Hoffman M.A.
A.M. Erlandsson Lampa, J.F. Petersson, D.J.P. Smith, L.M. Bång, M.A. Hoffman

Abstract number–118 Methods to assess the potential of reducing phosphorus loads from agricultural land

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Nationally, a total reduction of about 590 Tn-P/year in phosphorus load is necessary to achieve the goals of the EU Water Framework Directive in Sweden. If the total is distributed over all types of significant pressures proportional to their respective load, a total reduction of 400 Tn-P/year from agricultural land would be required.

Here we present how this phosphorus reduction target from agricultural land can be achieved, by an analysis of effectiveness, potential and cost of different mitigation measures. From a list of twelve potential mitigation measures, the measures that could be

proven to be cost-effective and with a quantifiable potential, were included in the analysis. These were: wetlands, buffer strips, site specific buffer zones and structure liming of clay soils.

We estimate that by these mitigation measures, it would be possible to achieve a reduction of 230 Tn-P/year, i.e. 57% of the total requirement. Provided that the measures are implemented and prioritized regarding cost-efficiency over the next twelve years as well as the current yearly governmental funding is constant over the time period, these measures are estimated to be covered by the available governmental funding. This should be viewed as a realistic target for reduction of agricultural phosphorus loads over the next two management cycles. However, it should not be seen as an absolute boundary of what is possible to achieve, as there are more potential mitigation measures which were not included in the calculations.

Our results can be used as information to decision makers, as planning material for governmental agencies and catchment management officers, and as a tool to set exemptions in form of less stringent objectives for water bodies with a high degree of pressure from agricultural activities.

Schönhart M., Schmid E., Jost E., Parajka J., Schürz C., Strenge E., Zessner M., Zoboli O., Mehdi-Schulz B.
M. Schönhart, E. Schmid, E. Jost, J. Parajka, C. Schürz, E. Strenge, M. Zessner, O. Zoboli, B. Mehdi-Schulz

Abstract number–120 Integrated assessment of policies to manage nutrient losses from agricultural land under climate change in Austria

Martin Schönhart[1], Erwin Schmid[1], Elisabeth Jost[1], Juraj Parajka[2], Christoph Schürz[1], Eva Strenge[2], Matthias Zessner[2], Ottavia Zoboli[2], Bano Mehdi-Schulz[1]

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The reform of the Common Agricultural Policy (CAP) requests EU member states to target policy measures to national requirements and regional conditions. These measures are outlined in national CAP strategic plans and will be implemented from 2023 onwards. Hence, they will influence the quality of production, environment and policy performance in agriculture during the years. We present an integrated modelling framework (IMF) to analyse the cost-effectiveness and nutrient leakage potential of selected measures dedicated to maintain or improve water quality such as limitations in mineral fertilizer use, diversified crop rotations, and planting of cover crops. The integrated modelling framework combines full nutrient emission accounting (MORE), bio-physical process modelling (EPIC), spatial economic land use modelling (BiomAT), and water quality assessment modelling (SWAT). SWAT is applied to model spatial relationships between agricultural nutrient management, soils, and water flows at watershed scale. MORE is applied to provide full nutrient emission

accounting at regional to national scale. The bio-physical process model EPIC simulates climate change impacts on crop yields and nutrient management measures. EPIC outputs are included in BiomAT to assess cost-effectiveness and nutrient leakage potentials of measures. The integrated modelling framework offers three advantages for policy support. High-resolution model outputs reveal the cost-effectiveness and nutrient leakage abatement potentials of particular measures ex-ante to implementation, either applied as stand-alone measure or in combination. It can complement and guide monitoring efforts. Furthermore, the IMF allows to consider climate change and socio-economic scenarios to test the long-term impacts and robustness of measures with respect to cost-effectiveness and nutrient leakage potentials. Finally, the IMF informs about trade-offs and synergies of measures in spatial and temporal context. Systematic comparison between model results and the results of both the obligatory ex-ante assessment and the strategic environmental assessment of the national CAP strategic plan improve the capacity of decision makers to interpret, evaluate and apply model results as strategic decision support tool.

Blicher-Mathiesen G., Hansen B., Tornbjerg H., Thodsen H., Larsen S.E., Kronvang B.
G. Blicher-Mathiesen, B. Hansen, H. Tornbjerg, H. Thodsen, S.E. Larsen, B. Kronvang

Abstract number–121 Effect of extreme climate events on responses of nitrogen leaching and concentrations in agricultural catchments in Denmark

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Water is the agent for NO3−-N transport and, consequently, climate and hydrology have a strong impact on the leaching and transport of NO3−-N through catchments to streams. Climate change impact the agricultural sector with both extreme increases in precipitation and flooding as well as risk of drought and decreases in the crop yield within North and Central Europe.
Years with extreme drought and extreme rainfall have great effects on the measured nitrate concentrations in soil water, groundwater as well as in streams. Denmark has since 1989 measured nitrate concentrations in a very dense network of monitoring stations under the national monitoring program for water and nature (NOVANA).

High nitrate concentrations in soils, upper groundwater and streams have been measured in drought years with reduced yield of crop biomass and thereby removal of nitrogen from the fields as well as in years with low annual precipitation. Contrarily, low nitrate concentrations have been recorded in years with high annual precipitation, percolation and runoff. When conducting traditional trend analysis, these extreme years in a monitoring dataset are difficult to include. Moreover, the influence of such extreme years might enhance the linkages between imposed management mitigation measures introduced in the catchment to reduce nitrogen loadings in order to reach good chemical and ecological conditions in groundwater and surface waters. We present long time series of measured nitrate concentrations and nitrogen loads to streams and suggest different methods that are robust for examining climate extremes and their impact on trends, concentrations and loads to the aquatic environment.

Strenge E., Zoboli O., Zessner M.
E. Strenge, O. Zoboli, M. Zessner

Abstract number–122 The model PhosFate as a decision support tool for implementing erosion mitigation measures in agriculture land

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The highest effect and efficiency of erosion mitigation measures aiming at the protection of surface waters can be achieved by implementing the measures in the catchments' areas mostly contributing to the emissions. This prioritization approach is currently used to support the development of a future Austrian agricultural funding program of erosion mitigation measures. To enable the localization of the measures, critical source areas (CSA) and transport pathways are identified with the help of the PhosFate model.
PhosFate is a raster-based, semi-empirical transport and emission model for the simulation of inputs of particulate or particulate-bound substances into surface waters. It was originally developed by Kovacs (2013) and further developed as an instrument for policy decision support by Hepp et al. (2019, 2022). The simulations are conducted at catchment scale with a spatial resolution of 10 x 10 m. The current application of the model focuses on the input of particulate phosphorous (PP) from agricultural soils into surface waters. The simulated pathways are above ground via surface runoff and beneath the ground via storm drainages along roads. Due to a back-tracing of the transport within the model, the sources of origin of PP loads entering surface waters can be identified in the field. This enables to localize erosion protection measures in both an effective and cost-efficient way. Additionally, CSA causing the bulk of erosive loads entering surface waters can be detected by the model. Based on the modeled transport pathways and identified CSA, the model can simulate the implementation of erosion protection measures and assess their effect and cost-efficiency. The effect is defined as the reduction of emissions entering surface waters, whereas cost-efficiency is the ratio of the emission reduction and the area needed for implementing the

measure. In order to test the model's performance as a decision support tool for funding future erosion protection measures, 11 catchments in Upper Austria were modeled. A mapping of 5 sub basins showed good agreement of the identification of CSA by the model with observations in the field. Additionally, greenings as buffer strips along CSA and greenings of preferential flow paths were simulated, and their effect and cost-efficiency were assessed, resulting in the highest efficiency for greenings of preferential flow paths. Based on such model's outcomes, this measure will be integrated into the next Austrian program for environmentally friendly agriculture (ÖPUL) in 2023. The preferential flow paths eligible for funding will be identified and localized by PhosFate. Therefore, PhosFate is currently applied at the national level to all catchments, which were identified to present a definite risk of agricultural pollution stemming from erosion, or a shortfall of the environmental quality targets regarding phosphorus in surface waters.

Ros M.B.H., Velthof G.L., Lesschen J.P.
M.B.H. Ros, G.L. Velthof, J.P. Lesschen

Abstract number–123 Exploring the potential of cover crops and balanced fertilisation to reduce nitrate leaching in Europe

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[1]*Wageningen Environmental Research*

Nitrogen (N) is a critical nutrient for plant and animal growth, but nitrate (NO3) losses from agricultural systems to ground and surface waters may decrease their suitability as drinking water sources. Several measures have been shown to reduce the risk of NO3 losses and adopted in policy. Using the static, deterministic model MITERRA-Europe, we explored the potential of balanced N fertilisation and cover crop measures to mitigate NO3 leaching in Europe and assessed at their effects on other N losses and the soil carbon balance. Activity and management data from the reference year 2016 were used to run several scenarios on adoption of balanced N fertilisation and cover crops. Averaged across the EU-28, balanced N fertilisation drastically reduced NO3 leaching to groundwater by 22%, N runoff by 8%, and N leaching to surface water by 81%. Omitting the current use of cover crops led to an increase in NO3 leaching of 3%, whereas additional adoption of cover crops could reduce NO3 leaching by 3% to 7%. A combination of the measures above could achieve a 36% reduction in NO3 leaching. However, issues related spatial variation in suitability of land, crops, and climate to apply these practices should not be overlooked. Additionally there are risks of pollution swapping when cover crops are not supplemented with balanced N fertilisation. These results show the value of European-scale deterministic models for assessing the impact of policy and/or management changes.

Lischeid G., Steidl J., Koch F., Engelke C.
G. Lischeid, J. Steidl, F. Koch, C. Engelke

Abstract number–124 The curse of the past – what can tile drain effluent tell about arable field management?

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Agriculture has substantial effects on groundwater and surface water quality at the global scale. To ensure both food security and to minimize harmful effects on the environment there is urget need to check and to improve agricultural management. Science, authorities and consultants provide many recommendations in this regard. However, the efficacy of these measures in everyday agricultural practice is rarely checked in a systematic way. A long-term monitoring programm was established by the authorities in the Federal State of Mecklenburg-Western Pomerania in Northeast Germany. At 19 sites within a 23.000 km2 region tile drains have been sampled from 2012 to 2019 at weekly intervals. A detailed survey of management practice on the field sites was performed. Meteorological data were available from weather stations close by. This data set was a solid base to study the efficacy of a variety of different management schemes on nutrient leaching, in particular nitrogen and phosphorus. To disentangle different effects, both natural and anthropogenic, solute concentration data were subjected to a principal component analysis. Principal component scores were interpreted as semi-quantitative measures of the size of various effects. They were related to meteorological and management data via Random Forest Modelling. Nitrogen concentration of most samples was far beyond the currently applicable limits. Phosphorus concentration was fairly high as well, indicating the effects of intense arable land use. Hydrological conditions and weather were identified as driving forces for nutrient discharge behaviour of the drain plots. In contrast, direct effects of agricultural management measures could hardly be identified. Instead we found clear evidence for long-term and indirect effects of agriculture on nearly all solutes, not only on nitrogen and phosphorus species. We conclude that the spatial pattern and the temporal dynamics of tile drain effluent quality reflected primarily the soil-internal mobilization or de-mobilization of nutrients and related solutes rather than allowing inferences on single agricultural management measures. On the other hand, principal component analysis revealed a variety of indirect and long-term effects of fertilisation on other solutes than nitrogen or phosphorus that are still widely overlooked in nutrient turnover studies. We found some evidence for complex interactions, e.g., antagonistic effects between nitrogen and phosphorus dynamics that are still purely understood.

Djodjic F., Geranmayeh P., Futter M., Markensten H., Collentine D.
F. Djodjic, P. Geranmayeh, M. Futter, H. Markensten, D. Collentine

Abstract number–125 Cost efficient nutrient retention in constructed wetlands at a landscape level

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Over 15 000 ha of constructed wetlands (CWs) have been implemented as a measure to increase biodiversity and reduce nitrogen (N) and phosphorus (P) loads to Swedish waters since the 1990s. Despite the considerable number of CWs and ambitious investments planned for the coming three years, there is a lack of follow up of the cost-efficiency of nutrient retention by existing CWs at landscape and catchment scales. Such follow up could provide clear guidance regarding the optimal size and location of future CWs. Therefore, this study assesses the cost-efficiency of 233 CWs in two large Swedish regions (East, 4321 km2, and West, 916 km2). Modelled nutrient retention in the CWs was predominantly low, especially in region East, due to their suboptimal location in catchments, e.g., with inadequate upstream areas and/or low share of arable land, and hence low hydraulic and nutrient loads. Suboptimal location of CWs generates both higher than necessary costs and low area-specific nutrient retention, which result in low cost-efficiency. However, high cost-efficiency CWs were also identified, especially for N retention in region West. Continued investments in CWs request clear guidance and instructions on the optimal position and size of CWs in relation to incoming hydraulic and nutrient loads to increase the cost-efficiency.

Ladekarl U., Stubsgaard E., Vægter B.
U. Ladekarl, E. Stubsgaard, B. Vægter

Abstract number–127 Targeted measures against pesticide contamination in main groundwater recharge areas in Aarhus – groundwater protection and management

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With a total of 300,000 inhabitants, the Municipality of Aarhus is the second largest in Denmark. As in the remaining parts of Denmark, groundwater is the only drinking water source, and the production of drinking water is based exclusively on groundwater treated through aeration and filtering. Targeted regulatory intervention such as injunctions to achieve pesticide-free production is required due to the discovery of pesticide contamination of the groundwater throughout the municipality of Aarhus. The ground water resources in Aarhus Municipality are described as critical keeping in mind current water consumption and available sources. In accordance with the Water Supply Act, the Aarhus municipality has adopted Groundwater Protection Plans for all vulnerable areas. Approximately 66% of the municipality is designated as high-priority water abstraction areas and 25% is vulnerable (groundwater protection zones). Analysis of some 20 years of monitoring data has shown pesticides in 40% of all wells, with the drinking water threshold being exceeded in about one in every six wells. Detailed mapping of the hydrogeological/geochemical status of aquifers was undertaken in Aarhus facilitating identification of the areas where the risk of pesticide

contamination is greatest, i.e. the areas where supplementary regulatory efforts are warranted. Since 1999, information campaigns have been implemented in these areas and farmers have been offered compensation for pesticide-free production. This voluntary scheme has only had limited effect and since 2013 it has been supplemented by a possibility of imposing pesticide free production in groundwater protection zones (vulnerable areas). The costs are primarily compensations given to the farmers who convert to pesticide-free production and are funded collaboratively by the water service providers. Additionally, all publicly owned areas are kept pesticide-free, and the authorities have initiated measures targeting historical point sources. To fulfil the decisions in the first action plan of the municipality mandatory pesticide free production was imposed in 2018 on about 100 ha of the vulnerable area. Danish Environment and Food Board of Appeal has confirmed the technical approach which is planned to be followed to protect the remaining 7000 ha that have to be protected during the next decade or two. The water service providers assess that protection of the groundwater is the most cost-effective way to maintain the possibility of using uncontaminated groundwater for drinking water without any form of water treatment. Without groundwater protection, it will most likely not be possible to abstract a sufficient amount of uncontaminated groundwater within the municipality hence water production costs increase.

Rozemeijer J.C., Barcala V., van der Grift B., Gerner L.
J.C. Rozemeijer, V. Barcala, B. van der Grift, L. Gerner

Abstract number–128 Impact of climate variability and water conservation on farm-scale P and N losses towards surface water from four years of high-resolution monitoring

Joachim Rozemeijer[1], Victoria Barcala[1], Bas van der Grift[2], Laurens Gerner[3]

[1]*Deltares*
[2]*KWR Water Research Institute*
[3]*Water Board Rijn and IJssel*

High nutrient concentrations are a widespread threat for the ecological functioning of surface waters. Agriculture is often a dominant nutrient source and water authorities are looking for options to reduce this. The aim of this study was to find links between climate variability and farm-scale phosphorous (P) and nitrogen (N) losses to surface water and to find cost-effective mitigation options. We selected a representative 24 ha dairy farm in the sandy eastern part of The Netherlands at which a single ditch collected all surface water discharge. Our detailed monitoring at the farm involved four years (2018-2021) of continuous recording of discharge, turbidity, nitrate, total-P, TRP, and groundwater levels, combined with distributed sampling of soil, groundwater, tile drain effluent, ditch water and ditch sediment.

For P, the legacy store in the upper 30cm of the farm fields was estimated at ca. 63.000 kg (ca. 2600 kg/ha). During the 2018-2021 monitoring period, the total P load towards downstream surface water was 11 kg. This shows that a very limited portion of the legacy

store was lost towards surface water. During discharge peaks, P-rich sediment was flushed downstream, causing short peaks in TP and TRP concentrations. Higher P losses occurred in the wet drainage seasons. During the 2020-2021 drainage season, water conservation measures caused relatively high groundwater levels. This probably mobilized extra P from the topsoil which led to higher measured P loads.

Nitrate was the dominant N species in groundwater and surface water. The total measured nitrate load for 2018-2021 was ca. 1700 kg, which corresponds to ca. 14% of the average soil N surplus for this period. Also for N, loads were higher in wet drainage seasons. The nitrate concentrations in the ditch increased with higher groundwater levels, indicating activation of nitrate-rich upper groundwater and tile drain contributions. Short nitrate concentration dips during rain events indicate quick flow routes without much interaction with the subsurface. The NO3 concentrations and loads were relatively low in the 2020-2021 drainage season, which was probably partly caused by water conservation and partly by a lower soil N surplus in 2020.

Our results reveal links between climate variations, water conservation, and water quality at farm scale. We observed higher N and P loads in wet conditions and extra mobilization of P after implementing water conservation. Climate projections foresee more frequent and intense rainfall extremes and droughts. Droughts reduce the nutrient uptake efficiency of crops and increase the need for water conservation. At the same time, more extreme rainfall increases the risk of nutrient losses. We therefore recommend combining water conservation with nutrient loss reduction measures. Intercepting the P-rich sediment within the surface water system would be the most effective way to reduce the downstream loading with P on the short term.

Broers H.P., van Vliet M.E., Fraters B.
H.P. Broers, *M.E. van Vliet*, B. Fraters

Abstract number–129 Hydrogeological constraints on age distributions and nitrate evolution in Dutch chalk springs

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The Netherlands holds one of the most intensive farming systems worldwide, which has significant impact on groundwater resources. In the southernmost part of the Netherlands, Zuid-Limburg, a total of 82 springs was sampled systematically to gain insight in the temporal evolution of nitrate concentrations. Leaching of fertilizers and manure in the catchment area of the springs typically led to nitrate exceeding the WFD threshold of 50 mg/l.

We aimed to better understand nitrate evolution in relation to the hydrogeological buildup of the area and to improve the nitrate forecasts. Therefore, we assessed travel time distributions (TTD) of the springs using a time series of tritium and nitrate from sampling campaigns in 2001, 2009, 2017 and 2018. The new data complemented detailed quarterly nitrate times series of a selection of 27 springs monitored by the province of Limburg. We convoluted the tritium time series in precipitation and the unsaturated zone nitrate time series for a set of unique shape-free travel time distributions over 7 age bins, yielding modelled nitrate and tritium concentrations for all 8008 possible distributions. This approach allowed us to mimic multi-modal distributions that may result from a hydraulic dual-porosity structure which seems to be an inherent feature of the chalk aquifers. The outcomes of the model distributions were compared with the measured data from each spring, optimizing for a best fit between measured and modelled tritium and nitrate. The 50 best-fit TTD/nitrate models were used to obtain a reconstruction and forecast of nitrate concentrations at the springs.

The results reveal that the nitrate concentrations are strongly correlated to both the fraction of water aged < 30 year and the mean travel time. Springs with large fractions of young water (aged < 30 years) and high nitrate were primarily found on the northern Central Plateau. This Plateau is characterized by rather thin, but permeable aquifers of Tertiary and Quaternary geologic age. Contrary, substantially smaller fractions of water aged < 30 years and lower nitrate were found at the springs that drain the Cretaceous Chalk at the southern Plateaus. A large part of these springs shows bimodal distributions, indicating mixing of young and old water components. Nitrate concentrations at the northern plateau decrease faster than nitrate concentrations at the southern plateaus, showing how measures to reduce N applications in farming affect spring nitrate differently, depending on the age distribution of the water discharged. Nitrate concentrations were forecasted for the years 2027 and 2035 for checking compliance with WFD objectives.

McCormack M.
M. McCormack

Abstract number–130 Socio-economic drivers of Nitrogen Use Efficiency and Nitrogen Balances on Irish dairy farms

Michele McCormack[1]

[1] *Teagasc*

Excess Nitrogen Balances at farm level continue to pose a threat to water quality in Ireland. At the same time Nitrogen is essential for grass production, and Ireland has a predominantly grass based livestock system. Finding this balance can be challenging, but as a first step measuring Nitrogen entering and leaving the system so that surplus Nitrogen and Nitrogen use efficiencies can be identified is crucial. In this paper we present trends in Nitrogen Balances and Nitrogen Use Efficiency on Irish dairy farms from 2010 -2019. Nitrogen Balances and Nitrogen Use Efficiency are then included in a suite of factors to capture the

Economic and environmental sustainability of Irish Dairy farms. While there are a number of difficulties in measuring these sustainability objectives, there also seems to be a conflict, in particular is it possible for farms to be both environmentally and economically sustainable? In this paper we examine the economic and environmental credentials of Irish dairy farms using Teagasc National Farm Survey data . Farms are categorised separately in terms of economic and environmental sustainability indicators. Farms are then categorised by percentile into top middle and bottom performing farms in terms of environmental and economic performances. We then investigate if there are farms which perform in the top percentile of both sustainability indicators. We investigate the socio-economic drivers of these trends, identify farms that are performing well and discuss potential changes on poorly performing farms.

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van Loon A.H., van der Grift B., de Wit J., Rozemeijer J.C., Karaoulis M., Schipper P., Groenendijk P., Lukács S., Herpen F.C.J.
A.H. van Loon, B. van der Grift, J. de Wit, J.C. Rozemeijer, M. Karaoulis, P. Schipper, P. Groenendijk, S. Lukács, F.C.J. Herpen

Abstract number–131 Linking nutrient leaching to agricultural activities and weather events by field-scale hydrochemical monitoring

Arnaut van Loon[1], Bas van der Grift[2], Janine de Wit[2,3], Joachim Rozemeijer[4], Marios Karaoulis[4], Peter Schipper[5], Piet Groenendijk[6], Saskia Lukács[7], Frank Herpen[8]

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[8]*Waterschap Aa en Maas, Postbus 5049, 5201 GA 's-Hertogenbosch, The Netherlands*

In The Netherlands, numerous ground water and surface water bodies are of insufficient quality regarding the goals for the Nitrates directive and Water Framework directive. Using a spatial targeted approach, the Dutch government aims at enhancing the implementation of measures to reduce nutrient losses from agricultural fields. The effectiveness of this approach, however, is determined by the ability to select and implement effective measures to mitigate the dominant sources and pathways. This requires detailed insight in the processes behind nutrient losses from agricultural fields and how these might change in future.

The objective of this study was to explore new monitoring strategies for field-scale monitoring to link nutrient leaching towards groundwater and surface water to agricultural activities and weather events on arable land. During 2021, we collected data on farm management practices and spatio-temporal dynamics on water chemistry for a drained

arable field in a sandy region. Temporal dynamics in water chemistry were monitored using a series of electrical conductance sensors for soil moisture, groundwater and drainage water. Spatial patterns in groundwater chemistry were monitored by Electrical Resistance Tomography and a survey of groundwater quality at 40 randomly selected points. Detailed data on gradients in groundwater quality along depth was acquired by monthly sampling of two nested series of mini-filters up to six meters depth.
During this presentation we focus on (1) observed leaching events related to intense spring irrigation and extreme summer precipitation, (2) attenuating effects of observed denitrification under influence of soil organic matter. According to the results, electrical conductance is an unreliable proxy for nitrate at sites with spatial or temporal variation in denitrification. Nevertheless, EC-sensors can provide valuable information on solute leaching dynamics and patterns, particularly when combined with hydrochemical monitoring. The results also imply that slow release of nutrients is beneficial to prevent summer leaching and that organic matter supply might also be effective to enhance denitrification at depth. We consider that field-scale hydrochemical monitoring may provide new perspectives for mitigating nutrient emissions to surface water and contributes to awareness among farmers.

Eisele M.
M. Eisele

Abstract number–132 Determination of nitrate polluted areas – Experiences in North Rhine-Westphalia (Germany)

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In recent years Germany was criticized by the European Commission for violating the European Nitrate Directive and was forced to review its regulation on fertilizer application. In 2017 a new regulation on fertilizer application obliged the federal states of German to determine areas with additional restrictions for fertilizer application. With the amendment of the regulation in 2020 these additional restrictions were tightened and a methodology for the determination of “nitrate polluted areas” was defined in a nationwide regulation.
In North Rhine-Westfalia (NRW) “nitrate polluted areas” were determined according to actual regulative requirements and officially published in 2019, 2020 and 2021. The main basis for the determination was a network of quality certified groundwater monitoring stations and a model for diffuse nitrate emissions. In the determination of 2019 entire groundwater bodies were labeled as “nitrate polluted areas” when the chemical status for nitrate according to the EU-WFD was classified as bad based on the monitoring. This changed in 2020, when groundwater bodies in bad status were differentiated using modeled results for tolerable N-surpluses to reach water quality targets. In 2021 the determination was adjusted to the new nationwide regulations. In addition to groundwater bodies in bad chemical status “nitrate polluted areas” were determined in groundwater bodies in good chemical status as well if targets for nitrate were exceeded at single monitoring stations. It was obligatory to

differentiate polluted and unpolluted parts within the groundwater bodies based on measured nitrate concentrations. In polluted parts agricultural areas were evaluated based on modeling results for tolerable N-surpluses and actual agricultural N-surpluses. Only agricultural areas where actual N-surpluses exceeded tolerable N-surpluses were determined as “nitrate polluted areas”. These areas are now officially in place since January 2021.
However the determination of 2021 was unsatisfactory both to the European Commission and stake holders. Water supply companies criticized that some drinking water catchments with nitrate problems were not included. Some farmers questioned the suitability of single monitoring stations with exceeded quality targets for nitrate and subsequently took legal action. The Commission declared the methodology of the nationwide administrative regulation as not acceptable. Main points of criticism were the small size of the resulting areas, lacking transparence of the methodology, use of models to calculate agricultural emissions and discrepancies in the resulting areas between the German states. Currently the federal government of Germany and the states are developing a new methodology addressing these issues.
This contribution will present methods and results of the different determinations of “nitrate polluted areas” in NRW, discuss the suitability of different methods and problems in application and acceptance.

Sundermann G., Wägner N., Cullmann A.
G. Sundermann, N. Wägner, A. Cullmann

Abstract number–133 Organic farming, water quality and drinking water supply costs – An empirical analysis for Germany

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Agriculture and in particular unsustainable farming activities contribute significantly to the transgression of the 'planetary boundaries'. Among other, they are associated with the overuse of essential but limited resources, interfere with the natural biogeochemical flows, and cause severe environmental pollution, such as groundwater contamination by agricultural runoffs. Nitrate groundwater pollution represents a global and pervasive problem to water management across the world. Under the European Green Deal (EGD) and within the Farm-To-Fork Strategy, European agriculture and food system are set to become a global standard for sustainability. Organic farming systems are described as crucial for this transformation. In contrast to conventional farming, organic farming systems use natural resources and local circulation systems, prohibit the application of synthetic pesticides and mineral fertilizer, maintain biodiversity, preserve the natural ecosystem, and protect soil fertility. Thus, organic farming is expected to increase water quality by reducing nitrogen loads and in turn nitrate groundwater contamination. While the link between land utilization

and water pollution is well established in the literature, other factors relating to agricultural practice such as organic farming and the effects of raw water quality on drinking water supply costs are poorly understood.
In a first stage, this paper empirically investigates the link between organic farming and nitrate groundwater pollution. We model annual nitrate levels as an auto-regressive process that depends on the share of organically farmed land, conditional on other factors affecting groundwater nitrate, such as mineral fertilizer application, land use and weather. We hypothesize, that organic farming in the vicinity of the groundwater sampling station significantly reduces groundwater nitrate, compared to agricultural land under conventional farming. In a second stage, we analyze the consequences for drinking water supply firms and estimate the implications of nitrate groundwater pollution for firm level treatment costs. If raw water nitrate surpasses the legal threshold, the companies must take additional measures to comply with the statutory requirements, i.e. secure its safety and purity, which will result in additional cost, indirectly effecting water prices for consumers. Empirical evidence is based on a large and unique data set for Germany for the years 2008-2016. Preliminary results suggest that organic farming decreases nitrate concentrations in groundwater. We further find that treatment costs of drinking water supply firms increase with the nitrate groundwater pollution.

Jordan P., Atcheson K.F., Cassidy R., Cook S., Doody D., Farrow L., Floyd S., McRoberts R., Mellander P.-E, Morton P.A., Glass C., Burgess D.
P. Jordan, K.F. Atcheson, R. Cassidy, S. Cook, D. Doody, L. Farrow, S. Floyd, R. McRoberts, P.-E Mellander, P.A. Morton, C. Glass, D. Burgess

Abstract number–134 MCPA herbicide: Revealing the pressures and addressing the challenges at catchment scale

Phil Jordan[1], Kevin Atcheson[1], Rachel Cassidy[2], Sally Cook[1], Donnacha Doody[2], Luke Farrow[2], Stewart Floyd[2], Robert McRoberts[2], Per-Erik Mellander[3], Phoebe Morton[2], Catherine Glass[2], Diane Burgess[2]

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[3]*Teagasc, Wexford, Ireland*

The herbicide 2-methyl-4-chlorophenoxyacetic acid (MCPA) is the most widely used agricultural pesticide on the island of Ireland with reports from both jurisdictions showing a combined annual application of 138 tonnes across a spray area of 1,096 km2. Most of these applications are to improved grassland and rough grazing areas to control rush (Juncus spp.) and some broadleaved weeds. However, MCPA is mobile following application and particularly when exposed to rainfall-runoff events. It is increasingly detected in water bodies, and this places a burden on abstraction and treatment processes to remove the pesticide prior to domestic water supply. Despite this, knowledge gaps exist related to: MCPA management and application; degradation and mobilisation in catchment soils; hydrological export pathways; and ecotoxicology and synergistic impacts. Some of these

gaps were addressed in the River Derg (384 km2), a drinking water source catchment in the Irish border area. Work focussed on investigating land use controls, understanding seasonality and hydrological pathways, and implementing a farm land incentive scheme (LIS) to reduce MCPA export to the river. In a before-after-control-impact study an enhanced MCPA river monitoring approach was employed where water samples were collected at least daily year round: from March to December, samples were collected every 7 hours, supplemented by hourly samples during a seven month spraying season.
A weekly spatial survey of river tributaries identified areas of improved grassland as key source areas for MCPA. Enhanced monitoring data at the catchment outlet indicated a maximum annual export load of 93 kg and, over the seven month spring-autumn application period, the export was 85 kg (0.55 kg km-2 by agricultural area). This seasonal export was partitioned into pathways and indicated a 72 % loss in quickflow. Thirteen percent was found in deeper baseflows implying imperfect degradation and a chronic presence. The LIS provided advice and workshops to farmers with funding to upgrade pesticide storage and handling facilities, and a switch from MCPA boom spraying to an alternative herbicide and application technique when treating rushes. Over four consecutive years (two post-LIS) the data indicated a reduction in MCPA concentrations in the River Derg by approximately 40 % due to the LIS, compared with the neighbouring control catchment when adjusted for flow conditions. A cost benefit analysis was included in the study which highlighted the substantial savings in water treatment costs that could be achieved through the LIS.
This work demonstrated the hidden magnitudes of water quality pressures that were revealed through enhanced monitoring approaches, and the reductions of those pressures through targeted farm advice networks and incentives.

Galloway J., Hawtree D., Mellander P.-E
J. Galloway, D. Hawtree, P.-E Mellander

Abstract number–135 The application of a hierarchical Bayesian model to understand water quality drivers in four agricultural catchments across multiple spatial scales

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Understanding the impact of agricultural practices on water quality is a prerequisite for designing efficient and effective mitigation measures and the subsequent assessment of those measures.
However the relationships between stream water quality, source pressures and the drivers which impact trends are complex, vary in time and space and are also scale-dependent. This can lead to seemingly contradictory conclusions regarding trends, the relationship to source pressure and catchment characteristics depending on the spatial scale considered. Robust approaches are therefore needed to understand and evaluate trends simultaneously on multiple scales in an interpretable and repeatable manner.

In this study a hierarchical Bayesian modelling approach was used in order to provide a systematic approach to evaluating data from multiple scales simultaneously while providing information regarding the range of likely parameter values and their probability distributions. The objectives of this study were to i) provide a robust approach in which to incorporate hydrochemical and physical information and ii) to apply this approach in order to explain relationships between drivers and water quality at across multiple scales.

Ten years (2010 – 2020) of monthly in-stream nitrate and phosphate concentrations were measured longitudinally throughout the stream network within 4 agricultural catchments along with a suite of physical and parameters relating to soil physical properties and source pressures. Digital terrain maps were used to delineate watersheds at multiple scale from sub-catchment to catchment level and a range of explanatory variables related to physical characteristic and land management were created for each watershed. A Bayesian hierarchical linear regression model was used to estimate the posterior distribution of linear coefficients (or weightings) for each explanatory variable.

We found that water quality trends at the sub-catchment level varied in both in their magnitude and direction with catchment-scale trends being a weighted average of the spatial scales below.

This approach offers a structured approach to analysis datasets collected at multiple spatial scales. This will allow practitioners to focus mitigation strategies at the appropriate scales and also provides a robust method to assess the efficacy of mitigation measures.

Ekholm P.O., Lehtoranta J.M., Uusitalo R.
P.O. Ekholm, J.M. Lehtoranta, R. Uusitalo

Abstract number–136 Release of soil-bound phosphorus in aquatic systems

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Runoff from fine-textured inorganic agricultural soils transports soil-bound and dissolved reactive phosphorus into water bodies. The latter is considered entirely algal available, but the share of available soil-bound phosphorus may range from 20% to 60%, depending on the methodological approach, soil in question and whether the release after sedimentation has been considered. The optimization of water protection measures requires more knowledge on the behavior of phosphorus, but only few studies have estimated how the conditions in the receiving aquatic system affects the release of soil-bound phosphorus.

We estimated the release of soil-bound phosphorus by simulating the conditions the eroded soil encounters after entering aerobic and anaerobic lake and sea water environments. The

soils included five clayey surface soils sampled from four agricultural fields and from a forest and showing a wide range in soil-test phosphorus, oxalate-extractable iron and aluminum. We took the test waters from a clear-water lake and brackish Archipelago Sea, differing in sulfate concentration. The soils were incubated for about four months separately in aerobic and anaerobic conditions in lake and sea water with and without added labile carbon. The release of phosphorus and the consumption of electron acceptors as well as the build-up of their end-products were monitored in addition to carbon forms.

The soils exhibited a large variation in phosphorus release, the release yet correlating with the soil-test phosphorus. The release was higher in anaerobic than in aerobic incubation. In anaerobic incubations more phosphorus was released from carbon amended units than from units with only native soil carbon as an energy source. Sulfate and organic carbon enhanced the sulfate reduction and formation of iron sulfides, unable to bind phosphorus in anaerobic systems.

The results suggest that a cost-efficient phosphorus policy may have to account for the chemical (sulfate concentration) and biological (trophic status) characteristics of the receiving water body. In eutrophic and anoxic systems, such as the Baltic Sea, soil-bound phosphorus may be massively released from sediments. On the other hand, in freshwater bodies low in sulfate, sediments may capture efficiently phosphorus, especially in oligotrophic conditions. Erosion control appears to be most important in the catchments discharging into eutrophic coastal waters. More importantly, reducing soil-test phosphorus not only decreases the losses of dissolved reactive phosphorus but also the availability of soil-bound phosphorus highlighting the need of avoiding surplus phosphorus balances in agriculture.

Kivits T., Broers H.P., de Jonge M.
T. Kivits, H.P. Broers, M. de Jonge

Abstract number–137 Assessing the land use specific vulnerability of public drinking water supplies using multi-tracer age dating

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Groundwater is an important resource for the production of drinking water. Approximately 60% of the drinking water produced in the Netherlands originates from groundwater. Currently, these resources are under pressure due to overexploitation and from point and diffuse pollution sources, especially by pesticides and nutrients from the intensive use of agricultural lands. Although European legislation aims at reducing the leaching of agricultural pollutants to groundwater resources, many well fields from public drinking water suppliers are still at risk resulting in a systematic closure or reallocation of shallow well fields during the past three decades.

The vulnerability of well fields strongly depends on the travel times of the infiltrating water to the pumping wells. Other key factors determining the vulnerability of the well fields are the leaching history of contaminants into the groundwater and the geochemical reactivity of the subsurface sediments. Production wells typically draw water horizontally from the aquifer where the screens are situated, but also from the aquifers above and below. The water that is abstracted in production wells is therefore a mix from different depths and ages, and the distribution of ages in the mix may be used to assess the vulnerability of the well fields.

We used multiple tracers to determine the age distribution of 19 large-scale production well fields. Tritium-Helium was used to characterize the youngest water up to a hundred years old. Argon-39 was used for groundwater between 100 and 1000 years old, and carbon-14 and helium-4 for the oldest water up to 100.000 years. We combined the age-dating tracers with water isotopes (oxygen-18 and deuterium) and major ion chemistry (Cl, SO4, alkalinity, hardness etc.) to determine the origin of the infiltrating water which we link to the land use of the catchment areas. For example, we differentiate between infiltrating river water, water that has infiltrated in agricultural areas and water infiltrating from forests and heathlands. The 19 investigated well fields showed a wide range of age distributions, some dominated by a large fraction of river-derived modern water and others with dominant ages of thousands of years. Combining the age distributions of the well fields with the origin of the catchment areas allows us to estimate the vulnerability of the well fields to possible pollution sources, helping drinking water companies with the sustainable management of their resources.

Adams K.J., Metzger M.J., Helliwell R., Macleod C.A.J., Melville N., Pritchard J., Edwards K., Glendell M.
K.J. Adams, M.J. Metzger, R. Helliwell, C.A.J. Macleod, N. Melville, J. Pritchard, K. Edwards, M. Glendell

Abstract number–139 Identifying and testing adaptive management options to increase catchment resilience using a Bayesian Network

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Stakeholders who manage freshwater resources require decision-support tools that increase their understanding of catchment system resilience and support the appraisal of adaptive management options. Our research aims to address the following question: Can a Bayesian Network (BN) model support stakeholders in the identification and testing of adaptive management options that help increase catchment system resilience to the impacts of cumulative future change? Using the predominantly arable Eden catchment (320km2), in

eastern Scotland as a case study, we invited stakeholders from multiple sectors to participate in a series of workshops aimed at addressing water resource issues and achieving good ecological status in the catchment both now and in the future. Reactive phosphorus (RP) concentrations were identified as a key parameter currently failing to achieve good status in the catchment. High current RP concentrations are attributed to wastewater discharge, diffuse pollution from agriculture and private septic tanks and river flow volumes. A BN model was developed with stakeholders to map the socio-ecological system within the catchment. The BN model simulates current catchment conditions and the impact of multiple future pathways on the catchment system to 2050. Outputs from the BN model compared current and future RP concentrations in the catchment. Contributions of RP by sector can be compared, enabling the relationships between sectors and their influence on the catchment system to be realised. Measuring the impacts of future change on water resources in the catchment highlighted the important interrelationships between natural and human systems and their impacts on both water quality and quantity. Outputs informed the identification of adaptive management options which were grouped into five management scenarios. The effectiveness of each management scenario in increasing catchment system resilience was tested using the BN model to support the appraisal of each management scenario by participating stakeholders. Two optimal adaptive management scenarios were identified; the first optimal management scenario focussed on predominantly nature-based management options such as wetland wastewater treatment methods and rural sustainable drainage systems. The second optimal scenario focussed on resource recovery, including phosphorus recovery from wastewater treatment works and constructed lagoons for crop irrigation. Outputs of the model describing the resilience of the catchment initiated conversations about feasible management options that could be applied across sectors to reduce risk and increase catchment resilience. The ability of the BN model to test and compare adaptive management scenarios in a time-effective manner was seen as an advantage in comparison to conventional methods.

Žurovec O., Lynch B., Richards K.G.
O. Žurovec, B. Lynch, K.G. Richards

Abstract number–142 Lysimeter-measured nitrate leaching on non-derogation and derogation farms in Ireland

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Agriculture is the dominant land use type in Ireland, with most of the gross agricultural output coming from pasture-based livestock production systems. There is an increasing concern about the negative effects of intensive farming on ground and surface water quality due to increased diffuse nutrient losses within these systems. More comprehensive appraisal of nutrient flows within grass-based farming systems is required in efforts to manage nutrients in a more efficient way and mitigate the losses to water.

Here, we present the preliminary results of lysimeter- measured nitrate concentrations in soil solution and nitrogen (N) leaching on two commercial farms. The monitoring sites have been established in November 2021 as a part of the Agricultural Catchments Programme. The selected catchment is located at the south of Ireland and represents one of the most intensively managed agricultural areas with well to moderately drained soils vulnerable to nitrate leaching. Both sites are located on well drained Brown soils dominant in the region. Site 1 is located on the extensively managed, non-derogation beef farm, with the rate of 140 kg N/ha/y applied as manure. Site 2 is located on the intensively managed dairy derogation farm, with the calculated manure N rate of 246 kg N/ha/y. Field-scale farming practices are recorded and used to calculate the N balance. Six passive capillary lysimeters were installed at each site below the root zone to collect drainage at 90 cm depth. Drainage from lysimeters is collected and measured weekly or bi-weekly, depending on the amount of rainfall. The collected drainage samples are analysed for total and mineral N (NH4-N and NO3-N). While the winter drainage period is still ongoing and the results are therefore inconclusive, early results suggest significant difference between the monitoring sites in terms of both nitrate concentrations in soil solution and the amounts of N leached below the root zone.

Gertz F., Tholstrup L.K., Bønnelycke Nørgaard L.
F. Gertz, L.K. Tholstrup, L. Bønnelycke Nørgaard

Abstract number–143 Water exchange in coastal waters affecting priorities of land-based measures

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Since the 1980s improving water quality in Danish coastal waters has been high on the agenda. In the 3rd water cycle 2021-2027 the national N reduction target to coastal waters is 23 %, but with large geographic variation from zero to over 60% N reduction targets. These reduction targets are established with marine modelling using yearly N loads without considering the seasonal changes in loads related to hydrodynamics in coastal waters. Danish coastal water is basically a large estuary with a 2-layer water column constituted by the brackish Baltic Sea and more saline North Sea. The high reduction targets are not enforced on open Danish waters but on bays and semi closed lagoons, fjords etc. The water resident time is for the most part less than a month, often smaller, and for some water bodies, weather events can replace the water within a few days. Due to this, autumn and winter runoff loads of nitrogen affects the summer primary production very little if at all, because these nutrients are no longer present in the water body at spring and summer. Several studies have shown this connection. So far, the prioritization of cost-effective measures in Denmark have been based on annual nutrient budgets. Focusing more on reducing N loads during the summer, will change the priorities. The distribution between

diffuse and point sources changes throughout the year and point sources will contribute relatively more in summer than in winter. In catchments characterized by clay soils, runoff from diffuse sources is large during the winter, but small during the summer. Therefore, the point source fraction can vary from a few % in the winter and up to 70% in summer, resulting in the impact from point sources on coastal waters being generally underestimated when only looking at annual loads. Also prioritizing measures in the field will change. Catch-crops primarily reduce the N loss during winter, and to reduce the loss from the fields during summer, other measures must be taken. In general, reducing the autumn and winter loads improves the water quality in open water areas such as the Baltic Sea, Kattegat and North Sea. Whereas improving the condition in near shore water bodies, demands reduction in the spring and summer loads. This knowledge is still not being implemented in the Danish water actions plans, but it will have a great impact on the reduction targets and priorities of land-based measures.

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van Vliet M.E., Broers H.P., Janssen G.M.C.M.
M.E. van Vliet, H.P. Broers, G.M.C.M. Janssen

Abstract number–144 Evaluating patterns of nutrients, pesticides and emerging contaminants in age-dated groundwater: Monitoring the Sand-Meuse groundwater body in the Netherlands

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The Netherlands is one of the most densely populated areas worldwide, and contamination of groundwater with nutrients, pesticides and emerging contaminants is widespread, due to inputs by agriculture, from urban areas and by infiltration of surface water. The origins and history of the contamination is not always known, and age dating is used to unravel the leaching history and origins of the contamination.
This study investigates spatial and temporal patterns of pesticides and emerging contaminants within age-dated groundwater of the Sand-Meuse groundwater body. We used the results of the surveillance monitoring of the province of Noord-Brabant and Limburg. Data from the 2012, 2016 and 2019 sampling years were used from multi-level wells previously age-dated using tritium-helium. This tracer was also used to identify recharging water from the river Meuse, which has shown elevated tritium concentrations over the last decades.

The concentrations of nutrients, pesticides, including metabolites, and emerging contaminants were classified based on infiltration year and land use. The infiltration year was defined by subtracting the tritium-helium apparent age of the sampled groundwater from the year of sampling itself. Jitter plots were used to visualize the contaminant patterns, which have the advantage that non-detects can easily be differentiated from “hits” of the contaminants above detection limits. The signatures of the tracer-based infiltration year

classes of pesticides and emerging contaminants were compared with those derived from groundwater transport modelling using MODPATH and MT3D.The idea behind the comparison was to see whether modelling may help to unravel transport patterns in case no tracer ages would be available.

Most of the hits of pesticides and emerging contaminants was observed in the youngest infiltration year classes (2000-2010 and 2010-2020) and in agriculture areas. As we only related those pesticide hits to the advective flow using the infiltration year approach, we cannot rule out that degradation is partly responsible for the lower number of hits in water from the earlier infiltration periods. However, several contaminants were found systematically in older water, such as metabolites BAM and desphenyl-chloridazon, and the microconstituents PFOA and EDTA; these substances are clearly mobile and persistent in the regional groundwater. Other contaminants could be related to the infiltration of river water, such as carbamazepine. This anti-epileptic drug was only found in the most recent infiltration years (2010-2020) and in the areas where Meuse water recharges the groundwater. Tracer-based ages performed better to reveal the prominent patterns than the modelled ages, a result which helps to improve the model for future use. Overall, the study shows that patterns of pesticides and emerging contaminants can well be related to land use and periods of application, especially when using measured groundwater ages.

Kristensen N.H., Pedersen B.N, Poulsen H.V.
N.H. Kristensen, B.N Pedersen, H.V. Poulsen

Abstract number–145 Effect of previous years fertilizer application rate on nitrate leaching

Nanna Hellum Kristensen[1], Betina Nørgaard Pedersen[1], Henrik Vestergaard Poulsen[1]

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Total leaching of nitrogen from fertilizers depends on several factors including application rates. It is crucial that farmers optimize the use of fertilizers, and therefore SEGES investigated the effect of mineral fertilizer application on nitrogen leaching. In total, 22 trials in five different locations around Denmark were completed from 2015-2021. All trials included different levels of added nitrogen and were designed so the same plots received the same amount of nitrogen each year. Leaching was measured with suction cups in one meter depth. The crops were mainly winter cereals, but also included maize, sugar beet and oilseed rape. The analysis showed no evidence of increased nitrate leaching caused by high nitrogen applications in previous years. The major variation within the trials was caused by the contrast in weather conditions between years and the total nitrogen application added in the present year.

The highest leaching occurred on the sandy soils and high precipitation increased nitrate leaching both in sandy and clay soils. The highest leaching was in maize cultivated in sandy

soil, and the lowest was found in sugar beet grown in clay soils.

In one of the locations, nitrate leaching from mineral fertilizer application was compared to leaching from pig slurry. Between 2017 and 2021 the same total of amounts of nitrogen were added in plots receiving only slurry and plots receiving only mineral fertilizer. The hypothesis was to measure intensified leaching due to an increased amount of organic matter added with the slurry in previous years. The rate of leaching per total added amount of nitrogen was the same for mineral fertilizer as for pig slurry. The addition of 400 kg total nitrogen with pig slurry did not increase leaching in the two following years. The period may be too short to increase the organic pool significantly and, furthermore, the organic content in the slurry was fairly low (20-30%).

The trials indicate that the largest effects on nitrate leaching is caused by climatic conditions and the amount of nitrogen added in the present year. The addition of large amounts of either pig slurry or mineral fertilizer caused intensified leaching in the present year but did not increase leaching in the following years.

Meldorf Deichmann M., Hansen B., Wiborg I.A., Dalgaard T., Jacobsen B.H., Ørum J.E.
M. Meldorf Deichmann, B. Hansen, I.A. Wiborg, T. Dalgaard, B.H. Jacobsen, J.E. Ørum

Abstract number–146 A new Danish concept for hectare-scale groundwater N-retention: Optimization of catch crop application at field and catchment scale

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The new River Basin Management Plan for the Danish marine waters was published for hearing at the end of 2021. According to the outline of the plan, Danish agriculture will have to reduce the Nitrogen (N) transport to the estuaries by around 13.000 tons. Part of the Danish strategy is a targeted N regulation through the application of primarily catch crops which is intended to achieve a N-reduction of 3500 tons.
A new concept and technologies have been developed through the Innovations Fund Denmark projects rOPEN and MapField (http://mapfield.dk/) to support targeted N regulation at field level. In the concept hectare-scale groundwater N-retention maps are produced with a horizontal scale down to 25 m × 25 m scale, and a vertical subsurface mapping depth of

down to 100 m. These new maps show a considerable variation of the groundwater N-retention ranging between 0 to almost 100 % within the ID15 catchments, which receives one retention value for the entire catchment in the current Danish national retention model used by the authorities. The new groundwater N retention maps have been employed in an economic optimization calculation, which shows that the efficiency of deploying catch crops changes depends on the groundwater N retention. Thus, in areas with low groundwater N-retention, the effect of catch crops rose from 0,9 kg N/ha to 2,1 kg N/ha while the efficiency decreased from 1,7 kg N/ha to 0 kg N/ha in areas where the groundwater retention was near 100%. According to the new River Basin Management Plan Skive Fjord catchment must obtain an N-reduction of 164,5 tons through the application of catch crops. Calculations based on the new groundwater retention map indicate that this reduction can be obtained if 1/3 of the catchment is sowed with catch crops, corresponding to the areas with a low groundwater retention. Additionally, the strategic placement of catch crops based on the new retention map is associated with a profit of 300-600 DKK/ha when compared to the situation where all farmers in the area have the same level of catch crops.
Thus, a more detailed understanding of the topsoil layers and their influence on the groundwater N-retention is highly valuable as it allows for more targeted placement of catch crops which is beneficial for both the aquatic environment and the farmer's economy.

Kyllmar K., Fölster J.
K. Kyllmar, J. Fölster

Abstract number–149 Adaptive water management in the agricultural landscape: A framework for integration of field experiments, long-term monitoring, modelling and local engagement

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Leaching of nitrogen and phosphorus from agricultural land contribute to eutrophication of inland waters and the sea. Due to the complexity of nutrient leaching, various methods and information from different sources are needed to support cost efficient water management. Updated knowledge from the scientific society on the efficiency of single measures must be available as monitoring data for follow-up in the recipient. At the national and down to catchment scale, source apportionment models and monitoring data are appropriate for targeting risk areas and identify areas with best potential for effects of mitigation measures. On the farm and in discussion with agricultural advisors, other tools are more suitable as guidelines, checklists and high resolution models for estimation of possible effects of measures. For the regional planning and also the follow-up, information on where, when and how measures have been implemented are necessary. Subsidised measures are often documented whereas information on measures implemented with other financing is seldom available. Surveys and remote sensing analyses are here potential sources. All data produced, from raw data to modelled information must be available for various purposes and

users, ideally through a portal. Finally, the importance of platforms for exchange of experiences on agricultural water management among stakeholders should not be underestimated. In this presentation we suggest a framework for integration of all this valuable information into a platform to support water management in the agricultural landscape. The suggestion focuses on Swedish conditions and build on existing activities as far as possible. However, the proposed structure is general and may be adapted for measures related to increased biodiversity and climate change mitigation. Financiers are the Swedish University of Agricultural Sciences and the Swedish Agency for Marine and Water Management.

Klištinec J., Cibulka R.
J. Klištinec, R. Cibulka

Abstract number–150 Groundwater nitrate pollution from agricultural sources and its monitoring in the Slovak Republic

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The Slovak Republic is obligate to designate and regularly review Nitrate Vulnerable Zones for the identification of nitrate-polluted waters from agricultural sources according to requirements of the Council Directive 91/676/EEC (Nitrate Directive). Nitrate Vulnerable Zones are reviewed based on 4 years cycle, with the last one reviewed in 2020 which determined 1344 zones. In these zones, precautionary agricultural practices are implemented to protect or lower nitrate concentration to <50 mg/l. Input data are derived mainly from Water Research Institute (WRI) monitoring network, Slovak Hydrometeorological Institute monitoring network, water suppliers, and Land Parcel Identifier system (LPIS) by National Agriculture Food Center, etc. Particularly WRI monitoring network, specifically built for the needs of the Nitrate Directive, underwent improvement in density, going from 0 monitoring wells in 2007 to 1129 monitoring wells as of today, which greatly improves monitoring network quality. Another important part of evaluating Nitrate Vulnerable Zones is trend analysis. This is an important aspect, not only to forecast the future development of already polluted areas but to identify future pollution. Trend analysis is also a useful tool to assess the effectiveness of already approved action plans. We used 2 methods (linear extrapolation and Mann-Kendall test) and two different data sets of NO3- concentrations (maximum and year averages) to evaluate nitrate concentrations from 2008 to 2014 after which we compare predicted concentrations with real-world concentrations from 2015 to 2020. The result shows the accuracy of the prediction decrease over time towards the more positive outcome, as the number of monitoring wells, where reality is better than prediction grow over time. This can indicate positive ramifications of implementing the Council Directive 91/676/EEC and good agricultural practices in Nitrate Vulnerable Zones, as the positive effect is due to show with delay. However, there are still localities and broader areas where concentrations are higher than 50 mg/l and in some cases even hazardously high as above 250 mg/l. The most extreme value of nitrates on

record was a staggering 4340 mg/l. We register 199 localities with a concentration above 50 mg/l NO3- monitored by WRI, where we conducted on site survey, from which 18 localities went through a more complex investigation, with the plan of an additional 16 in 2022. These localities usually shape hotspots and are part of a larger polluted area. These areas are planned to be studied in even greater detail with the focus on hydrogeological parameters, pesticides, and additional pollutants as well as more advanced methods to trace sources of pollutants. As groundwater is the most important raw material of the future, we aim to develop complex monitoring and reporting structure to protect and conserve this precious commodity.

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van der Grift B., Hockin A.E., de Jonge M.
B. van der Grift, A.E. Hockin, M. de Jonge

Abstract number–151 Unexpected impact of land use on hardness of groundwater abstracted for drinking water supply

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Hardness, as sum of the calcium and magnesium concentration, is natural constituent of groundwater. Hardness which is too high is, however, undesirable when groundwater is used for drinking water supply as it has adverse effects in domestic use. Hardness has different direct and indirect sources. Manure contains calcium and magnesium, and lime fertilizers are used to maintain pH conditions in the soil. In addition to these direct sources, hardness can be mobilized in groundwater as a result of a variety of geochemical buffering processes in the subsurface, especially when carbonates are present. For this reason the changes in groundwater hardness can be indicative of a variety of anthropogenic activities at ground level.

Many public supply well fields in the Netherland face increasing hardness of the abstracted groundwater. So far, however, little attention is paid to the relationship between agricultural practices in the capture zone of the well field and the hardness of the abstracted groundwater.

In the presentation we show the results of a trend analysis on a long timeseries of hardness measurements in groundwater abstracted at public supply well fields in the Netherlands. This trend analysis revealed a remarkable difference between agricultural-dominated and nature-dominated well fields. The land use, in combination with the carbonate content and redox conditions in the subsurface determines both the absolute level of hardness and the trend in concentrations. The absolute hardness level in agricultural-dominated well fields

was twice as high as nature-dominated well fields, while the trend of increasing concentrations was up to four times higher in the agricultural-dominated well fields.

These results showed a large impact of agricultural land use on the hardness of groundwater which is unlikely to be explained by the use of manure and fertilizers alone. We studied water quality patterns of the abstracted groundwater to distinguish hardness caused by dissolution of carbonates due to increased CO2 pressures in the subsurface and due to leaching of strong acids from the unsaturated zone. The hardness caused by CO2 pressure showed large differences between the individual well fields and was higher in the agricultural-dominated well fields compared with the nature-dominated well fields. These results indicate that land use has a significant effect on the CO2 pressure in the subsurface and thereby impacts the hardness of groundwater.

Solheim A.L., Tolvanen A., Skarbøvik E., Collentine D., Kronvang B., Blicher-Mathiesen G., Hashemi F., Juutinen A., Kløve B., Hellsten S., Pouta E.
A.L. Solheim, A. Tolvanen, E. Skarbøvik, D. Collentine, B. Kronvang, G. Blicher-Mathiesen, F. Hashemi, A. Juutinen, B. Kløve, S. Hellsten, E. Pouta

Abstract number–152 Quantifying stakeholder opinions on how bioeconomic development could change land-use, agriculture and forest production in the Nordic countries

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[4]*Sveriges lantbruksuniversitet (SLU)*
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Future increases in the role of bioeconomy production is expected to change land use in the Nordic countries, both in agriculture and forestry. To explore possible change and uncertainty related to them, a set of five scenarios or pathways were developed based on the system of global Shared Socio-economic Pathways (O'Neill et al. 2017). The five Nordic bioeconomic scenarios NBPs (sustainability first, business as usual, maximizing production, self-sufficiency and city first; Rakovic et al. 2019) were used to describe a set of variables characterising possible land-use changes under these scenarios. The variables and changes in these driven by the scenarios were evaluated by stakeholders and experts from four Nordic countries (Denmark, Finland, Norway and Sweden). The agricultural variables include cropping system diversity, tillage conservation effort, fertiliser use, animal husbandry, biogas production from manure and implementation of mitigation measures in the catchment and river channel to reduce nutrient losses. The forestry variables include dominant tree species, stand management, biomass removal at harvest, catchment management strategy,

fertiliser use and land cover. Stakeholder and expert perceptions and discussions have been compiled for each variable and for each of the five different NBPs. A compilation methodology allows quantifying and comparing the stakeholder and expert opinions by country for each variable and scenario. The compiled stakeholder and expert opinions for both agriculture and forestry show strong agreement for most of the variables for the two contrasting scenarios: sustainability first and maximizing production but differed more for the other three scenarios. The results from these stakeholder evaluations have been used as input to models for estimating the impact of those land-use attributes and scenarios on nutrient run-off from catchments across the Nordic countries (e.g. Kronvang et al. this issue). Furthermore, these results will facilitate policy level discussion concerning the consequences of the shift to greater bioeconomy production on nutrient pollution.

Fujita Y., Berndsen A., Ros G.H.
Y. Fujita, A. Berndsen, G.H. Ros

Abstract number–153 Assessing effects of agricultural soils and measures on water quality: National and regional scale case studies with farm specific monitoring tools

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Elevated nutrient loss from agricultural soils is one of the main causes for degraded water quality. Regional and national authorities often set targets to safeguard clean water and promote measures on agricultural fields to improve water quality. To efficiently achieve the targets, field-level information is crucial so that right measures can be applied on right places. On agricultural field, not only fertilization doses but also soil quality matters in regulating the amount of nutrients which is lost to water. However, due to the multidimensionality of soil quality and various processes with which soils can influence water quality, it is a challenge to properly evaluate the potential risks of soils to water quality and link that to recommendation for measures.
This study aims at exploring potentials risks and challenges of agricultural fields in regard to water quality on national and regional level. For that aim, we used the assessment tool BedrijfsBodemWaterPlan (BBWP). It evaluates risks of nutrient loss on field level and identify effective measures for that field. The risks for nitrate leaching, nitrogen runoff, and phosphor runoff, water storage, and nutrient efficiency are quantified and evaluated given region-specific optimum thresholds, based on field data derived from routine soil analyses from agricultural labs and public datasets describing generic geohydrological properties. Included measures ranges from those related to fertilization (source-related) to those intervening water and nutrient transport (route and receptor-based).
We first applied the BBWP to all agricultural fields in the Netherlands to reveal general trends and spatial patterns of potential risks for water quality. Some of the field attributes

(such as soil type and land use) were related to high risks for water quality. Furthermore, measures which have high potentials to lower the risks were identified for each field. To test the plausibility of the assessment tool, the calculated field-level risk indicators were compared with national monitoring data of water quality. Secondly, the BBWP was applied to a smaller region, for which detailed data of farms, soil properties, and fertilization records are available.
The case studies showed that the risk for nutrient loss to water is influenced by many aspects of soil and fields, such as buffering capacity, nutrient availability, soil physical characteristics, and topography. Nutrient concentrations in water from monitoring data were only weakly related to the calculated risk indicators, partly due to high uncertainty in input data. A holistic assessment tool such as the BBWP has a potential to bridge policy targets for water quality and local measures, and to facilitate communication with landowners to promote effective measures to improve water quality.

Daatselaar C.H.G., van Duijnen R.
C.H.G. Daatselaar, R. van Duijnen

Abstract number–154 Farm management, nutrient results and water quality with focus on maize

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Nitrogen being left in a soil under maize, in the Netherlands usually silage maize, is more vulnerable to leaching than when left in a soil under grass, certainly if the grassland is more or less permanent. Furthermore maize is mainly grown on sandy soils, especially the drier sandy soils. And these latter soils are also more prone to leaching of nitrate.
Silage maize has a relatively low protein content in the dry matter. That makes silage maize an interesting crop to obtain a more balanced feed ration for the dairy cattle, especially in summer to compensate for a surplus of protein from fresh grass. Maize is also better able to endure drought, often has a higher dry matter yield and has less losses between harvest and uptake by the cattle, compared to grass and grass products.
Within the research of the Dutch Minerals Policy Monitoring Program (LMM), Wageningen Economic Research registers a part of the data concerning the agricultural practice per crop. This concerns fertilisation and yields as well as some soil data. The Netherlands National Institute for Public Health and the Environment (RIVM) records some data of the 16 groundwater samples per farm by the Nitracheck method before these 16 samples are mixed up to one farm sample. Connecting these Nitracheck data per crop to the data per crop concerning the agricultural practice gives the opportunity to investigate the relations between farm management and water quality for an individual crop, so also for maize.
So this analysis offers the chance to find possibilities for dairy farmers to mitigate the nitrate

leaching under maize. Subsequently silage maize could continue to fulfil its correcting role in the feed ration that it has today. If mitigation of nitrate leaching under maize is not successful, then a further shrinkage of the maize acreage threatens. First results for maize show decreases in nitrogen soil surpluses and nitrate concentrations over years. Further dairy farms realise lower nitrate concentrations under maize than mixed farms whereas nitrogen soil surpluses do not differ between these two farm types. First in depth analysis shows limited possibilities for farmers to decrease nitrate concentrations under maize: soil type, groundwater table and weather have more influence.

Hansen B., Auken E., Duus Børgesen C., Vest Christiansen A., Dalgaard T., Rumph Frederiksen R., Jacobsen B.H., Jakobsen R., Kallesøe A., Kim H., Møller I., Madsen R.B., Blicher-Mathiesen G., Schaper S., Sandersen P.B.E., Voutchkova D.D., Wiborg I., Aamand J.
B. Hansen, E. Auken, C. Duus Børgesen, A. Vest Christiansen, T. Dalgaard, R. Rumph Frederiksen, B.H. Jacobsen, R. Jakobsen, A. Kallesøe, H. Kim, I. Møller, R.B. Madsen, G. Blicher-Mathiesen, S. Schaper, P.B.E. Sandersen, D.D. Voutchkova, I. Wiborg, J. Aamand

Abstract number–155 A new Danish concept for hectare-scale groundwater N-retention mapping – Presentation, implementation and validation of the concept

Birgitte Hansen[1], Esben Auken[1], Christen Duus Børgesen[2], Anders Vest Christiansen[2], Tommy Dalgaard[2], Rasmus Rumph Frederiksen[2], Brian Jacobsen[3], Rasmus Jakobsen[1], Anders Kallesøe[1], Hyojin Kim[1], Ingelise Møller[1], Rasmus Madsen[1], Gitte Blicher-Mathiesen[2], Stefan Schaper[2], Peter Sandersen[1], Denitza Voutchkova[1], Irene Wiborg[4], Jens Aamand[1]

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This abstract consists of a presentation of a new Danish concept for hectare-scale groundwater N-retention mapping called N-MAP. It encompasses how the concept could be implemented on a national scale by using a decision support prioritization tool which can assist in selecting, which catchments and areas are most suitable for implementing the N-MAP concept. N-retention maps from the Danish Agricultural Monitoring Areas (the LOOP areas) used for validation of the concept, will be presented.

Targeted N-regulation is an important cost-efficient measure in the Danish governmental agreement of a green transition of Danish agriculture from October 2021 where targeted N-regulation is aimed to reduce the annual load to coastal areas by up to 6,500 ton N out of a total N reduction demand of 13,100 ton N.

The idea of targeted N-regulation is to adjust the local N-regulation of a field to the natural denitrification potential of the subsurface, which depends on the water pathways and the N-

reduction rates and capacities of the subsurface media below the field (Hansen et al., 2021). The N-MAP concept and technologies have been developed through the Innovation Fund Denmark projects rOPEN and MapField (http://mapfield.dk/) to support targeted N-regulation at field level. It is based on the collection, interpretation, and modelling of large amounts of geophysical, geological, hydrological and geochemical data to calculate the transport and turnover of water and N in the subsurface (Kim et al., 2021; Madsen et al., 2021; Sandersen et al., 2021). In the concept, hectare-scale groundwater N-retention maps are produced with a horizontal scale down to 25 m × 25 m, and a vertical subsurface mapping depth of down to 100 m.

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Malik W., Oehler F., Sgro L., Durand P.
W. Malik, F. Oehler, L. Sgro, P. Durand

Abstract number–156 Modelling nitrogen mitigation scenarios to reduce coastal eutrophication

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Macroalgal blooms in coastal areas pose unique risks to the environment, citizens, stakeholders, and economy and is mainly due to riverine nitrate pollution. The Saint Brieuc

Bay is one of the most concerned algal bloom area in Brittany (Western France). It is fed by three catchments, the Gouessant (420 Km2), Gouet (256 Km2) and Anse d'Yffiniac (130 Km2) characterized by oceanic climate and mix farming with high livestock density. The main objective of this study is to assess the effectiveness of different Nitrogen (N) mitigation scenarios aiming to reduce N emissions using TNT2, a spatially distributed agro-hydrological model focusing on the spatial interactions within the landscape (Beaujouan et al, 2002; Oehler et al., 2009).
Once the TNT2 model was calibrated and validated, a set of scenarios was simulated from 2018 to 2035 for each considered catchment: a) agricultural management practices scenario (AMP) (management of mineral fertilization and organic manure, cover crops, crop rotations); b) increasing percentages of agricultural land conversion (ALC) into unmanaged grassland, from downhill to uphill and c) combined scenarios of AMP and ALC.
Results show that drastic changes in management practices could reduce the N load in the bay by 31% compared to the baseline scenario. Land conversion is much more efficient when located downhill (Casal et al. 2019), with more than 50% of the maximum efficiency with 10% converted area. 7% of downhill land conversion would produce the same N load reduction as the AMP scenario. These results vary strongly between catchments, mostly because of differing landuse composition and organization. Since reducing coastal eutrophication requires a drastic decrease of N loads, we advocate the combination of both scenarios to achieve good environmental status, although the efficiency of the combined scenario is less than the sum of AMP and ALC. The study illustrates the interest of the modelling tool in simulating complex scenarios and guiding mitigation policy.
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Boekhold A.E., Wuijts S.
A.E. Boekhold, *S. Wuijts*

Abstract number–157 From farm to drinking water: Improving governance conditions to better protect drinking water resources against agricultural pollution from nitrate and pesticides

Sandra Boekhold[1], Susanne Wuijts[1]

[1]*RIVM*

Over the last decades, nutrients and pesticides have proved to be a major source of pollution of drinking water resources in Europe. In response, the EU has developed an extensive regulatory and policy framework, including directives to protect drinking water resources (Drinking Water Directive), surface and groundwaters (Water Framework Directive and Groundwater Directive) and directives and policies to limit agricultural pollution (Nitrate Directive, Pesticides Directive and the Common Agricultural Policy CAP). However, despite all efforts, the challenge to attain water quality objectives is still ongoing. With the recent European Green Deal aiming to promote sustainable food production, the pursuit for increasing effectiveness of EU regulations in this field becomes even more apparent.
The H2020 FAIRWAY project has identified necessary changes in policy implementation approaches and governance conditions at local/regional, national and European level using case study material from 11 European countries, scientific literature and questionnaires filled out by experts and policymakers on national implementation. This triangulation of methods has resulted in the identification of gaps and overflows in between the European regulatory and policy framework and local practices.
In a policy brief aiming at the EU policy domain, five key messages were identified that need to be discussed and/or implemented. The key messages relate to coherence and consistency of EU regulations, sufficient capacity at the local level, feedback mechanisms, intersectoral learning and incorporation.
During the conference, the key messages and the underlying data analysis will be presented and discussed.

Rosendorf P., Trepel M., Ollesch G., Duras J.
P. Rosendorf, M. Trepel, G. Ollesch, J. Duras

Abstract number–161 Strategy for nutrient reduction in waters in the international Elbe River Basin district – Goals and opportunities

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[3]*River Basin Community Elbe (FGG Elbe), Germany*
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The International Commission for the Protection of the Elbe River (ICPER) set up an ad hoc expert group “Nutrients” on October 2014 in Berlin with the aim of ensuring a coordinated approach to reducing the nutrient inputs in waters in the international Elbe River Basin District. One output of the group’s activities is the Strategy for Nutrient Reduction in Waters in the International Elbe River Basin District which was approved in October 2018. The stimulus for drafting the Strategy was, and still is, the current situation in which the nutrient content of waters in the Elbe River Basin remains high.
The presentation of the Strategy contains 1) review and comparison the methods and evaluation of water status in terms of nutrients considering nitrogen and phosphorus in the

Czech Republic and Germany, 2) common assessment of current nutrient load in main rivers in the Elbe River Basin, 3) setting mutual basin-wide objectives for nutrients for the relevant types of waters in the Elbe River Basin and definition the nutrient reduction needs at crucial monitoring stations of the Elbe to ensure the protection of the North Sea, 4) evaluation the extent, importance and main areas of nutrient sources and input pathways in the Elbe River Basin, and characterize the dominant types of pollution sources that endanger the achievement of the objectives and 5) compilation a drafting of appropriate measures and further recommendations that should result in an efficient decrease in nutrient content of waters in the Elbe River Basin.

Spill C., Ditzel L., Gassmann M.
C. Spill, L. Ditzel, M. Gassmann

Abstract number–162 Water quality monitoring in headwaters with mixed land use: First insights into water quantity and quality

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Headwater catchments and small streams are commonly influenced by agricultural activities, with small villages and farms often located nearby. Infrastructure associated with such urban areas, like mixed sewer overflows and wastewater treatment plants (WWTPs) discharge directly into these streams, contributing a big share of the total water volume during low flow conditions as well as during event discharge. However, the influence of such facilities in rural areas is not often directly addressed in research.
We monitored the water quality and quantity of two neighboured headwater catchment: the Nesselbach catchment (3.23 km²) is mainly influenced by agriculture and forests, while within the Kelze catchment (2.64 km²) there is also a village located. The village is mainly drained by a mixed sewer system, which is connected to a small WWTP. The WWTP as well as two sewer overflows discharge directly into the Kelze stream. Our monitoring campaign includes discharge measurements, UV-Vis probes for Nitrate, conductivity probes and automatic samplers for Nitrite, Ammonium, ortho-Phosphate, total Phosphate and stable water Isotopes. The sewer overflows are monitored with low budget conductivity loggers. Additionally, we took some grab samples along the Kelze stream.
First measurements from the Kelze catchment show that during low flow the WWTP causes increased levels of Nitrite, Ammonium and ortho-Phosphate concentrations, while Nitrate gets diluted by the WWTP outflow. Nutrient concentrations undergo a yearly cycling, with higher concentration of Nitrate, and Nitrite and lower concentration of Ammonium, and ortho-Phosphate during summer month. Rising concentrations of Nitrate and Nitrite along the stream after the WWTP input indicates a nitrification process, which makes Ammonium an indirect input for Nitrate and Nitrite into the stream. The Nesselbach in comparison, shows significantly lower Ammonium and ortho-Phosphate concentrations while the Nitrate concentration is elevated.

During rainfall events, the sealed area of the comparatively small village within the Kelze catchment leads to fast runoff, which is directly transported to the WWTP where the water flows through very fast, leading to higher discharge peaks compared to the Nesselbach catchment, which has a generally higher specific baseflow discharge.
These first insights show, that understanding the interplay between agricultural and urban areas is crucial to understand the coupling of different hydrologic and biogeochemical processes, not only during high flow peaks, but also during baseflow condition, when WWTPs contribute a big share of the stream discharge.

Enge C., Nesheim I.
C. Enge, I. Nesheim

Abstract number–163 A clear mandate and political anchorage is needed for sustainable stakeholder engagement in water management

Caroline Enge[1], Ingrid Nesheim[1]

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The achievements of platforms for stakeholder involvement in water management are associated with their position within the larger governance system. Platforms that have been able to establish relationships and networks with other institutions such as water companies, agricultural and environmental authorities, farmers and civil society have a better foundation for long-term meaningful engagement for improved water quality. Issues raised in stakeholder platforms are often local, but it is important to engage authorities from higher governance levels, as premises for local action derive from national and regional level policies and regulations. Interaction is important to build trust and develop better understanding of different perspectives among stakeholders. An analysis of the establishment and development of nine multi-actor platforms included a comparison of their ability to establish relationships and networks with other institutions. The long-lasting platforms had all been able to create ties to other institutions and provide access to policy information and economic resources. The more recently established platforms had not yet developed such network links. For the platforms that had been able to develop some connections, uncertainty and lack of funding were identified as risks for long-term continuation of the collaboration.

Bieger K., Kronvang B., Hashemi F., Vodder Carstensen M.
K. Bieger, *B. Kronvang*, F. Hashemi, M. Vodder Carstensen

Abstract number–165 Impacts of the transition to a Nordic bioeconomy on streamflow and nitrogen loads in the Odense Fjord Catchment, Denmark

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A societal transformation towards a bioeconomy in the Nordic countries will have extensive implications for the environment and might conflict with the goal of the European WFD to achieve good ecological status of the majority of European water bodies. This study aims to explore the environmental impact of different bioeconomy scenarios combined with climate change on a Danish estuary, the Odense Fjord. We used the Nordic Bioeconomy Pathways (NBPs), which describe five possible future scenarios for a Nordic bioeconomy in 2050, to identify plausible changes in land use in response to the transition. The catchment of the Odense Fjord is intensively farmed, so the attributes selected for this study included changes in farming intensity (chemical fertilizer and manure amount), land cover change (agriculture vs. forest), and nutrient loss mitigation (buffer strips and wetlands). The NBP narratives were translated to quantitative values that can be modelled at catchment scale by local stakeholders. The semi-distributed Soil and Water Assessment Tool (SWAT) was used to simulate the land use and climate scenarios. First, extreme values of each attribute were simulated to ensure plausibility of the model response to the changes. Subsequently, the combined effects of all changes were quantified for each NBP with and without climate change. The differences in simulated streamflow between the five NBPs were very small, whereas the impact of the different pathways was on the simulated nitrogen loads was more pronounced, especially during the winter months. The model predicted an increase of both streamflow and nitrogen loads due to climate change. The next step will be to couple the SWAT-simulated nutrient loadings to the Odense Fjord with empirical models assessing the ecological response in the estuary.

Nesheim I., Enge C., Sundnes F., Graversgaard M., van den Brink C.
I. Nesheim, C. Enge, F. Sundnes, M. Graversgaard, C. van den Brink

Abstract number–171 The role of structural input factors for the functioning of stakeholder involvement in decision making: Economic resources, a specified mandate and a pressure for change

Ingrid Nesheim[1], Caroline Enge[1], Frode Sundnes[1], Morten Graversgaard[2], Cors van den Brink[3]

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It is acknowledged that to solve today's complex environmental challenges e.g. in the water-agriculture nexus, more efficient consultation and involvement of various stakeholder groups in society including actors from industry, farmers, civil society, politicians, etc. are needed. While scientific knowledge is important for knowledge-based policy development, combining science and local knowledge from stakeholders is necessary for developing more inclusive approaches and locally targeted solutions to be reflected in the WFD Programme of Measures. However, debates continue over what are best practices for ensuring meaningful

participatory approaches. The functioning of different multi-actor platforms vary with local contexts, and with structural input factors such as economic resources, specified mandate, and connections to the government system. Engagement processes can ensure that produced knowledge is scientifically valid and relevant, and can contribute to democratic rights if engagement is representative, transparent, and the processes legitimate.
This presentation draws on experiences from multi-actor engagement processes over the period of 2019 – 2021 as part of the EU project FAIRWAY, aiming at reducing the agricultural impact on sources for drinking water. A conceptual approach based on literature is used to discuss how long-term and successful multi-actor engagement to reduce agricultural impact is constituted of four elements: 1) meaningful engagement, 2) the social network and social interplay, 3) a defined pressure for change to work towards a common goal, and 4) an added value for the participants in the platform. The multi-actor engagement platforms in the project represent different histories and legacies of engagement; some are recent initiatives, and some were affiliated with previous government-initiated projects, while other initiatives are long-term engagement platforms. The results show that stakeholders concern for water quality improvements translating into pressures for change, trust among the actors, and financial means available for organizing the platform are important for enabling stakeholder engagement. The benefit of meaningful stakeholder engagement is tailored and effective policy implementation.

Merz C., Taie Semiromi M., Steidl J., Hayashi M.
C. Merz, *M. Taie Semiromi*, J. Steidl, M. Hayashi

Abstract number–172 Are kettle holes across agricultural landscapes a potential medium for redistribution of solutes towards their nearby river network?

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It is of paramount importance to characterize the possible transportation of solutes of kettle holes, scattered across agricultural landscape, towards their nearby river network. This is due to the fact that leaching and transporting of fertilizers from crop lands towards kettle holes and thereafter their redistribution to the river network may adversely deteriorate the water quality of downstream waters. As kettle holes are seemingly isolated with no surface water connection to their surrounding river network, transportation and redistribution of solutes should likely occur via a subsurface connection. Therefore, identification of subsurface hydrologic connection between kettle holes and their nearby river network should receive a great attention. In the present study, we have aimed to assess such a subsurface connection between kettle holes, distributed across the Quillow watershed in the northeast of Brandenburg, Germany, and the Quillow river. For the purpose of doing so, 8 geochemical parameters Ca, Mg, K, Na, Cl, Br, NO3, SO4, 4 in situ physicochemical parameters (temp.,

pH, EC, and redox), and two stable water isotopes (δ18 O and δ2 H) of 36 kettle holes and 7 sites of the Quillow river, distributing from the upstream to the downstream of the watershed, were sampled and analyzed on a monthly time scale during 17 months. The possible lag time between the stable water isotopes of the Quillow river and the kettle holes has been analyzed using cross-correlation functions. Moreover, a multivariate statistical analysis was conducted based on a promising algorithm, i.e. Gaussian finite mixture modelling to cluster the geochemical parameters of the Quillow river and kettle holes. In the light of finding of this study, if a strong relationship between the geochemical parameters of the Quillow river and the kettle holes is established, we may consider the healthiness of kettle holes as a viable indicator for development of an advanced warning system on healthiness of downstream waters.

Pugliese L., Heckrath G.J.
L. Pugliese, G.J. Heckrath

Abstract number–173 Phosphorus retention by compact filter systems treating agricultural drainage discharge

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Phosphorus (P) losses in subsurface runoff from artificially drained agricultural land can locally contribute to surface water eutrophication. These losses are a function of hydrological processes and long-term P accumulation in soils due fertilization practices, which is why agronomic mitigation options tend to be ineffective. However, as subsurface drainage systems concentrate water flow spatially, drainage filter technologies represent a potentially cost-effective end-of-pipe mitigation practice for P losses. The aim of this study was to test such a compact, full-scale P filter system under field conditions.
The system is located in the Fensholt catchment, Denmark, and has two main compartments: a sediment filter for retaining particulate P and a porous reactive filter consisting of iron-coated sand (ICS) for dissolved P. A pump feeds drainage water from an adjacent ditch into the filter system at flow rates of typically 1-1.5 l/s. Hydraulic loading of the system and drainage water composition were monitored continuously on a daily basis to evaluate system performance. Measurements of total P (TP), total dissolved P (TDP) and turbidity (NTU) were done. Suspended sediment was estimated in all water samples from turbidity measurements.
During the runoff season October 2020 to June 2021 the hydraulic load to the filter system was 18000 m3 corresponding to an average hydraulic retention time (HRT) for the sediment filter of 92 minutes. Total P concentrations in drainage water at the system inlet varied substantially between 0.03 and 2.47 mg P/l, while TDP varied between 0.04 and 0.84 mg P/l. On average TDP represented 60% of TP. The sediment filter retained 71% and 64% of the estimated sediment and PP load, respectively. However, occasionally TDP was remobilized from the sediment filter in late spring due to chemical and biological processes. The TDP retention in the ICS filter averaged 51% for the drainage season. On a monthly

basis TP retention in the filter system varied between -33% and 88% averaging 61% in 2020/21. This compares positively with other end-of-pipe solutions such as constructed wetlands which tend to have lower TP retention efficiencies under Danish conditions. However, the effective storage capacity of the compact P filter system has to be better understood including the mechanisms of potential P release processes and the required frequency of filter cleaning.

Maagaard A., Meldorf Deichmann M., Petersen R.J., Kronvang B., Ovesen N.B., Audet J., Hoffmann C.C., Zak D.H.
A. Maagaard, M. Meldorf Deichmann, R.J. Petersen, B. Kronvang, N.B. Ovesen, J. Audet, C.C. Hoffmann, *D.H. Zak*

Abstract number–174 Saturated buffer zones treating agricultural drainage water: A new mitigation measure in Denmark

Astrid Maagaard[1], Majken Meldorf Deichmann[2], Rasmus Jes Petersen[3], Brian Kronvang[1], Niels Ovesen[1], Joachim Audet[1], Carl Christian Hoffmann[3], Dominik Henrik Zak[1]

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Denmark reached a new political agricultural agreement in the fall of 2021, obligating Danish agriculture to reduce nitrogen (N) leaching to aquatic environments by 10.800 tons by 2027. Of the 10.800 tons N, 1500-tons must be reduced using collective methods, such as afforestation and natural and constructed wetlands.
New mitigation measures are currently being tested in Denmark as acknowledged mitigation measures like constructed wetlands are expensive to construct and only have an N-retention efficiency of around 25%. Saturated buffer zones (SBZs) are a recognized mitigation measure in the USA showing N removal rates of up to 84%. This promising result is obtained with a simple design of water saturating the riparian zone. The SBZ is now being evaluated under Danish conditions.
Two SBZ called ‘Gylling’ and ‘Ulvskov’ were constructed as pilot-scale testing facilities near Odder, Denmark funded by “Promilleafgiftsfonden” as part of the project “Videreudvikling og optimering af målrettede dræn- og lavbundsvirkemidler”. Monitoring began in September 2019 and includes investigations of hydrology, vegetation, soil, and water chemistry. Water samples were collected using automatic ISCO samplers and in piezometers installed in the SBZ. The phosphorus (P) retention and the N removal was evaluated using a mass balance approach. The investigation of the SBZ ‘Gylling’ ended in December 2020 due to low infiltration capacity of the soil matrix. Presumably due to a combination of a high groundwater table and a strongly degraded peat soil. The SBZ ‘Ulvskov’ showed greater promise with a water infiltration up to 8.6 L/s, before the adjoining bypass pipe was needed. The infiltration capacity, however, did decrease over time with bypass flow starting at 1 L/s, which might be explained by fine particles from the upland clay soil settling in the distribution pipe. Inlet flow to the SBZ increased to 2.1 L/s with no bypass flow, after rinsing the

distribution pipe in December 2021. The SBZ 'Ulvskov' showed an overall N removal and P retention of 87% and 76%, respectively. Additionally, biomass analysis from 'Ulvskov´ shows that the plant uptake could explain 30% of the N removal and all of the P removal. This underlines SBZs as promising mitigation measure for agricultural drainage water. In conclusions, SBZ has great potential to be implemented as a mitigation measure. The Gylling case, however, shows that SBZ are not suitable at all locations. Consequently, more data are necessary before SBZ can be an approved mitigation measure in Denmark.

Scott A., Cassidy R., Arnscheidt J., Jordan P.
A. Scott, R. Cassidy, J. Arnscheidt, P. Jordan

Abstract number–175 Quantifying sediment and phosphorus erosion at riverbank cattle access points

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Unrestricted livestock access to watercourses can be a water quality pressure. Direct defecation in rivers, and excessive fine sediment and nutrient inputs from eroded or poached bank faces can have negative ecological and human health impacts. Bank trampling and associated soil compaction have also been found to exacerbate diffuse runoff pathways for pollutants from adjacent grassland. Exclusion measures such as riverbank fencing are common features of agri-environment schemes (AES). However, there are conflicting views within the literature regarding the significance of cattle access to declining water quality and a lack of evidence on the cost-benefit of exclusion measures.
This work aims to quantify the erosion consequences of cattle access points in unfenced river sections, to provide an evidence base for future AES in Northern Ireland. Seven active cattle access points in two river catchments were identified. Both catchments are characterised by intensive livestock enterprises, and cattle had unrestricted access to the sites for the duration of the study. To estimate annual erosion, change at the river-bank scale was measured using repeated terrestrial laser scanning surveys at the beginning and end of the grazing season (May and October 2021) and following the subsequent winter period of high river flows. To compliment this, a drone photogrammetry survey of both active and recovering cattle access points was completed to estimate the total volume of eroded bank at each site. Adjacent deep soil cores were used to quantify the proportion of fine sediment and total phosphorus (TP) available for erosion. Bank face bulk density provided an estimate of mass sediment and TP export.
Results will be discussed in the context of AES and riparian protection measures in grazed grasslands.

Curk M., Glavan M., Pintar M.
M. Curk, M. Glavan, M. Pintar

Abstract number–177 Balancing environmental and economic impacts of groundwater protection measures for sustainable development of agriculture in nitrate vulnerable zones

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Despite the decades of ongoing scientific endeavors groundwater in many parts of Europe is still in a bad state according to Water Framework Directive. Past research has shown that generalized one-size-fits-all types of measures are not efficient at improving the state of groundwater in certain vulnerable areas. In order to mitigate nitrate leaching, it is important to take a focused approach with an emphasis on local environmental factors. There are several such vulnerable areas in Slovenia that still need further work in order to meet the environmental goals. Current measures seem inefficient at improving the state of groundwater beyond a certain point, and applying stricter ones could be harmful to the economic state of agricultural production. In this research, we focused on two such vulnerable areas in Slovenia. With the use of the SWAT model nitrate leaching for the main soil types in both areas was evaluated. The current scenario and several alternatives including climate change impacts were simulated with the aim of identifying the most promising environmentally effective measures. Simultaneously, the same measures were also evaluated for their economic impacts on agricultural production. Combining and optimizing both the environmental and economic impact of the measures we were able to select the measures that at the same time reduce nitrate leaching to groundwater and improve the economic state of the agricultural sector.

Izydorczyk K., Frątczak W., Szymańska M., Biernacki M.
K. Izydorczyk, W. Frątczak, M. Szymańska, M. Biernacki

Abstract number–178 Raising farmers' environmental awareness for wider use of NBS measures (nature-based solutions) in agricultural areas

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The use of nature-based solutions (NBS) such as buffer strips, mid-field afforestation, restoration of wetlands or construction of artificial wetlands can be effective measures to reduce agricultural water pollution. However, their widespread use faces barriers due to

farmers' lack of awareness of their multifunctionality. Understanding the impact of NBS measures on increasing water retention in the landscape, influence on water self-purification processes and increasing biodiversity will be crucial for the acceptance and cooperation of farmers in the implementation of the measures.
Raising environmental awareness of farmers on the use of NBS measures as a complement to rational fertilizer management in order to reduce agricultural pressure on aquatic ecosystems is one of the objectives of the LIFE Pilica Basin CTRL integrated project. Specialist training will be held for agricultural advisors and farmers, as well as education meetings addressed to rural inhabitants in selected areas with the highest emissions of nutrient pollution in the Pilica river basin (Central Poland). Awareness raising activities on water protection and its connection with farming methods will be targeted especially at pupils of agricultural schools, who will become owners of farms in the future. In this age group we can expect the greatest potential in terms of sheer readiness for change, risk taking, openness to modern technologies and the ability to use them.
The project has also planned a demonstration implementation of measures for reducing agricultural pressure within individual farms, which will become Demonstration Farms of the Integrated Project life Pilica. Experience from the application of good agricultural practices with associated with application of NBS measures at farm level will be passed on directly by the owners to the participants of the study classes conducted in the demonstration farms during specialist training courses for agricultural advisors and farmers. An additional advantage of the demo farms focused on a given type of production is the possibility of efficient training of sectoral groups of farmers in order to effectively counteract environmental pollution and human health hazards.

This work is an outcome of the LIFE Pilica Basin CTRL integrated project: Implementation of River Basin Management Plan in the Vistula basin on the example of Pilica river catchment (LIFE19 IPE/PL/000005), which has been supported by the LIFE+ Environment Policy and Governance Programme, and the Polish National Fund for Environmental Protection and Water Management.

Sapiano M., Schembri M., Dahan O., Mamo J.A., Debattista H.
M. Sapiano, M. Schembri, O. Dahan, J.A. Mamo, H. Debattista

Abstract number–179 Monitoring the fate of nitrate contamination in the vadose zone in Malta’s Mean Sea Level Aquifer system

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The Malta Mean Sea Level Aquifer (MSLA) system is by far the most important resource of freshwater in the Maltese islands. The MSLA however fails its good status objectives under the EU Water Framework Directive (WFD), with nitrate contamination being the main status failing parameter. Studies on the sources of nitrate in this groundwater system indicate soil

nitrogen coming from over-fertilization practices in agriculture as the most relevant source of contamination.

In order to address contamination by nitrates, Malta is implementing its Nitrate Action Programme which includes measures intended to reduce over fertilization in agricultural practices. However, current groundwater monitoring is unable to reliably gauge the impact of these measures, mainly due to the long-response time of deep groundwater systems such as the MSLA. Assessing the impact of measures therefore requires a pre-emptive monitoring framework, focusing on the Vadose Zone instead of the Saturated Zone. An increased understanding of the fate of contaminants in the Vadose Zone will enable the assessment of the effective impact of measures, and enable the development of corrective actions in case the expected mitigation impact is not being achieved.

A Vadose Zone Monitoring Network has been developed in the Malta MSLA made up of 16 representative stations spread across the aquifer system covering different soil typologies and depths, different geologies (coralline and globigerina limestones) and also different agricultural activities (irrigated, rain-fed, greenhouses) and crop-types. The network is based on the Vadose Zone Monitoring System (VMS) developed by Sensoil Ltd which integrates a series of flexible time-domain reflectometry (FTDR) probes for continuous tracking of water content profiles in the rock-matrix and vadose zone sampling ports (VSP) for frequent sampling of the deep vadose pore water at multiple depths. Direct sampling of percolating water enables the determination of nitrate content in percolating water at different depths in the Vadose Zone. Furthermore, the monitoring framework includes a dedicated data management system to facilitate the assessment of collected data.

The development of the monitoring network was based on a strong engagement with farmers, who are providing crucial information such as irrigation scheduling and fertilizer application. There is also high interest from the farmers in the results of the project, since a better understanding of nitrate flows will enable them to better manage fertilizer applications and limit operational costs.

From a policy perspective, the results from the monitoring network enable a better understanding of the quality of recharging water, and hence through the development of mixing models the estimation of the time required for the achievement of the WFD good qualitative status objectives. In so doing, the monitoring network will provide key information to support the development of RBMPs.

Heidecke C., Klages S., Buis E., Elings L., Eory V., D'Haene K., Higgins S., Hofman G., Luostarinen S., Nesheim I., Provolo G., Surdyk N., Osterburg B.
C. Heidecke, S. Klages, E. Buis, L. Elings, V. Eory, K. D'Haene, S. Higgins, G. Hofman, S. Luostarinen, I. Nesheim, G. Provolo, N. Surdyk, B. Osterburg

Abstract number–180 Aspects of implementing Farm to Fork nitrogen targets with tools, measures and policy instruments across Europe

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The Farm to Fork (FtF) strategy by the European Commission proclaimed a reduction of fertilizer use by at least 20 % and a reduction of nutrient losses by at least 50 % by 2030. To fulfill this ambitious goal in the coming years a variety of measures and policy instruments will be necessary across member states to draw down nitrogen inputs and enhance nitrogen efficiency to support the transition to a more sustainable food system. Using results from an European wide expert survey we discuss the differences between current fertilization planning systems in Member States and challenges for implementing the FtF strategy with more unified fertilization planning tools, including nutrient management and monitoring. Results from 18 different countries across Europe show that the potential to meet FtF nitrogen targets is linked to current nitrogen surplus levels in Member States and partially also might come to the costs of yield losses, particularly if nutrient management practices (e.g., split fertilisation, injection, NIRS-technology) and monitoring routines (e.g., budgeting and soil analytics) will not be adapted. According to the experts, the three most promising measures/innovations to meet the FtF targets are precision farming techniques, followed by the substitution of mineral versus organic fertilizer, Nmin determination by soil analytics and innovative plant breeding to improve plant uptake of N. The most promising policy options were more support for farmers and advice services, followed by more mandatory limits on fertilizer inputs, more direct integration with direct CAP measures and more financial incentives.

Graversgaard M., Thorsøe M.H., Dalgaard T.
M. Graversgaard, M.H. Thorsøe, T. Dalgaard

Abstract number–181 Catchment officers in Denmark – how does this new concept in Danish water management fit into the existing governance set-up?

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The Water Framework Directive (WFD) seeks to achieve good ecological status for all water bodies in the EU (including rivers, lakes, transitional and coastal waters) before 2027. To achieve this ambitious goal, the reduction of nitrogen and phosphourous from agriculture with specific source- and effect-based measures is needed. Even though improvements in the ecological status of Danish waters is seen, there is still a need to further reduce the diffuse loads from agriculture. In Denmark, the third´River Basin Management Plan are currently in public consultation, the plans shows that to achieve good ecological status there is a need to reduce the nitrogen discharge to coastal areas by 13.000 tons N. The proposed ways of achieving the nitrogen reductions is by using both collective and targeted efforts and measures. Collective measures include four voluntary subsidy schemes; constructed wetlands, afforestation, nitrogen wetlands and set-aside of lowlaying areas.
In 2017, based on a government decision from 2015, a new national program with the introduction of 25 catchment officers were introduced to help landowners achive and implement collective measures. The catchment officers work on a regional and local basis and comes mainly from farmers organisations. They serve as intermediaries between landowners, municipalities and national authorities and have in their first years mainly had a role in helping farmers apply for funding to implement constructed wetlands. In this presentation, we present an evaluation of this new water management concept and describe how the catchment officers are percieved by the local authorities. Through interviews with municipalities it is shown that the role of catchment officers is percieved very differently. A key finding from our interviews are the lack of coordination in implementing nitrogen mitigaiton measures. We show that the most important barrier that the municipalities perceive, concerns how coordination of efforts is not present in the current water governance. The presentation will describe opportunities and barriers to improve cooperation and knowledge sharing between catchment officers and municipalities in the work of implementing collective efforts in rural areas. It is concluded that there are a number of ways in which the cooperation between catchment officers and municipalities can be improved, which, however, requires that the scheme are to be re- organized and changed in a number of areas.

Strand J.A., Schneider L.D., Hedman S., Feuerbach P., Feuerbach Wengel L., Klatt B.
J.A. Strand, L.D. Schneider, S. Hedman, P. Feuerbach, L. Feuerbach Wengel, B. Klatt

Abstract number–183 LIFE-Goodstream for Good Ecological Status in a holistic approach: Reduced nutrients and increased biodiversity in an agricultural stream using multifunctional wetlands and Integrated Buffer Zones

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In LIFE-Goodstream (2015 – 2022) we have constructed some 35 wetlands and Integrated buffer zones with the combined purposes of reducing nutrient transport to the stream, decrease downstream flood events and to increase biodiversity in and along the stream (Trönningeån). In addition, we have constructed approx. 30 amphibian ponds and 30 other, small creotopes (created biotopes) to increase biodiversity. Other measures include removing of migration barrier (to improve fish migration), widening of stream cross section (to reduce floods), replacing piped stream sections with new open channels and the deployment of approx. 550 nest boxes for birds, bats and solitary bees along the stream. Monitoring have been extensive and include several sampling campaigns for nutrient concentration, measuring of the water flow in the stream, automatic remote sensing data collection of water levels in several of the wetlands and the stream, and biodiversity surveys of various organism groups (e.g. adult dragonflies, pollinators, birds, amphibians, aquatic invertebrates, mammals).
The results show that a focused and holistic approach on a drainage area level, in close cooperation with the landowners, is a good approach to increase and improve the status of a water course. The stream Trönningeån has improved considerably according to almost all monitoring and survey data we have collected. Regarding nutrient concentrations (N and P) in the stream, our results indicate that the agricultural parts of the stream now reach Good Ecological Status, and that it is now only the urban areas (village and small industry area) in the downstream area that have higher nutrient concentrations. The biodiversity has increased to a high degree for all organism groups and the responses have been swift. Somewhat surprising findings is that a large number of mammal species have been documented in our surveys (wildlife cameras, track and sign surveys) including reproduction of Otter (lutra lutra). Other interesting findings is that constructed wetlands (CWs) are veritable “species islands” for dragonflies in the agricultural landscape and that CWs might be of rather large importance for pollinators (bumblebees, solitary bees) including a possible positive effect of high nutrient load leading to algae mats used for water access.
LIFE-Goodstream also show that good communication with landowners and a strong participatory action which facilitate co-creation processes are important and lead to an increased willingness to further carry out nature and environmental conservation measures on private land, and an active management of constructed measures.

Strand J.A., Feuerbach P., Feuerbach Wengel L., Hedman S., Schneider L.D.
J.A. Strand, *P. Feuerbach*, L. Feuerbach Wengel, S. Hedman, L.D. Schneider

Abstract number–184 Widening of stream cross sections of agricultural water courses as a tool to reduce floods and erosion in downstream areas

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Streams in the agricultural landscape are commonly straightened and excavated to increase arable land consolidation and to promote drainage capabilities. Land users are through memberships in drainage associations tasked with maintenance of the water coursers (e.g. dredging). The result is straight and deep ditches with steep slopes crossing the agricultural landscapes. Through activities in agriculture (crop production), the levels of adjacent land have been lowered the last 100-150 years, leading to a situation where the drainage efficiency of the streams and ditches are reduced and where re-occurring floods of arable land is a common situation. In addition, climate change scenarios predict that these events will increase in both frequency and amplitude.
In order to improve water transport and reduce floods in such agricultural streams, we have through the project LIFE-Goodstream tested a method where we increased the cross section of the stream Trönningeån by widening the top part of the stream bed. This was done for ca 1 km stream length, through intensive farmland, just downstream of a village, also experiencing flood problems. The increased cross section was done until the stream reached an area with grassland and wider flood plain, where floods do not affect nutrient transportation, crop production or infrastructure. In effect we moved the problem of flooding to an area where floods are no problem. After this initial test which seemed promising, we also did cross section increase in another agricultural stream, the stream Skintan, with similar problems of re-occurring floods. We measured the water flow (m3/s) before and in the test area to verify the increase in water transport.
It is difficult to test effects scientifically since there of course is a problem with replication but we have documented high flow situations, where the Swedish Meteorological and Hydrological Institute has issued warnings, and where the new stream part seemed to cope very well with the high flows without any floods of the nearby village or arable land. A survey (telephone interview) of all involved parts where done after the widening of the stream Skintan, which showed the importance of good communication between; project leader – landowners – authorities – drainage association – constructing companies. Since these kinds of project involves several persons and organisations and the measures that should be done are dependent on each other, a clear step-wise development of the processes is needed including readiness for e.g. time for permits, weather conditions, change of land ownership and accidents.

Müller-Karulis B., McCrackin M.L., Dessirier B., Gustafsson B.G., Humborg C., Savchuk O.P.
B. Müller-Karulis, M.L. McCrackin, B. Dessirier, B.G. Gustafsson, C. Humborg, O.P. Savchuk

Abstract number–186 Legacy nutrients in the Baltic Sea drainage basin: Large scale modelling of nutrient storage and transfer to the sea

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Net anthropogenic nitrogen and phosphorus inputs (NANI and NAPI, respectively) to the Baltic Sea drainage basin have increased roughly 30 times between the year 1900 and the 1980s, largely due to the application of mineral fertilizers. Since the 1980s, inputs have decreased by 36% for NANI and 49% for NAPI. Between 1900 and 2017, 245 402 ktons of nitrogen (N) and 31 475 ktons of phosphorus (P) have been brought into the Baltic Sea drainage basin. The transport of both nutrients to the Baltic Sea roughly followed the anthropogenic inputs and since the 1980s, waterborne loads have declined by 24% for N and 45% for P, largely due to improved sewage treatment and reduced fertilizer usage.

However, in total only 17% of the NANI applied to the drainage basin between 1900 and 2017 reached the sea as river loads, point sources, or atmospheric deposition. Of total NAPI inputs for the same period, only 5% reached the sea as river loads or coastal point sources. The remainder is, either partially removed by denitrification (N), or still stored in the soils and groundwater of the drainage basin.

We present a simple model for NANI and NAPI fate in the Baltic Sea drainage basin. NANI and NAPI can be flushed into rivers directly or enter a mobile storage pool, from which they are either transported into rivers, or transferred into a stable pool that does not contribute to waterborne losses. Our model reproduces long-term waterborne loads to the Baltic Sea and suggests that P has a longer residence time on land compared to N (21 vs. 8 years). Of total NANI inputs since 1900, 61% has been removed by denitrification or immobilized in a stable pool, 21% remain in mobile pools, and 17% reached the sea as river loads, point sources, or atmospheric deposition. Of total NAPI inputs for the same period, 73% and 21% have been stored in stable and mobile pools (respectively) and only 5% reached the sea as river loads or coastal point sources. Immobilization or immobilization/loss by denitrification dominates by far the fate of NAPI and NANI. After decades of accumulation, the system has shifted to a depletion phase, suggesting that absent further reductions in NANI and NAPI, future waterborne loads could continue to decrease over the next few decades, in particular for P.

Thodsen H.
H. Thodsen

Abstract number–188 Danish Year 1900 nitrogen load to the sea

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A comprehensive multi-disciplinary study on the nitrogen load from Denmark to the sea in year 1900 has been committed. The project included historical climate data collection and data treatment, estimated of nitrogen point sources from towns and industry, year 1900 land use, estimation of historical agricultural nitrogen leaching, hydrological modelling using historical climate data to model year 1900 runoff and soil percolation. Modelling of ground water nitrogen retention and retention in surface waters all at both year 1900 and present conditions.
The work included applying the National Nitrogen Model, which simulates retention in groundwater and six surface water environments with year 1900 forcing data (Højberg et al., 2015). The study shows that the arable land use was substantially larger than at present with 75% compared to about 60% at present, the total amount of livestock was about the same as at present (Christensen et al., 2021). The climate was colder and a bit dryer than at present (Vejen, 2021). The total nitrogen leaching was a little smaller than at present and the total percentage nitrogen retention was higher in year 1900. Point sources from urban areas were found to be substantial in year 1900 but lower than at present (Brudler et al., 2020). The total load from land to sea for year 1900 were found to be about 60% of the present day load (not including direct point sources to the sea in any of the periods). The geographical variation in the development of nitrogen loads show some regional differences, with the largest increases the load in the western parts of the country. Another conclusion is that it is important that this kind of studies included specialists from different fields with a variety of expertise, in climatology, point source assessments, hydrology and especially agriculture and nitrogen leaching is essential, possibly with the addition of historians.

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Vermaat J.E., Skarbovik E., Kronvang B., Juutinen A., Helsten S., Kyllmar K.
J.E. Vermaat, E. Skarbovik, B. Kronvang, A. Juutinen, S. Helsten, K. Kyllmar

Abstract number–189 Projecting the impacts of the bioeconomy on Nordic land use and freshwater quality and quantity – an overview

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This presentation wraps up the findings from a five-year multi-partner project that assessed the possibly adverse effects of a developing Nordic bioeconomy on water resources. We used a catchment perspective and have combined several approaches: long-term data set mining from well-monitored catchments (agricultural, with forestry, and near pristine) across Fennoscandia, catchment biogeochemical modelling and ecosystem services assessment for integration. Common scenario projections were downscaled from the benchmark Shared Socio-economic Pathways and further articulated in dialogue with national stakeholder representatives leading to our five Nordic Bioeconomy Pathways (NBPs) describing plausible but different development trajectories towards 2050.These, together with climate change scenarios, were then used for catchment modelling and ecosystem service assessment. The outcomes have been presented to stakeholders in a final dialogue. Some selected findings are: Strongly contrasting scenarios (one maximizing resource circularity versus one maximizing short-term profit) can lead to very similar monetary estimates of total societal benefits, though for very different underlying reasons – a pattern similar across the studied Nordic catchments. Also, the estimated monetary value generated by recreation generally exceeds that of agriculture or forestry. Riparian buffer strips and similar nature-based solutions can help mitigate negative impacts on water quality due to increased biomass extraction, but only when carefully planned given the local hydrological regime. Also, the ecological quality of small to medium sized rivers in agricultural landscapes benefitted greatly from an increase in riparian forest cover from 10 % to 60 %.

Capell R., Bartosova A.
R. Capell, A. Bartosova

Abstract number–190 Effectiveness of upstream remediation measures on macro-nutrient loads to the Baltic Sea

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The Baltic Sea is an enclosed sea which suffers from riverine nutrient load pollution. Here, we use an integrated hydrological and nutrient transfer model (E-HYPE) for the Baltic Sea Drainage Basin (BSDB) to quantify sources of current riverine net nitrogen and phosphorus

loads to the Baltic Sea. We then model and analyse different scenarios of remediation measure implementation within the BSDB for their effect on nutrient load reductions at sea outlets. Remediation measures include ecological buffer strips along streams, fertiliser application reductions, stormwater ponds, and rural sewage release reductions. Our results indicate that significant load reductions at sea outlets are only achieved with substantial reductions in anthropogenic emissions over large areas. Measures targeting local improvements, possibly across multiple ecosystem functions, do not automatically contribute to downstream reduction goals. This highlights the need to explicitly consider large scale impacts when designing programmes of measures. We also show the effect of within-catchment retention, chiefly through lake systems, which can mask the effect of upstream measures at sea outlets. Lastly, we use a limited ensemble of climate change projections to assess the impact of projected changes on riverine nutrient loads to the Baltic Sea and their impact on modelled efficiency of remediation measures. Here, our results indicate contrasting impacts for nitrogen and phosphorus, with phosphorus loads projected to increase due to increased (surface) runoff in the region, while nitrogen decreases with decreasing atmospheric deposition projections.

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De Neve S., De Waele J., Van Camp M., Walraevens K.
S. De Neve, J. De Waele, M. Van Camp, K. Walraevens

Abstract number–191 Long term (50 years) simulations of average root zone nitrate concentrations partially explain slowly improving water quality in northern Belgium

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Despite 30 years of action to reduce nitrate concentrations in surface and groundwater in the North of Belgium, excessive NO3 concentrations are still found in about 25% of the measuring points for surface water in the area. One of the reasons for slow improvement of the water quality may be the contribution to nitrate input in surface water by nitrate rich "old" groundwater, but it is extremely challenging (often thought impossible) to quantify these inputs. Using the unique wealth of data (crop rotations, soil properties, nutrient inputs,

geology, …) collected and available in the region, we wanted to calculate historical evolution of NO3 inputs leaching from agricultural land to groundwater, spanning a period of 50 years (1968-2017) with unprecedented accuracy. These available data are highly accurate and field specific in the last decade, but are gradually less specific and need more approximations in the further past. The yearly average nitrate concentrations and nitrate loads at the bottom of the root zone (assumed to be -90 cm) were calculated for 10 catchments with sizes ranging between 100 and 1000 ha, using a mechanistic simulation model (EU-Rotate_N, run on 50*50m grid size) that has been widely validated already in the study area. Despite considerable deviations on yearly basis, field scale validations (possible for the most recent 10 years) revealed similar trends between measured and simulated NO3 concentrations in the soil to 90 cm depth, demonstrating that simulations were reliable. Simulations of the average NO3 concentrations in the 1968-2017 period showed a strongly increasing trend up to a maximum in the beginning of the 1990's, followed by a gradual decrease. Overall the yearly average concentrations were surprisingly high, even in 2017. Unexpectedly, simulations of possible mitigation measures showed that implementation of catch crops will lead to increased losses of NO3 in the long run, the reason being that catch crops increase the long term mineralization potential of soils. Catch crops thus need to be combined with overall reduced N fertilizer application to have a positive effect on water quality. Overall, surface waters that are fed with old groundwater (20-30 years) may take a long time still to achieve good quality even if best fertilization management practices are implemented.

Middleton B., Smith P.
B. Middleton, P. Smith

Abstract number–192 Linking evidence and delivery: evaluating and improving delivery of water quality measures at the farm level

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Catchment Sensitive Farming is a long-term programme delivering advice to farmers in England. Since 2006 the programme has delivered field work involving the engagement of over 20,000 farmers integrated with a comprehensive evidence programme that evaluates the direct impact of advice and the associated environmental outcomes. CSF is being expanded to cover the whole of England with changes to the scope and scale of the evidence programme.

This presentation outlines the overall CSF delivery model and demonstrates the importance of evidence and evaluation to help optimise the effectiveness of adviser work with farmers and to assess the range of CSF benefits and environmental outcomes. It will show how evaluation has driven the development of the farm advice offer from a modest test project to a nationwide programme. It will outline the consequential benefits for water quality – short

and long term. The evaluation has shown why CSF farm advice works and the essential criteria for success that are transferable to other mechanisms aimed at addressing agriculture's environmental impacts, including farm advice. It shows the importance of action by farmers complementing a wider range of measures to achieve shared goals for the water environment.

De Neve S., D'Haene K., De Waele J., Hofman G.
S. De Neve, K. D'Haene, J. De Waele, G. Hofman

Abstract number–193 Spatial distribution of the relationship between nitrate residues in soil and surface water quality revealed through attenuation factors

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Thanks to the intense efforts over the past decades to reduce nutrient losses, the annual average nitrate (NO3-) concentrations in the European surface waters have decreased between 1990 and 2010, but the reduction has levelled off since then. Nitrogen (N) mitigation measures adapted to the local conditions are needed to further reduce the N pressure from agriculture on surface water quality.
The NO3--N residue measured before the onset of winter has been used as a simple indicator of the N pressure from agriculture. However, the vulnerability of a stream to NO3- inputs depends on dilution and reduction of NO3- during its transport towards the surface water, which can be expressed by the attenuation factor for surface water (AFsw), i.e. the ratio of the average NO3- concentration at the bottom of the rooting zone and the average NO3- concentration in the surface water. In this study, we combined NO3--N measurements in the soil in autumn, NO3- concentrations measured in the surface water during the winter period and a relatively simple soil-crop model to calculate AFsw at subcatchment level, in order to estimate the effect of mitigation measures without collecting detailed information on the subsoil and groundwater processes. Simulations demonstrated that in Flanders (the northern part of Belgium) the further optimisation of the N fertilisation rate is the most effective measure to reduce surface water NO3- concentrations. Maximising the acreage of catch crops had a limited additional effect on the NO3- concentrations in surface water given that this is already widely practiced at present. Although the removal of N rich crop residues is highly effective at field level, it contributed little to the reduction of NO3- concentrations in the surface water because of the small acreage of these crops. The implemented scenarios show that in subcatchments with low AFSw, targeted and subcatchment-specific combinations of measures, but including the trade-off with the potential economic and other negative effects, may not be sufficient to obtain acceptable NO3- concentrations in the surface water at subcatchment level. In regions with low AFsw, end–of-pipe technologies

might be more cost-effective and even imperative to avoid the risk of eutrophication and a low surface water quality.

Hiscock K.M., Garrard N.L., Cooper R.J., Marca A.D., Wexler S.K.
K.M. Hiscock, N.L. Garrard, R.J. Cooper, A.D. Marca, S.K. Wexler

Abstract number–194 A stable isotope and hydrochemical approach to investigating denitrification in an agriculturally-impacted arable catchment in eastern England

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The rise in global population brings an increased pressure on food production. To meet this challenge, the development of synthetic fertilisers has significantly improved global food security by matching the amount of nitrogen fixed naturally. Whilst improving crop production, the pool of reactive nitrogen has effectively doubled, leading to detrimental effects on human health and ecological function, particularly eutrophication of freshwater ecosystems from agricultural runoff. As a naturally attenuating process, bacterially-mediated denitrification consumes nitrate within the environment. Therefore, denitrification is an important process to understand in terms of process and how it contributes to nitrate reduction under different field conditions and cultivation practices.
In this study, part of the Wensum Demonstration Test Catchment Project, the denitrifier method was used to examine denitrification within an arable catchment in Norfolk in eastern England. The stable isotopes of nitrate (15NNO3 and 18ONO3) were measured alongside hydrochemical characteristics of field drains (representing the soil zone), stream water, benthic sediment pore water and hyporheic zone water (located directly beneath and to the sides of the stream bed). The hyporheic zone was sampled from a series of nested piezometers, installed to 0.5 m, 1.0 m and 1.5 m beneath the stream bed at five locations along a 1.6 km stream reach. A mass balance approach was then used to assess the magnitude of the observed denitrification of inorganic ammonium nitrate fertiliser applied to the study catchment.
There was strong evidence for denitrification within the soil zone, demonstrated by dual fractionation of nitrate isotopes (15NNO3 and 18ONO3) and negative correlation between dissolved nitrate concentration and δ15NNO3 and δ18ONO3 values. Soil type appeared to influence denitrification with a positive correlation between percentage of clay and nitrate and δ15NNO3 and δ18ONO3 values. Tillage regime was also suggested to be potentially significant as a result of potential differences in soil moisture and temperature between reduced till and direct drill methods. In-stream denitrification was also detected, though there was no associated reduction in dissolved nitrate concentration. In the hyporheic zone, no isotopic evidence for denitrification was found, despite low dissolved nitrate concentrations.
The results of this study demonstrated that the soil zone has great potential for denitrification

and so land managers should be encouraged to focus on cultivation practices, such as direct tillage, that improve soil conditions and enhance soil nitrogen cycling potential. From an ecological perspective, enhancing soil denitrification reduces the risk of eutrophication of surface water bodies.

Dessirier B., Müller-Karulis B., McCrackin M.L., Humborg C., Andersen H.E., Blicher-Mathiesen G., Gustafsson B.G.
B. Dessirier, B. Müller-Karulis, M.L. McCrackin, C. Humborg, H.E. Andersen, G. Blicher-Mathiesen, B.G. Gustafsson

Abstract number–195 A century of Nitrogen dynamics in agricultural watersheds of Denmark and Sweden

Benoit Dessirier[1], Bärbel Müller-Karulis[1], Michelle L McCrackin[1], Christoph Humborg[1], Hans Estrup Andersen[2], Gitte Blicher-Mathiesen[2], Bo_ Gustafsson[1]

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The Nitrogen cycle has undergone tremendous changes in agricultural watersheds of Scandinavia in the past 100 years, often with direct consequences for water quality in lakes, rivers and the Baltic Sea. The integrated crop and livestock ley farming systems, introduced in the region in the mid 1800s, were nearly closed Nitrogen cycles and relied on clover and other leguminous crops to replace the exports of Nitrogen via plant and animal products, and the losses via erosion, leaching or denitrification. Manure recycling was key to maintain a sustainable soil Nitrogen content and soil fertility in general in that context. Sustained increases in population and food demand led to an expansion and then high plateau of agricultural areas between 1900 and 1940 but these agricultural systems endured on principle and kept incrementally improving until the second world war. At this point, the use of industrial N-fertilizers took off and allowed the progressive establishment of new agricultural systems geared toward export markets, with lesser levels of Nitrogen recycling and the potential for Nitrogen buildup in soil, groundwaters and surface waterbodies. Quantifying the consequences of these changes in terms of water quality is not straightforward as the local hydrological system imparts considerable delays from the fields to the recipient water bodies and is subject to substantial climatic variability.
To better understand these dynamics, we compile land use, agricultural and hydrological time series in an array of watersheds in Denmark and Sweden (ranging from 193 to 2650 sq.km) where agriculture has been the dominant land use and the major contributor to riverine Nitrogen loads. These data are used to build and run a parsimonious model of the Nitrogen cycle in agricultural soils, groundwaters and export to rivers. By an inverse-modeling approach against riverine Nitrogen loads estimated from monitoring (starting in the 1970s), we attempt to jointly understand the mean effective response time for the different watersheds, as well as the magnitude of the Nitrogen stores built-up in agricultural soils and

in groundwater, the uncertainty on those estimates, and their expected impact on water quality in coming years.

Cvejić R., Mali N., Mulec J., Petrič M., Pintar M., Urbanc J., Prelovšek M., Curk M.
R. Cvejić, N. Mali, J. Mulec, M. Petrič, M. Pintar, J. Urbanc, M. Prelovšek, M. Curk

Abstract number–200 Advancing land use practices to ensure suitable groundwater quality for the aquatic salamander Proteus anguinus in the Dinaric karst (Bela krajina, SE Slovenia)

Rozalija Cvejić[1], Nina Mali[2], Janez Mulec[3], Metka Petrič[3], Marina Pintar[1], Janko Urbanc[2], Mitja Prelovšek[3], Miha Curk[1]

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Karst areas are usually sparsely populated due to lack of surface water, small segmented patches of arable land, and hilly rocky ground. The past poor living conditions and low population density with less intensive agricultural production resulted in little environmental pressure. As a result, the conservation status of generally oligotrophic underground habitat was favourable despite some species, like white aquatic salamander Proteus anguinus and Proteus anguinus parkelj, tolerating as much as 9.2 mg NO3-/L in underground water.

In the last half of the century, increased population density with an increased amount of wastewater and agricultural production stimulated by mineral fertilizers and new massively-produced fertilizer sources (like biogas slurry) intensified environmental pressure resulting in the elimination of local populations of underground species probably due to excessive nitrate concentration in underground waters (23 mg NO3-/L as an annual average). Advanced agricultural models are needed to meet the requirements of the Water Framework Directive. Ambitious Farm to Fork Strategy (EU Green Deal) aims to reduce the use and risk of chemical and more hazardous pesticides by 50 %, reduce fertilizer use by 20 % and reduce nutrient losses by 50 % without compromising soil fertility. But will this be enough in catchments where even higher groundwater protection standards are being sought (9.2 mg NO3-/L) to protect endangered species, considering Common Agricultural Policy - the leading European financial instrument for the advancement of farm practices to promote sustainable agricultural water management - is voluntary?

To decrease environmental pressure and threats 2-years-long research project was launched in the problematic region of the Bela krajina, SE Slovenia. The project is focused on the definition of mitigation measures that would effectively assure suitable habitat for living and reproduction of underground species in the study area. To define scientifically supported, relevant, and targeted mitigation measures, determination of rate and sources of pollution of underground water with special emphasis on nitrate is underway. Spatial determination of catchment area (and hydrochemical characteristics) of studied springs was

set up at the area. By continuous flow rate and nitrate concentration measurements at springs, as well as later evaluation of nitrogen emission primarily from agriculture and wastewater sources, quantitative nitrogen mass balance will be calculated to will show the share of individual activities in the catchment area to the total nitrogen load defined at karst springs. SWOT modelling will be applied to co-develop advanced agricultural measures and discussed at workshops and interviews with farmers, professional services (municipal public service, agricultural advisory services, nature protection services), local population (farmers, societies), governmental institutions, and the local community.

Harter T., Kourakos G., Henri C., Cao Z., Yang M.
T. Harter, G. Kourakos, C. Henri, Z. Cao, M. Yang

Abstract number–204 Quantifying long-term regional groundwater quality benefits from agricultural practices

Thomas Harter[1], Giorgos Kourakos[1], Chris Henri[1], Zhendan Cao[1], Michael Yang[1]

[1]*University of California Davis*

Agriculture is the most dominant contributor to groundwater nitrate found at often excessive levels. Hence, groundwater nitrate is increasingly sought to be regulated by regional, state, or country agencies. The design of regulatory and other policy programs that aim at improving agricultural practices is driven not only by feasibility and cost of practices, but also by an understanding whether and how much practices may improve groundwater quality. In some jurisdictions, groundwater quality metrics that define “good” or “drinkable” or “sustainable” groundwater quality set the bar for assessing the desirability/permissibility of agricultural practices. Models used in policy- and decision-making can account for the complexity of the agro-environmental system, but also provide a forecasting tool to assess proposed future scenarios. We have developed a nitrate forecasting tool for the 50,000 sq.km Central Valley aquifer system. The aquifer system serves about 10,000 community wells, over 20,000 agricultural irrigation wells, and over 100,000 domestic wells in a region that is predominantly dependent on groundwater for its drinking water. We utilize our recently developed Nonpoint Source Assessment Tool in this Central Valley application (CV-NPSAT). CV-NPSAT extracts a representative steady-state from existing transient subsurface flow models to provide relevant flow fields down to a 10 m scale resolution, then employs an efficient 3D-transport algorithm to hind- and forecast decade- to century scale nitrate dynamics in all wells across the aquifer system. We have validated CV-NPSAT against measured age distributions and against measured history of nitrate pollution in the Central Valley. By combining CV-NPSAT with historic and future scenario field-scale information on nitrate leaching from the root zone, long-term groundwater quality impacts and their spatio-temporal variability are obtained for assessment and evaluation at various spatial scales. Agricultural stakeholders and their regulatory counter-parts employ CV-NPSAT to assess agricultural practices for future outcomes and to constrain the industry toward a suite of practices anticipated to bring groundwater quality into long-term compliance.

Deakin J.
J. Deakin

Abstract number–205 Science-Policy-Action-Outcomes – Ireland's journey towards improving water quality

Jenny Deakin[1]

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Approximately 50% of monitored rivers and lakes, and 70% of monitored estuaries in Ireland require further action to achieve water quality objectives. Excess nutrient loss from agriculture is still the most widespread and difficult issue to resolve. In recent years the science, policy and action programmes have been significantly advanced. We are on a journey, and while there are some early encouraging indicators of success, there is still a lot of work to do.

Science. Policy-driven research programmes have provided a good understanding of how, when and where nutrients move through the landscape. This has been used to develop maps of critical source areas which drive catchment scale losses. Monitoring data and models have been used to differentiate the nutrient sources in catchments, and the scale of nutrient reductions needed to achieve environmental outcomes. Farm scale models have been used to quantify the effects of changing farm practices on nutrient losses. The next step is to link the farm scale and catchment models to determine the scale of practice change that will be needed in specific catchments to achieve the required water quality outcomes.

Policy. New multi-tiered governance structures are in place to deliver the Water Framework Directive objectives. Three key principles have been adopted: a catchment-based approach, implementing the right measure in the right place, and working collaboratively in targeted Areas for Action to address multiple pressures together. Actions that can achieve co-benefits for climate, biodiversity, air quality and flood management are encouraged.

Action. Local teams of catchment scientists and community water officers are working to identify and address issues in targeted Areas for Action. A team of state and industry funded farm sustainability advisors are advising farmers on measures to address the specific water quality problems identified. The next step is to develop integrated catchment management plans that will set local objectives and targets.

Outcomes. There has been a net improvement in water quality in the Areas for Action, but net deterioration elsewhere. Covid has delayed progress but farmers are engaged. Although it is challenging to align policy, regulation, schemes and CAP supports to target the required actions in the right places, joined up messaging and delivery is essential. Communicating the science in a user-centred way is an important implementation mechanism.

van Beelen P.
P. van Beelen

Abstract number–206 An R package for the quality control of groundwater and surface water measurements

Patrick van Beelen[1]

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At the RIVM we have developed a system for quality control of the input data. Basically, there are two methods to detect measurement errors. The first method uses chemical relationships between the measured parameters. The total nitrogen should correspond with the major measured nitrogen compounds. The same is true for phosphorus. The electrical charge equivalence of cations and anions must be present. The conductivity calculated from the ion composition should match the measured conductivity. An R script was developed to use the electrical charge equivalence and the conductivity in combination to identify measurement faults. Only measurement faults which give an elevated concentration can be detected with this script. When the fault causes elevated anion measurement the electrical charge equivalence will be negative and the calculated conductivity will be higher than the measured one. When the fault causes elevated cation concentrations the electrical charge equivalence will be positive and the calculated conductivity will also be higher than the measured one. This however requires an accurate bicarbonate measurement since the anion bicarbonate can be neutralized to carbon dioxide and escape from the sample. Our script will be compared with other scripts calculating conductivity such as the PHREEQCI script from USGS.
The second method to detect errors relies on previous samples taken from the same water. In that case the current measure is compared with previous ones. A statistical model is used to generate artificial data with a known detection limit and dilution error. In the absence of a substance a good detector will produce equal amounts of positive and negative signals which are zero on average. At concentrations above the detection limit the dilution error causes a relative error which can be described as a percentage of the measurement. A logarithmic transformation of these data gives an absolute error which is the same over the concentration range above the detection limit. This facilitates the comparison of a measurement with previous samples when these are above the detection limit. The detector signals below the detection limit must be transformed to an estimation of the concentration using proper statistical methods. Substituting these detector signals with a concentration of half of the detection limit is generally not a proper statistical method although it is widely practiced.

Hasler B., Filippelli R., Levin G., Nainggolan D.
B. Hasler, *R. Filippelli*, G. Levin, D. Nainggolan

Abstract number–207 Cost-effective implementation of the WFD in Denmark – a national scale modelling approach

Berit Hasler[1], Raphael Filippelli[1], Gregor Levin[1], Doan Nainggolan[1]

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In recent years, spatially differentiated regulation has been on the political agenda in Europe., having the potential to take into account differences in productivity and hydrology in agricultural catchments. Combining the diverse sets of information on agronomy, hydrology and economics for policy purposes require integrated modelling. We have developed an integrated model system TargetEconN for Denmark, and have applied this integrated catchment model system for cost-effectiveness assessment in 108 coastal catchments. Nitrogen reduction targets have been set by the Ministry of Environment to achieve the WFD objectives.
The model minimizes the costs of achieving nitrogen load reduction targets in each of the 108 catchments. The model has been set up for both Nitrogen and Phosphorus, providing the options for modelling trade-offs and synergies between the regulation of both nutrients. In this presentation we focus only on Nitrogen targets, but have also assessed the side effects on Phosphorus from Nitrogen target achievement in the coastal catchments.
The detailed modelling at catchment level, including data at field level, combine data layers on crop types (average on field level in a rotation of 5 years), fertilization levels, soil types, .retention, nitrogen leaching effects from measures as well as detailed modelling of the potential for implementing measures at field scale. The model also include information on the economic returns from the crop production at field level and costs of measure implementation. The modelling takes into account that a lot of effort already has been implemented in agriculture, and that the marginal costs of achieving the targets are now high at many locations. Integrating economics, agronomics and hydrology provides the possibility to assess targeted policies including the differences in environmental effects and economic costs among locations and farms, thus providing essential information to the targeting. The model applies is a social planner approach, not taking policy instruments and incentives for the implementation into account, but the results can provide valuable insight for e.g. design of result based schemes and the importance of differentiating these between locations and actors.
The results indicate that permanent set aside and forestation are the most cost-effective measures at a large share of the catchments, and also that requirements for targeted catch-crops, as set out in the governmental plans, will be less cost-effective and therefore not part of the optimal solution to the same degree as in governmental plans.- The implementation of permanent set aside and forestation also provides significant, positive effects on climate mitigation as well as phosphorus losses from agricultural fields.

Hasler B., Filippelli R., Levin G., Andersen H.E.
B. Hasler, *R. Filippelli*, G. Levin, H.E. Andersen

Abstract number–208 Cost-effective phosphorus load reductions to lakes – an integrated modelling approach

Berit Hasler[1], Raphael Filippelli[1], Gregor Levin[1], Hans Estrup Andersen[2]

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Improving water quality has been on the political agenda in Europe, as well as in other parts of the world, for decades. Phosphorus loads from agricultural non-point sources (NPS) has been a continuous environmental problem and phosphorus loss reductions are required to achieve water quality targets in freshwater bodies.
To facilitate assessments and implementation of cost-effective and targeted measures to reduce phosphorus measures an integrated hydro-economic land use model has been adapted for this purpose, the TargetEconN_P model. The model has been developed for cost-effective Nitrogen abatement to coastal areas, but now adapted to include Phosphorus reductions to lakes in Denmark. The model covers the entire land area of Denmark, subdividing the land into lake- and coastal catchments. The model is a result of interdisciplinary cooperation between economists and hydrologists, building on field level land use data (crop composition in 5 year rotations for each field,) fertilisation, soil types and data on phosphorus loss risk mapping for four different loss paths: erosion from fields, matrix losses, macropore losses and erosion from waterway shores. The effects of phosphorus measures implemented in the model are estimated for specific locations according to the loss risk, and therefore the approach build on highly spatially specified data. In addition to this detailed field level modelling approach the model include links between lakes in chains, to mimic the loads of phosphorus between lakes and the effects of a phosphorus measure upstream on the downstream lakes in that chain.
The results indicate that it is both difficult and costly to reach the phosphorus targets as required by the WFD, but also that there are large differences between lake catchments. The results also indicate some synergies between phosphorus and nitrogen loss reductions, but also trade-offs as the location of the measures differs to facilitate phosphorus loss reductions to lakes and nitrogen losses to coastal areas, respectively. Furthermore the results indicate that it is important to achieve more information about effective phosphorus measures to reduce phosphorus losses, as well as on the potential to implement these measures in the landscape. Such development still requires interdisciplinary cooperation between hydrologists, agronomists and economists to facilitate detailed model developments taking the spatial differences of phosphorus losses into account, and link that to spatial data on the economic costs. There are also ample opportunities to link this to spatial assessments of the ecosystem services provided by the phosphorus loss measures in the lake catchments.

Acutis M., Minin V., Zaharov A., Perego A., Walkama E.
M. Acutis, V. Minin, A. Zaharov, A. Perego, E. Walkama

Abstract number–209 Is organic farming a solution to promote water quality and ecosystem services in the Russian part of the Baltic Sea catchment area?

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Organic farming systems are often regarded as more environmentally friendly than conventional farming systems. Organic agriculture frequently results in higher microbiological activity and soil organic matter, which in turn leads to enhanced water holding capability, lower runoff and concentration of nitrate in soil. In such a context, the risk of nitrate leaching loss from the soil to water bodies is reduced. However, environmental performance strictly depends on pedoclimatic conditions and management practices as, for example, leaving bare fallow and excessive manure application cause a risk for nitrate leaching loss in subsequence years. To evaluate preliminarily the performance of organic systems in the current and future climate scenario in light texture soils of the Baltic Sea region, the ARMOSA simulation model was used to evaluate the effect of a set of agronomic practices. The model was calibrated on the 14-year experiment at the Menkovo Experimental Station (Agrophysical Research Institute) in St. Petersburg (Russia). The cropping system was a 6-year rotation of barley, timothy with clover, rye, potato, and oats with vetch. Four treatments of organic and mineral fertilizations were applied to the cropping systems over time. Model showed a good capability to predict yield, soil mineral nitrogen and the evolution of organic carbon in soil (RRMSE between 10 and 20%, R2 >0.5). The calibrated model was used to evaluate different management practices under the current (1980-2010) and future (2040-2070) climate scenarios (annual average +3.5◦C, -54 mm). In the current climate, a medium rate of mineral fertilizer with crop residues incorporated to the soil resulted in lower leaching (8.2 kg of N ha-1 yr-1) than the organic systems (12.6 kg of N ha-1 yr-1), due to higher yield and the better synchronization of crop uptake with nitrogen availability. Nevertheless, organic systems allowed for greater increase in soil organic carbon over time. In the future climate, nitrate leaching increased by 30 % with respect to the current scenario and did not differ between treatments. However, when barley was replaced by an adapted variety to the future scenario (adequate thermal requirement), the organic cropping system showed improved yield and environmental performance, leading to about 15% less N leaching loss (13.5 kg of N ha-1 yr-1) compared to conventional system (16.2 kg of N ha-1 yr-1) and positive annual rate of carbon sequestration (+0.69%).
This modelling analysis showed that organic system can have good yield and environmental performances (i.e., provision of ecological services) when adequate management practices and the choice of a variety are adopted to avoid nitrate leaching loss from organic fertilization in this kind of light soils.

Sinclair M., Turner R.D.R., Neelamraju C., Orr D., Ferguson B., Warne M.S.J., Mann R.
M. Sinclair, R.D.R. Turner, *C. Neelamraju*, D. Orr, B. Ferguson, M.S.J. Warne, R. Mann

Abstract number–210 Near real time water quality monitoring based on co-design, fostering real-life adaptive management

Matt Sinclair[1], Ryan Turner[1,2,3], Catherine Neelamraju[1], David Orr[1], Ben Ferguson[1], Michael Warne[1,2], Reinier Mann[1]

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In 2015, the Australian and Queensland Governments released the Reef 2050 Long-Term Sustainability Plan that focuses on actions to address key threats and directly boost the health and resilience of the Great Barrier Reef. The plan identifies land-based runoff of nutrients, pesticides, and sediment from agricultural lands as major causes of poor water quality, the plan also highlighted in north-eastern Australia the Lower Herbert catchment and Lower Burdekin (Haughton) catchment as a priority for improvements in dissolved inorganic nitrogen runoff. Previously only one location was monitored in the Herbert catchment and two locations in the Haughton catchment. While this was sufficient for its scope at the time, it did not provide stakeholders with water quality data for their local areas.

This led the Water Quality and Investigations (WQI) team to expand their real-time monitoring network. With cheaper water quality sensors becoming available, WQI were able to install around 40 nitrate and sediment sensors throughout these two catchments. The data produced by this real time, fine-scale monitoring will help identify and raise community awareness of water quality issues, help local industry bodies and resource management groups increase their knowledge of how land use management practice may be affecting water quality. It will also support proactive land management adaptation and will strengthen Reef protection efforts through greater spatial and temporal data delivery to the Paddock to Reef modelling.

This presentation will give a complete background of this project, including the collaborative site selection process (co-design), site design and setup. It will also detail the important water quality features of each site and how they were affected by rainfall and first flush (early wet season) runoff events. Linkage to local landholders and industries that are using the real-time data will be discussed. Lastly, it will look at the catchment-level comparison between site types and how the project might develop.

Blombäck K., Mårtensson K., Lindsjö A., Persson K., Djodjic F., Collentine D., Johnsson H., Kyllmar K.
K. Blombäck, *K. Mårtensson*, A. Lindsjö, K. Persson, F. Djodjic, D. Collentine, H. Johnsson, K. Kyllmar

Abstract number–212 A new calculation system to evaluate the effect of leaching reducing measures for P from arable land in the local scale

Karin Blombäck[1], Kristina Mårtensson[1], Anders Lindsjö[1], Kristian Persson[1], Faruk Djodjic[2], Dennis Collentine[1], Holger Johnsson[1], Katarina Kyllmar[1]

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In order to make the efforts against eutrophication more efficient and systematic, measures need to be implemented where the need for improvement is most urgent and where measures have the greatest potential to have a good effect. A method for identifying these areas and calculating the effect and cost-effectiveness of a number of measures against nutrient losses from arable land was developed and tested in three small catchment areas in close collaboration with local advisory and water management coordinators. The areas were selected within the pilot project LEVA (Local commitment to water), organized by the Swedish Agency for Marine and Water Management.
Two different scenarios for measures were calculated, one maximum scenario where all possible measures were taken into account and one with targeted measures in the existing production system. The goal in the scenarios was to achieve good ecological status, which meant that major focus was to reduce the phosphorus load in the catchments.
For the scenarios, a new leaching coefficient calculation system was used. This leaching coefficient calculation system is an extension of the NLeCCS-model (Nutrient Leaching Coefficient Calculation System), which is used to calculate normalized leaching coefficients (mg/L and kg/ha) of nitrogen and phosphorus for combinations of different climate, crops, soil types and management practices from arable fields. In the new leaching coefficient system high resolution coefficients were calculated from the NLeCCS results to be used for areal aggregation of the N and P leaching losses in the catchments. For this project, leaching coefficients for phosphorus were aggregated in relation to the situation in each of the selected catchments to estimate the leaching load from the arable fields. For location of phosphorus retention ponds, i.e a measure outside the field, a system for assessing optimal location based on the relationship between hydraulic load and nutrient levels based on leaching coefficients was applied.
The results of the scenarios showed that the reduction in phosphorus losses reached about 30% if the measures were used to the maximum. The best effect was obtained in catchments with high clay content in arable soils. The targeted measures had almost as great effect as in the maximum scenarios. The costs per kg reduced P were lower in the scenario with targeted measures. The method developed and tested in this project shows how the potential for implementing a certain measure depends on both the area that is available and suitable for the measure, but also how the effect of the individual measure decreases when several measures are combined. We suggest that the leaching coefficient system could be used as a local advisory tool to evaluate the potential effect of various measures in local scale.

Blombäck K., Mårtensson K., Johnsson H., Lindsjö A., Persson K., Kyllmar K.
K. Blombäck, *K. Mårtensson*, H. Johnsson, A. Lindsjö, K. Persson, K. Kyllmar

Abstract number–213 Effects of bioeconomy scenarios on agricultural management practices and nutrient leaching losses using high resolution leaching coefficients

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The Nordic Bioeconomy Pathways (NBPs), is a set of regional sectoral storylines nested within the global Shared Socioeconomic Pathways (SSP) framework. The NBPs were developed to provide the BIOWATER research program with land management scenarios for projecting future developments to explore possible conflicts between land management changes and the Water Framework Directive (WFD).

Five NBPs describing different aspects of development in agricultural management systems where chosen. The aspects were diversity of cropping system, conservation effort in tillage system, implementation of mitigation measures (buffer zones) and implementation of in-field mitigation measures (cover crops). The effect of the NBPs with a future climate scenario was also included.

Each NBP was adopted to the NLeCCS (Nutrient Leaching Coefficient Calculation System). NLeCCs was applied to two nested catchments in the Örsundaån area in Central Sweden. Climate normalized leaching coefficients (mg/L and kg/ha) for different combinations of climate, crops, crop management practices, soil types, slope (only P) and soil P content in the area were then calculated. High resolution coefficients were further calculated from the NLeCCS results to be used for local areal aggregation of the N and P leaching losses in the catchments, both as a baseline and for the five scenarios (NBPs).

The scenarios showed that diversity in cropping system and conservation effort in tillage system caused the largest changes in leaching losses for both N and P. The diversity in cropping system could cause both increase and decrease in leaching, while the factors conservation effort in tillage system, implementation of mitigation measures (buffer zones) and implementation of in-field mitigation measures (cover crops) caused decrease in leaching. The climate scenario increased leaching losses for both N and P. Biowater is a Nordic Centre of Excellence (2017-2022) financed by NordForsk.

Manshanden M.T., Greijdanus A.F., de Koeijer T.J.
M.T. Manshanden, A.F. Greijdanus, T.J. de Koeijer

Abstract number–216 Goal based approach using maximum allowed level of nitrogen soil surplus on Dutch cropping farms

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The 7th action programme nitrate consists of a wide variety of measures ranging from application standards, regulations regarding the time and method of application, cropping restrictions, etc. to achieve the required water quality. This multitude of regulations and restrictions provides less incentive for entrepreneurs to look for the best possible measures given their own specific business situation. Therefore, they have indicated that they would like more possibilities for customisation in the 7th AP. This customisation can be realised by the change of the current rules based policy towards a goal-based approach. The 7th AP provides that customisation will be allowed if the entrepreneurs themselves demonstrate that they are achieving the required water quality. One indicator that could be used as a guideline is the nitrogen soil surplus. An advantage of steering on nitrogen soil surplus is that there is a direct link to management practices. This allows entrepreneurs to make economically optimal choices for their own specific farm circumstances, aimed at realising the required water quality.
The question is what the effect of the introduction of a maximum allowed level of the nitrogen soil surplus is on: the income, the operational management such as fertilisation and crop rotation; and on the realised nitrogen soil surplus. A quick scan explores these effects for three representative arable farms in the Netherlands. The farms differ in size, cropping plan and/or soil type. Two scenarios are distinguished: 1) the baseline scenario based on the current measures in the 7th AP Nitrate and 2) a scenario with the introduction of a maximum allowed nitrogen soil surplus as an alternative to the current measures of the 7th AP. For this scenario the level of the maximum nitrogen soil surplus is determined, using the leaching fractions for nitrogen, at that level where the groundwater quality meets the EU drinking water standard of a maximum of 50 mg nitrate per litre.

Karlović I., Marković T., Smith A.C., Kanduč T.
I. Karlović, T. Marković, A.C. Smith, T. Kanduč

Abstract number–217 Impact of land use on groundwater quality in the Varaždin alluvial aquifer

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The Varaždin aquifer is a vital source of water used by approximatelly 170,000 inhabitants of the Varaždin County in NW Croatia for public supply, agriculture, and industrial purposes. Agriculture is dominant activity in this region, with 68% of total land use attributed to agricultural land. High nitrate concentrations in groundwater observed during the last decades raised public concern regarding groundwater quality.
Within this work an interdisciplinary approach was used to investigate nitrate behavior in the critical zone, i.e. the upper layer of the Earth extending from vegetation to groundwater. Isotopic composition of groundwater (O-18 and H-2) revealed that the aquifer is recharged by surface waters and precipitation. A shift in the local meteoric water line indicates ongoing climate change during the last 10 years. A dual isotope approach in nitrate (O-18 and N-15) identified the main sources of nitrate in groundwater as: manure, wastewater, and soil organic nitrogen. The results of an isotope mixing model showed that manure is the dominant nitrate source in agricultural regions, wastewater in urban, and soil organic nitrogen in natural areas. Numerical groundwater flow and nitrate transport models confirmed that agriculture is the main controlling factor of nitrate contamination in the Varaždin aquifer.
Our findings suggest that this region is particularly vulnerable to climate change. Longer droughts could further affect the groundwater quantity and reduce water reserves that are necessary for the local population. Conversly, intense precipitation events could facilitate nitrate leaching from the soil and unsaturated aquifer zone, further deteriorating groundwater quality regarding nitrate contamination.

Duy Ta P., Tetzlaff B., Trepel M., Wendland F.
P. Duy Ta, B. Tetzlaff, M. Trepel, F. Wendland

Abstract number–218 Implementing a state-wide deficit analysis for inland surface waters according to the Water Framework Directive – An exemplary application on phosphorus pollution in Schleswig-Holstein (northern Germany)

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Deficit analysis—which principally deals with the question “how big are the gaps between current water status and good ecological status?”—has become an essential element of the river basin management plans prescribed by the European Water Framework Directive (WFD). In a research project on behalf of the Ministry of Energy, Agriculture, the

Environment, Nature and Digitalization Schleswig-Holstein (MELUND), a deficit analysis based on distributed results from the water balance and phosphorus emission model system GROWA-MEPhos at high spatial resolution was performed. The aim was, inter alia, to identify absolute and relative required reduction in total phosphorus at any river segment or lake within the state territory as well as to highlight significant emission sources (wastewater treatment plants, industry, artificial drainage, erosion etc.). The results of the deficit analysis were successfully validated against available monitoring data and show an exceedance of the phosphorus target concentrations in 60% of the analyzed subcatchments. Statewide, 269 tons of phosphorus needs to be reduced yearly, which corresponds to approximately 31% of the total emission. Detailed data as well as maps generated by the deficit analysis benefit the planning and implementation of regionally efficient measures, which are indispensable with regard to meeting the environmental quality objectives set by the WFD. Further developments are planned, for example, to apply the described deficit analysis to other substances such as nitrogen, or to assess a set of applicable measures in a subcatchment and subsequently determine the best one or the best combination based on multiple-criteria decision analysis.

Guejjoud H., Curie F., Grosbois C.
H. Guejjoud, F. Curie, C. Grosbois

Abstract number–219 Phosphorus surplus in France: Model and trends over the period 1920-2020

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Increase in agricultural production over the last decades has necessitated an excessive use of nutrients, notably phosphorus. The surplus of phosphorus transferred to hydrosystems represent a source of potential harm to the environment especially in terms of water pollution (e.g. eutrophication of surface water and groundwater pollution).

This work aims to quantify phosphorus fluxes in and out of agrosystems and to identify their drivers. The objective was to quantify the trend of phosphorus surplus both at a fine spatial scale (departments) over the last century regarding agricultural practice evolution (e.g. the green revolution, Common Agricultural Policy reform and U.E. directives).

A soil surface balance model, CASSIS-P (Calculation of Soil SImplified Surplus-Phosphorus) was used to calculate surplus of P. Required data mostly came from agronomical annual statistics of the SSP (Service de la Statistique et de la Prospective) and UNIFA (Union des Industries de la Fertilisation). Special attention was given to the evaluation of uncertainties of each parameter used in the model. This model was applied over a period of time (1920-2020) firstly at the NUTS3 level, a seldom-used spatial resolution, corresponding to the French administrative departments, and Corsica (NUTS2). For each department, CASSIS-P

quantified P input from chemical fertilizers, manure and atmospheric deposition, and P output represented by harvested crops, including fruit, vegetables and grazing. All units are in kg P2O5/ha UAA/year.

Over the last century, the P surplus, calculated for France as a whole, averaged 24 kg P2O5 ha UAA-1 year-1 and departmental P surpluses mean ranged from -1.5 to 47 KgP2O5/ha.UAA/year. Imprecision that corresponds to 80% confidence interval in P surpluses, was calculated using 200 Monte Carlo simulation. Average imprecision for the whole period ranged from 1.3 to 18 KgP2O5/ha.UAA/year across different departments. Segmentation of time series and identification of trends showed that all departments were characterized by a decrease of phosphorus surplus after 1974. This decrease is clearly related to decrease in mineral fertilizer use in most departments.

The next step of this work will be to apply the model CASSIS at the municipality scale. In fact, all these results can be related to the variation of phosphorus storage in soils and be used to apprehend P fluxes in water bodies as entry data for models or to estimate time lag between agrosystems and hydrosystems.

Brauns B., Banda K., Lapworth D.J., MacDonald A.M., Mudimbu D., Namaona W., Owen R., Sinda M.C.
B. Brauns, K. Banda, D.J. Lapworth, A.M. MacDonald, D. Mudimbu, W. Namaona, R. Owen, M.C. Sinda

Abstract number–220 Assessing differences in groundwater recharge flows under conservation agriculture and conventional tillage

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Under the pressure of growing populations and risks to food security by increased extreme weather events (droughts and floods), many countries, particularly in semi-arid and arid regions, such as sub-Saharan Africa have promoted a shift to climate-smart agricultural systems such as conservation agriculture (CA). The core principles of CA, along with crop diversification/rotation, comprise minimum tillage and mulching, and previous studies indicate positive effects of these practices on soil moisture balance. However, effects of CA

on groundwater recharge, for example changes to quantities, timing or altered recharge pathways have scarcely been investigated in the sub-Sahara environment, and need consideration because they may affect not only groundwater renewability, but potentially also contaminant transport and therefore groundwater quality.
In this study, we introduce a plot-scale approach at three sites in Zambia, Zimbabwe and Malawi using a suite of investigation methods to characterize recharge patterns under CA and conventionally tilled plots. In our presented setup, high-resolution (30 minutes) groundwater level and weather data are complemented by monthly groundwater chemistry (major, minor, and trace elements) and stable water isotope analysis from shallow monitoring boreholes over a monitoring period of multiple (2—3) recharge seasons. Annual repeat measurements of residence time tracers (CFCs and SF6) add additional information on groundwater age. Preliminary data analysis indicates that differences in onset and pattern of groundwater recharge between conventionally tilled and CA treatment plots can be observed, which could be valuable information for example in informing best management such as timing of fertilizer and pesticide application. The results of this study can therefore inform policy and decision makers and further our understanding of the effects promoted land use changes may have on local groundwater resources.

Kronvang B., Windolf J., van 't Veen S.G., Ovesen N.B., Tornbjerg H., Thodsen H., Blicher-Mathiesen G., Larsen S.E.
B. Kronvang, J. Windolf, S.G. van 't Veen, N.B. Ovesen, H. Tornbjerg, H. Thodsen, G. Blicher-Mathiesen, S.E. Larsen

Abstract number–221 Pitfalls and new solutions in water quantity and quality monitoring

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Assessing the state of and trends in water quantity and quality in the aquatic environment calls for a strategically designed network of monitoring stations in streams that covers the countrywide span in climate, soil types and land use. In addition, the monitoring programme should be able to capture the temporal variation in discharge and nutrient concentrations. Finally, and not least, the monitoring programme has to produce reliable data of high quality related both to field sampling and measurement procedures, laboratory analysis procedures, statistical calculations and modelling procedures. Quality and consistency of the time series of data are especially crucial when looking for longer-term trends in water quantity and quality data caused by changes in management practices in the catchment and/or climate. Changes in field and laboratory procedures, station networks, instruments, models, etc. might cause smaller or larger breaches of homogeneity in time series.
In Denmark, a national water quantity and quality monitoring programme has been ongoing for more than 30 years in groundwater, streams, rivers, lakes and marine waters. During this period, changes in the monitoring station network, laboratory procedures for analysis of

water samples, sampling frequency and instruments for measuring discharge have taken place. Even though several data quality assessment procedures are included in the national database, and data are assessed and reported every year, several breaches of homogeneity in time series have recently occurred. Some of these have led to problems when evaluating the state and trend of water quantity and quality in the aquatic environment. A number of examples of the pitfalls in monitoring will be shared in this presentation related to: i) importance of changes in monitoring station networks; ii) impact of changes in sampling frequency; iii) impact of changes in laboratory methods used for analysing total nitrogen and total phosphorous (UV versus autoclave); iv) impact of changes in flow measurement instruments. Lastly, it has become increasingly evident that new online sensor methods for monitoring nutrients in streams are needed in order to obtain reliable unbiased transport estimates for further analysis of sources, pathways, loadings to vulnerable recipients, etc.

Gallé T., Farlin J., Braun C., Huck V., Pittois D., Bayerle M.
T. Gallé, J. Farlin, C. Braun, V. Huck, D. Pittois, M. Bayerle

Abstract number–224 Catchment property- load regressions as a simple management tool for agricultural impact mitigation

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Agricultural impact on surface waters needs fact-based management measures for targeted mitigation. The simpler the concept the easier the communication of goals and the means to get there. Here we report a case-study from the catchment of a drinking water reservoir in Luxembourg which is affected by eutrophication. Thanks to a homogeneous geology and soil typology in the catchment, the yearly loads calculated for a wide distribution of land uses could be used in significant (multiple)regressions to address the impact of agriculture (and wastewater treatment) on the reservoir. Regressions of specific annual loads [kg NO3/ha/a] of nitrate against arable land percentage allowed to determine the nitrate emissions of the average arable plot. The same was possible for green land and woods. Based on these regressions, scenarios of mitigation could be developed by setting reduction goals on the culture (by decreasing the slope of the regression) or by reducing the fraction of that culture in the catchment. The regression concept could be validated for groundwater-originating pesticide transformation products like metolachlor- and metazachlor-ESA. The advantage of the concept is a very clear and quantitative communication of mitigation scenarios in a catchment to achieve water quality goals in the reservoir. The poster shows the methodology and the limits of the concept.

Shockley D.J.
D.J. Shockley

Abstract number–228 Assessing mobility of microplastics from soil to groundwater using soil leaching columns to enhance effectiveness of field sampling of groundwater for microplastics presence

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Microplastics (MP) within groundwater are an area of increasing concern, particularly with groundwater drinking water sources. They have been identified as being of significant interest due to their geographical global extent, constituting approximately 25% of the world's drinking water sources. Only a handful of studies to date have identified MPs in groundwater, with no standardised strategy to sampling. Findings are highly variable between studies, indicating that the risk of transport is not uniform and that factors such as soil cover may be highly influential, particularly with MP transmission through soil, such as those from sewage sludge applied to land. Without concrete proof of a source-pathway-receptor link, mitigation of this risk will be problematic, and sampling of groundwater cannot be targeted without first understanding the mechanisms which govern MP transmission to groundwater.
A soil column leaching methodology has been designed using a range of relevant soils, MP polymer types and sizes to will address this and assess under what conditions, with what polymers and at what size ranges, transmission will most likely occur using both fresh and 'weathered' polymers to simulate more realistic conditions, and thus help better direct subsequent field sampling. Findings will be compared with MPs detected in UK pilot field samples for verification – the first time these have systematically been collected in the UK. Optimisation of recovery and detection of weathered MPs at the size range relevant to this environment (25-150µm) is also incorporated into this methodological design.

Lauryssen F.
F. Lauryssen

Abstract number–231 Estimation of the natural background of phosphate in a lowland river using tidal marsh sediment cores

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Elevated phosphate (PO4) concentrations can harm the ecological status in water by eutrophication. In the majority of surface waters in lowland regions such as Flanders (Belgium), the local PO4 levels exceed the limits defined by environmental policy and fail to decrease, despite decreasing total phosphorus (P) emissions. In order to underpin the definition of currents limits, this study was set up to identify the pre-industrial background PO4 concentration in surface water of the Scheldt river, a tidal river in Flanders.

We used the sedimentary records preserved in tidal marsh sediment cores as an archive for reconstructing historical changes in surface water PO4. For sediment samples at sequential depths below the sediment surface, we dated the time of sediment deposition and analysed the extractable sediment-P. The resulting time series of sediment-P was linked to the time series of measured surface water-PO4 concentrations (data 1967-present). By combining those datasets, the sorption characteristics of the sediment could be described using a Langmuir type sorption model. The calibrated sorption model allowed us to estimate a pre-industrial background surface water PO4 levels, based on deeper sediment-P that stabilised at concentrations smaller than the modern.

In three out of the four cores, the sediment-P peaked around 1980, coinciding with the surface water PO4. The estimated pre-industrial (~1800) background PO4-concentration in the Scheldt river water was 62 [57; 66 (95%CI)] µg PO4-P L-1. That concentration exceeds the previously estimated natural background values in Flanders (15-35 µg TP L-1) and is about half of the prevailing limit in the Scheldt river (120 µg PO4-P L-1). In the 1930s, river water concentrations were estimated at 140 [128; 148] µg PO4-P L-1, already exceeding the current limit. The method developed here proved useful for reconstructing historical, background PO4 concentrations of a lowland tidal river. A similar approach can apply to other lowland tidal rivers to provide a scientific basis for local, catchment specific PO4 backgrounds.

Saavedra F.
F. Saavedra

Abstract number–233 The effect of hydrological extreme events on nitrate export patterns

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Diffuse sources of water contamination within catchments, such as agriculture, are a challenging problem for water quality management. Nutrient excess (e.g., nitrate and phosphate) harms ecosystems by producing eutrophication in water bodies and leading to biodiversity loss. The relationship between solute concentrations and discharge rates (C-Q) observed at catchment outlets provides valuable information on hydrological functioning and biogeochemical transformations at the catchment scale. C-Q relationship of nitrate expressed as a linear regression in log-log space is a suitable tool for representing catchment export patterns and quantifying exported loads.

Previous studies reported non-stationary nitrate export patterns in single catchments related to long-term changes in sources or meteorological conditions. Many German catchments exhibit a long-term decrease in nitrate concentration during the 1990s due to improvements in water treatment plants and a reduction in fertilizer application. However, the variability of

C-Q export patterns at the intra-annual scale is still high and possibly related to non-stationary hydrometeorological conditions. In fact, hydrometeorological extremes such as droughts and floods can alter hydrological responses in catchments for a considerable period after their occurrence. Hydrometeorological extremes might in turn affect nutrient transport to streams at the intra-annual scale. Previous studies show that severe droughts can alter nutrient cycling for months and years after the occurrence of an extreme event. We hypothesize that extreme hydrological events can also modify the C-Q export patterns of nitrate in German catchments.

To prove this hypothesis, we analyzed the variability of nitrate export patterns during and after extreme hydrological events in 40 mesoscale catchments in Germany. First, we identified hydrological droughts and floods from daily discharge time series. We defined droughts as consecutive months with a mean discharge rate below 75% of monthly mean values. In addition, we defined floods as the 0.1th highest percentile of daily discharge rates. In the next step, we computed C-Q export metrics within a moving window using low-frequency nitrate concentration measurements from 1980 to 2014. We choose as C-Q export metrics the fraction of coefficients of variation of concentration and discharge and the log-log C-Q linear regression coefficients, r2, and p-values. Finally, we explore differences in C-Q export metrics before, during, and after the occurrence of extreme hydrological events in each catchment to quantify the percentage of change. We further plan to link changes in C-Q export metrics before and after extreme hydrological events with extreme events characteristics (e.g., length and severity of droughts, hydrograph characteristics of floods) and explore its spatial variability across German catchments.

Møllerhøj L., Sivertsen J.
L. Møllerhøj, J. Sivertsen

Abstract number–234 Danish strategy for governmental groundwater monitoring

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In Denmark the program for Groundwater monitoring (GRUMO) have existed since 1989. The GRUMO-net originally consisted of 65 clustered areas of 5-50 km2 each with 20-25 wells and 1 m screen. The main purpose was to monitor the level of nitrate and give an early warning of especially pesticides in regard to drinking water. Generally GRUMO reflects landuse in rural areas.

Apart from GRUMO the national groundwater monitoring also includes detailed monitoring of surface near groundwater in five small agricultural catchments (LOOP), multilevel monitoring in 5 deep groundwater wells with changing redox conditions (REDOX) and detailed monitoring of pesticide leaching in 6 agricultural fields (VAP).

Since the introduction of the Waterframe Directive there has been a development towards a more evenly distribution of the wells for monitoring across Denmark, reflecting the distribution of groundwater bodies. However quite a few of the original wells are still in use due to the need for time series concerning especially nitrate and pesticides. Recently the monitoring network consist of more than 1000 intakes in about 700 wells.

In general data from the same wells are used for both assessment of the status of water bodies in regard to the Waterframe Directive, for reporting in regard to the Nitrate Directive and for annual revision of the Danish Order on Drinking Water.

As for the development in the level of nitrate in the groundwater and evaluation of the effect of various national action plans, this is supported by age dating of the groundwater.

The Order on Drinking Water controls which substances the water plants have to analyze for. To recognize the relevant substances in this regard screening for “new” substances is essential. The past 4 years a comprehensive screening for pesticides (578) have been conducted. Also the diffuse occurrence of a number of PFAS have been investigated during the recent years.

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