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An Roinn Talmhaíochta, Bia agus Mara
Department of Agriculture, Food and the Marine

ORAL PRESENTATIONS

Lowering the carbon footprint of pasture-based milk production

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The Climate Action Plan 2023 aims to lower greenhouse gas emissions from agriculture by 25% by 2030 compared to 2018 baseline. This is an enormous challenge, particularly in terms of the timeframe for adoption of appropriate management practices on commercial farms. Dairy farming in Ireland accounted for 15% of national greenhouse gas emissions in 2020. There are also national and European Union targets for the reduction of fertilizer N use by 2030. Hence, there is an urgent need to implement low emission practices on farms in order to reach national and European emission reduction targets. The objective was to investigate the economic impact of pasture-based dairy systems incorporating various practices for lowering GHG emissions including pasture legumes to replace fertilizer N in grassland, NBPT protected urea, Low Emission Slurry Spreading (LESS) and dairy cattle with high Economic Breeding Index. This study was conducted at Solohead Research Farm (52˚30'N, 08˚12'W) between 2019 and 2021. There were three systems with an average of 27 cows per system per year at an average annual stocking rate of 2.58 cows per ha. The control received an annual average of 275 kg per ha of fertilizer N applied as urea and calcium ammonium nitrate, and slurry was applied using a splash plate. The WC90 system was a clover-based system receiving 90 kg per ha of fertilizer N each year applied as NBPT-urea and slurry was applied using LESS. The WC0 system did not receive any fertilizer N and slurry was applied using LESS. The average EBI of cows on the control and WC90 was €147 and on WC0 was €185. Life cycle assessment was used to determine the GHG emissions per kg fat and protein corrected milk (FPCM). GHG emissions were 0.90, 0.78 and 0.69 kg carbon dioxide equivalents per kg FPCM for the Control, WC90 and WC0, respectively (SEM = 0.143; $P<0.001$). Net margins (mean of three years) were €1470, €1561 and €1695 per ha (43.3; $P=0.066$). The WC0 system had substantially lower GHG emissions and similar net margin relative to the other systems.

Heterogeneity in the effect of GHG mitigation strategies on Irish dairy farm

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The agricultural sector is increasingly under pressure to participate in the greenhouse gas (GHG) emission reduction effort. At the farm level, significant improvements can be achieved through the adoption of new technologies. Nevertheless, to date, little is known about differences in effect reduction across farms. This study specifically explores heterogeneity in the effect of GHG mitigation strategies across the distribution of GHG emissions on Irish dairy farms. The econometric analysis is performed on an unbalanced panel dataset by using fixed effects unconditional quantile regression models. The preliminary results reveal that GHG mitigation strategies have a differential effect across the distribution of GHG emissions. This suggests that relying on estimations of a technology's effect at the mean can be somewhat misleading. Moreover, the study shows that the effect of GHG mitigation strategies is larger for high emitting farms than for low emitting farms. Overall, this study is expected to advance the level of knowledge on technology adoption and how best to achieve GHG reduction targets.

Ireland's carbon monitoring network – the National Agricultural Soil Carbon Observatory (NASCO)

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The 2021 Climate Action and Low Carbon Development (Amendment) Act sets out in law Ireland's commitment to reduce overall greenhouse gas (GHG) emissions by 51% by 2030 and achieve climate neutrality by 2050. There are large uncertainties associated with the measurement of agriculture and land use, land-use change and forestry (LULUCF) emissions and removals due to the biogenic nature of the emissions, making it difficult to both mitigate emissions, enhance removals and to verify the extent of the mitigation achieved. These uncertainties can have significant effects on national inventory estimates. Currently, the emission and removal calculations for grasslands in the national inventory use generic Tier 1 emission factors and there is an urgent need to generate national-specific factors for grassland on mineral, organo-mineral and organic soils. Teagasc is currently establishing the Department of Agriculture Forestry and Marine (DAFM) funded National Agricultural Soil Carbon Observatory (NASCO) which consists of 30 sites where field-scale carbon dioxide (CO_2) (n = 30), methane (CH_4) (n = 8) , nitrous oxide (N_2O) (n = 2) and water (H_2O) (n = 30) fluxes will be directly measured using eddy covariance (EC) towers. Sites were selected using a multi-criteria analysis approach which accounted for farm type, land-use and climatic representation of the site. The NASCO platform operates at different spatial and temporal scales, incorporating soil carbon stock measurements from Teagasc's Signpost Farms, as well as using the EC flux measurements as ground truths for earth observations of gross primary productivity (GPP) in partnership with Terrain-AI (a Science Foundation Ireland [SFI] and Microsoft co-funded project). The objective of NASCO is to help Ireland to refine its national inventory for greenhouse gas (GHG) emissions from different land-uses, soil types, climate and agricultural activity, with a strong focus on measuring carbon sequestration potential in agricultural soils. Through a combination of EC-derived GHG measurements and activity data, Ireland aims to develop a Tier 2 approach to reporting emissions from the agricultural and LULUCF sectors, where available measured data can additionally be incorporated into process based models (such as RothC) to develop Tier 3 carbon emission factors.

Rockets vs. Bazookas: Comparing Two Techniques to Monitor Ammonia from Low Emission Slurry Spreading Equipment

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Gaseous ammonia is detrimental to both human and environmental health. Due to higher cattle densities than many other countries, a third of ammonia emissions on the island of Ireland arise from landspreading of cattle slurry. Cattle slurry is used as the primary source of nutrients on livestock farms, reducing the need for artificial fertilisers. However, the traditional splashplate spreading method broadcasts slurry over a wide area, encouraging ammonia volatilisation. Low Emissions Slurry Spreading (LESS) techniques reduce the slurry surface area and spread lower to the ground, reducing ammonia emissions, although there is uncertainty regarding the effect of such measures under Irish conditions. Typically, ammonia emissions within landspreading experiments are measured with Integrated Horizontal Flux (IHF) shuttles ("rockets"), which is labour-intensive with low-frequency measurements. This study compared high-frequency Fourier-Transform Infrared Open Path Spectroscopy (FTIR-OPS) ("bazookas") combined with backward Lagrangian stochastic modelling with IHF measurements. The main objective was to determine whether this could be an accurate but labour-saving monitoring method, by investigating ammonia emissions from slurry spread by different LESS techniques at field scale on Irish soils.

Cattle slurry was spread three times per year over the growing seasons of 2021 and 2022 on six 50 m x 50 m plots at each of two permanent grassland sites, Loughgall in Northern Ireland and Johnstown Castle in Ireland. Two plots at each site were spread by splashplate and trailing shoe, whilst trailing hose was used for the other two plots at Loughgall and open-slot injection at Johnstown Castle. On each occasion, ammonia emissions were monitored for five to eight days immediately following spreading using both IHF (on all plots) and FTIR-OPS (on three plots, one of each treatment). Emissions were modelled with concentration data from FTIR-OPS using Windtrax, enabling comparison between the two methods.

Ammonia emissions from IHF and FTIR-OPS were broadly comparable but variable. Both methods demonstrated that emissions often peaked within the first few hours of slurry spreading and rapidly returned to background concentrations within five days. However, when rain fell on partly dry slurry later in the week, emissions could briefly increase. On most occasions, spreading by splashplate resulted in the highest ammonia emissions but they were lowest on one occasion. Variability was high between the LESS techniques. The comparability of the two measurement methods will be explored, as will the variability of ammonia emissions from the different spreading techniques and the influence environmental conditions had on this variability.

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Soil climate mitigation - strategy challenges

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Climate change and its effects are increasingly felt globally. There are few, if any 'no safe' places to hide from its ever increasing and continuing effects. The soil which stores up to 2500 Pg of carbon, 1550 Pg in organic and 950 Pg in inorganic C can play a key role in mitigation the effects of increasing atmospheric CO_2 levels by enhanced C sequestration. The required value is small, i.e.. less than 4 per mil of the current organic C stocks and technically feasible. If, this aspiration is achieved in practice also is under intense debate. There are inherent problems with the detection of annual C sequestration rate, restoration or recultivation may lead to rapid recovery of the vegetation but not soil C, especially in the subsoil. There are limits how much organic residues are available to enhance soil C and C sequestration rates are moderated by soil texture and other soil characteristics. We see confounding issues with land use legacy and soil memory effects. Overall, there is a sense lack of more localised and regional framework and inherent goals of what we do with the various animal, plant and urban waste residues, which are available to our society and inherently the farming community, to maintain or improve the soil carbon status of agricultural soils. This hinders to some extent maximising the many positive initiatives many local communities are making to protect and maintain a sustainable planet.

What can we learn from 12 years of soil nutrient data in Irish agricultural catchments?

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Over the past decade, Irish agriculture has witnessed notable shifts, ranging from changes in farming practices, variation in costs of agricultural inputs and outputs, to policy reforms aimed at optimizing productivity while minimizing environmental impacts. Since the inception of the Agricultural Catchments Programme (ACP), comprehensive surveys of soil pH and nutrient levels have been conducted at the field scale within the catchments. Here, we present the results for soil pH, soil test phosphorus (STP) and potassium (STK) collected over 12 years in four agricultural catchments in Ireland, both as mean values and in the context of soil index system in Ireland. The entire agricultural area of each catchment is divided into defined sampling units and soil samples are repeatedly taken from each unit every 4 years. The analysis of the overall summary statistics (n=1984) reveals the increases in soil pH, STP and STK over the study period (2009-2021). However, when the sampling units are analysed in a spatial context and supplemented with additional soil and land use data, a more intricate narrative unfolds. While soil pH consistently improved within optimal ranges across the studied catchments and enterprises, the situation with STP, STK, and their associated indices proved to be more varied, reflecting the differences related to farming practices and the primary enterprises in the catchments. Notable findings include substantial increase in STP in one of the catchments, generally higher STP and STK increases on tillage and dairy farms as opposed to drystock and a decrease in STP on soils classified as risky in terms of P losses to watercourses. Despite some positive trends, there remains a significant need for substantial efforts in on-farm nutrient management planning to achieve agri-environmental objectives.

Broad scale multiple year temporal changes in agricultural soil structure across three catchments in Scotland

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A healthy soil structure is vital for successful productivity from agricultural land and for the maintenance of important ecosystem services. The structure and porosity of soil impacts its water retention and drainage properties, with deterioration of soil structure leading to susceptibility to compaction, erosion and nutrient loss. As a result, soil structure degradation is a serious threat to both agriculture and the environment in Scotland. Through a resampling strategy using the Visual Evaluation of Soil Structure (VESS), together with the collection of quantitative soil physical data, we investigated temporal changes in the physical structure of soil. This builds on a study undertaken in winter 2015/16 which considered the effect of soil structure and field drainage on water quality and flood risk on agricultural soils across Scotland. The 2015/16 survey of 120 fields across 4 river catchments in Scotland found widespread soil physical degradation over the winter months, with severe soil structural degradation recorded in 18% of topsoils and 9% of subsoils. A subset of 42 of these fields was revisited in January 2016 following the most severe rainfall event ever recorded in Scotland, which led to a 30% increase in severely degraded topsoils. While this study demonstrated the short-term negative impacts caused by weather, the longer-term impacts are not known. I therefore conducted a resampling in winter 2022/23 of the subset of 42 fields from three river catchments: the River Ugie, the South Esk, and the East Pow. The previous sampling strategy was repeated, using GPS to identify the original locations sampled in each selected field, with three samples from in-field locations, three from heavy traffic areas with visible damage to the soil surface, and three from the field margins. In addition to VESS I also measured penetration resistance and collected an undisturbed soil core from a 2-7cm depth. These cores were then used for the measurement of soil bulk density and macroporosity. Analysis of the results of this investigation is underway, however preliminary analysis found most soils to be VESS scores 2 and 3 in in-field locations, and an average of 4 in areas categorised as ‘degraded’, indicating changes in management may be required to improve the overall soil physical health. Research such as this is important for both an increased understanding for farmers on how to actively manage their soils to reduce environmental impacts, and for the development of future governmental policies on land management.

Environmental load and productivity under controlled drainage and subirrigation in a boreal sandy loam field

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Controlled drainage and subirrigation are gaining popularity in Finland, partly as a means of decreasing greenhouse gas emissions in peat soils, and partly for agronomic reasons. Maintaining high groundwater level during the growing season improves water availability to plants and controlling drainage discharge is thought to diminish nutrient loss through leaching.

To quantify the benefit of controlled drainage and subirrigation under boreal conditions, the effect of controlled drainage and subirrigation on agricultural productivity and nutrient load was investigated in Sievi, Finland in 2021-2022. The experimental site consists of a plot with controlled drainage, which also receives subirrigation, and a reference plot with conventional drainage, each plot approximately 1 ha. The texture of the soil varies between loam and sandy loam, and the average slope is less than 0.2%. The field drains into river Vääräjoki, which flows approximately 300m south of the field and receives drainage waters from surrounding fields, elevating its nutrient content.

Perennial grass timothy (*Phleum pratense*) was grown for seed production on the experimental plots. The outlet of the controlled drainage was maintained at 0.5 m below the soil surface throughout the investigated period. The controlled drainage plot was irrigated by pumping water from river Vääräjoki into the drain system in the summer.

Groundwater level was measured manually from 56 points 1-2 times a week and automatically from 8 points every four hours. Drainage discharge was measured automatically every hour. Suspended solids, total phosphorus and nitrogen contents were determined from flow weighted composite water samples. Yield was observed in twelve replicates within each experimental plot. Irrigation amount was measured automatically in 2022.

Groundwater level in the controlled and irrigated plot was above that of the conventional drainage plot during the growing season, but the level dropped below drainage depth during dry periods. Drainage discharge was smaller on the controlled drainage plot than on the conventional drainage plot by 22.7%, not accounting for the added discharge caused by the irrigation. Nitrogen content and load were found to be smaller in the controlled drainage plot by 4.3%, but no such effect was observed for phosphorus. Yield was 9-16% higher on the controlled drainage plot than on the conventional drainage plot. The results suggest that subirrigation paired with controlled drainage can be used for maintaining higher groundwater level and ensuring water availability to crops, as well as diminishing nitrogen leaching.

The riparian reactive interface – the challenges of interdisciplinary and international riparian observatories

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Riparian ecosystems, semi-terrestrial areas adjacent to and influenced by freshwaters, act as gateways for the transport and alteration of nutrient fluxes from terrestrial to aquatic ecosystems. It is well known that nutrient fluxes are spatially and temporally dynamic and are under considerable pressures through superimposed land-use and climate change. While a lot of research has been done on individual nutrients, the biogeochemical understanding across linked C, N and P processes is limited. Prompt research progress is needed to capture current baseline conditions in climate sensitive riparian biogeochemical processes. Our interdisciplinary project has established six UK riparian observatories, linking with partner international sites (Sweden and Germany) across contrasting landscapes and climate zones. These explore dynamic properties (water table, temperature, soil moisture etc.) relating to physical and biogeochemical mechanisms controlling nutrient stocks, mobilisation and transport with varying sensitivity to climate change. We aim to continuously monitor soil and river water level, soil moisture, redox/pH, and collect monthly soil solution and river water samples to understand changes in C, N, P concentrations, organic matter quality and dissolved C/N/P stoichiometry within the riparian zone and relate it to site attributes and water table dynamics. Additionally, to determine the C, N, P concentrations and stocks of the soils and relate to characterisation of reactivity we analysed the soils for microbial biomass and enzyme activity, nutrient stocks, and soil organic matter composition at the initial installation of the observatories. Here we discuss the goals and challenges of data collection and interpretation of dynamic seasonality (moisture-temperature-redox) informing ability to predict long-term climate signals. Overall, our study is complex and challenging by combining microbiology, biochemistry, hydrology and soil science, but it is an important steppingstone into gaining a better understanding of change processes in complex riparian ecosystems.

The influence of soil structure on chemical and physical mechanisms of phosphorus release

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The influence of structure on the availability and release of legacy soil phosphorus (P) stores is not fully understood. Consequently, there are limited options available to improve mining of P reserves, and current recommendations are based predominantly on soil chemistry. The hypothesis of the present research is that poor soil structure impedes change in P index and mobilisation of P reserves. While poorly structured soils may be more difficult to change chemically, structural improvements could allow a more effective manipulation of indices. The influence of soil structure on mobilisation and availability of phosphorus is being examined through a pot trial. The aim is to study the influence of contrasting soil structures on build-up and draw down of soil P, across low to high P indices. Soil of varying soil test Morgan's P values (2.5 – 10 mg/l) was collected, air dried, and sieved. Each soil was packed into pots at three different bulk densities (1.2, 1.4, and 1.6 g/cm^3), to reflect good, average, or poor soil structures. Perennial ryegrass was sown and rooting was allowed to establish over a 6 month period to encourage structural development. After the priming period (2022), baseline measurements of Morgan's soil P were taken in Spring 2023. Treatments of draw-down and build up rates of P will be applied over two years. Soil P is measured annually to detect trends in P build-up or drawdown. Herbage measurements will be taken at intervals typical to grazing rotations of 21 to 28 days throughout the growing season, to allow P balance to be calculated. Soil physical quality will be assessed at the conclusion of the trial in 2025. Intact soil cores will be extracted from each pot and soil water retention curves will be measured. Porosity, hydraulic parameters, and physical quality (SPQ) will be calculated. It is anticipated that the results of this work will indicate if structural variations influence the manipulation of Morgan's soil P levels and mobilisation of P reserves.

A region-wide strategy to reduce diffuse agricultural losses to the water environment

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Combined high agricultural source pressures and a hydrologically connected landscape pose considerable challenges for improving water quality in Northern Ireland (NI). Phosphorus availability is driven by a grass-based farming system centred on livestock production, where a dependency on feed and fertiliser imports and limited investment in slurry processing or redistribution has resulted in a P balance of around 12 kg P/ha. Land connected to river systems by overland flow dominated pathways has contributed to almost 70% of rivers and 86% of lakes at less than good ecological status, with diffuse phosphorus transfers a factor in many failures.

The challenges are clear - balancing the requirements of food production and water quality protection requires a sound, fine scale risk assessment that is of utility from field to catchment scale across wide regions.

Research in NI has shown a strong relationship between the proportion of catchment land area above the agronomic optimum for soil test phosphorus, runoff risk and waterbody concentrations. Indications from ongoing work are that when soil P is regulated to reduce surpluses - but without impacting optimum agronomic conditions - water quality will show improvement. Hydrological connectivity is also a control, with proportions of hydrologically sensitive areas for overland flow in catchments a strong influence on losses. Soil testing, on-farm nutrient management planning, and risk area identification are key strategies to achieving this, delivering the potential for better utilisation of these valuable resources and reducing the availability of P for loss to waterbodies.

Recognition of this was one of the drivers behind the government-funded Soil Nutrient Health Scheme which aims to sample all 700,000 fields in Northern Ireland by 2026. This will provide farmers with clear information on soil nutrient and pH status for each field, LiDAR-derived runoff risk maps highlighting sub-field scale hot-spots with potential for contaminant loss to waterbodies, and training to help farmers turn this information into effective management plans on-farm.

This paper reflects on the ambition and challenges of the Soil Nutrient Health Scheme, presents key findings to date, and examines how this can be used to inform efforts to reduce source and pathway pressures and improve water quality.

Understanding the prevalence and variability of antimicrobial resistance genes in two livestock-dominated catchments, southwest Scotland

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Antimicrobial resistance (AMR) is a major threat to public health. A holistic 'One Health' approach that recognises the linkages between human, environmental and animal health is necessary to tackle this issue and the UK AMR strategy has recognised the role of the environment as a conduit for AMR. While there is increasing understanding of AMR from point sources, understanding of 'background' AMR prevalence in livestock-dominated agricultural catchments is limited.

Here, we examined the abundance and temporal variability of four antimicrobial resistance genes (ARG) in two agricultural catchments in south-west Scotland dominated by intensive grassland and livestock production to determine the key drivers of ARG over time. The surface water quality in Cessnock (31km^2) and Mein Water (19km^2) catchments were monitored twice a week between May 2017 and October 2019 (which encompassed a severe drought event) using 24hr composite samples. The ARG ermB, tetM, sul1 and int1 are associated with resistances to erythromycin, tetracycline and sulfonamides; and with integrons (a mobile genetic element, capable of moving ARG between bacterial cells), respectively. The environmental variables monitored included discharge, precipitation, nutrients (TN, TP, NO_3, PO_4, NH_4, DOC, organic N and organic P) and faecal indicator organisms (intestinal enterococci and *E. coli*). In addition, the microbial community composition was determined by sequencing of the 16S rRNA gene in the Cessnock catchment.

The association between ARG relative abundances and the environmental and microbial community composition variables was investigated within a machine learning framework. Generalised additive models (GAM) were applied to understand seasonal patterns, while predictive models such as random forests (RF), stochastic gradient boosting machine (GBM), support vector machine (SVM), partial least squares regression (PLS) and elastic-net regression (ENET) were tested to elucidate the role of driving variables.

Modelling revealed that environmental variables, especially time (as a proxy for season), TP, PO_4, DOC (in Cessnock catchment) and time and discharge (in Mein Catchment) had a stronger influence on ARG abundance than microbial community composition. Intestinal enterococci were significantly associated with ARG in the Cessnock catchment and *E. coli* in the Mein catchment, suggesting that faecal pollution could contribute to ARG prevalence. This study demonstrated that higher temporal resolution and longer-term data collection (at least one year) is required to capture variation in ARG abundance. This is the first study to capture high resolution temporal data of ARG in catchments to inform targeted mitigation strategies for land managers.

Impacts of crop type on nitrate leaching – a multi-year dataset across the Wessex region, UK

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Nitrogen losses through leaching from agricultural land can contribute to elevated nitrate concentrations in receiving waters. Where groundwater is abstracted for drinking water supply, raw nitrate concentrations approaching or exceeding the UK's Drinking Water Standard of 11.3 mgNO3-/l require treatment or operational management to ensure compliance. In surface waters, nitrates can lead to rapid algal growth which can negatively impact habitat quality in certain situations.

In field, nitrogen lost through leaching is subsequently not available to support crop production and can lead to the application of additional fertiliser to address any shortfall. Leaching through soils is generally highest over the winter period in this region (typically October – April), and therefore, nitrate availability for leaching is dependent on nitrogen content of the soil before the onset of the rainfall period and the over-winter cropping during the rainfall period.

For over fifteen years, Wessex Water have been working with farmers, through catchment management, to reduce nitrate leaching to improve raw water quality in ground and surface waters. Measures such as cover crops have been widely supported to reduce the risk of leaching in the over-winter period and a subset of these are monitored to demonstrate their effectiveness against a normal practice control. In addition, overwinter leaching resulting from key cropping rotations of harvest crops (primary control on residual soil nitrogen) and overwinter cropping have been monitored to understand nitrate loss risk.

Nitrate leaching is estimated using monitored nitrate concentrations (mgN/l) and modelled soil drainage. Water samples are collected frequently from sets of ceramic porous pots installed at 90-cm during the overwinter rainfall season and these are combined with soil drainage estimates. Estimated cumulative overwinter nitrate flux across the dataset (n=794) is analysed alongside cropping information to understand crop type influence. This cropping information details the previous crop, i.e., the crop harvested before monitoring began, and the overwinter crop, i.e., the crop growing during the rainfall period.

Results show that median overwinter nitrate leaching was greatest where oilseeds were the previous crop, however, cereals, maize and grass had greater scatter in their datasets, likely influenced by the overwinter crop type and corresponding management. When considering the impacts of overwinter crop choices following the harvest of cereal crops, cover crops reduced median nitrate leaching compared to uncropped soils (cultivated or uncultivated, bare or weedy soils). These data provide an important evidence base to support decision making to minimise nitrate leaching from agricultural soils.

Developing a Bayesian Network model to account for faecal indicator organism losses from septic tanks

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Changing frequencies and magnitude of rainfall associated with climate change are predicted to impact faecal pollution of water, inferred by the presence of faecal indicator organisms (FIOs). Common sources of FIOs in catchments include wastewater discharge, sewage spills and agricultural diffuse water pollution. While these sources are well recognised, little is known about risk posed by septic tank systems (STS) often common in rural catchments. Modelling approaches can help identify potential sources of FIOs in catchments to inform spatial targeting of land management mitigation measures for protecting water resources. However, given that empirical investigations of STS are limited due to challenges in monitoring STS effluent and uncertainties surrounding STS condition and maintenance, many models fail to account for STS contributions in their predictions, resulting in large uncertainty regarding their environmental risk. Bayesian Network (BN) models are widely acknowledged for their ability to integrate expert knowledge into model structures, and therefore, advantageous when empirical evidence or large-scale datasets are scarce. Here, the aim was to develop a probability-based model to predict FIO losses from STS to receiving waters by modifying an existing BN model developed to account for phosphorus losses from STS. The concept and need for an FIO BN model to inform on STS risk is presented, including, identification and justification of model variables and BN structure, approaches to model parameterisation and a description of the spatial data to be used to test this model in Scotland. The study will enhance understanding of BN FIO modelling to quantify FIO loads from septic tanks and inform on options for addressing STS pollution.

Rethinking norms in agricultural catchments to identify macro to field-edge scale opportunities

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Increasing food production while protecting and improving water quality is a worldwide challenge. Intensive agriculture to meet this demand, with excess nutrient (inorganic or organic) application, can inadvertently cause water quality degradation. While conventional agricultural sees farmers making decisions based on market demand the European Union (EU) alternative soil-based land use framework aims to achieve economic and environmental objectives in agriculturally dominant watersheds; this framework has been little explored in the United States (US). We present findings of several studies focused on potential implementation of a soil-based land use framework, combined with a 'manureshed' approach, to enhance water quality and sustain crop yields in a sub-watershed of the Chesapeake Bay, USA. The manureshed concept aims to create sustainable systems by connecting areas where crops absorb nutrients (nutrient sinks) with areas where livestock agriculture produces nutrients (nutrient sources). We utilized the Soil and Water Assessment Tool (SWAT) to model crop growth and quantify the losses of total nitrogen (TN), total phosphorus (TP), and sediment and we adjusted land use strategies to maintain profitability while reducing water pollution. Additionally, we employed SWAT to explore manure nutrient management scenarios based on the concept of the 'manureshed' by comparing a 'business-as-usual' scenario with 'watershed nutrient balance' scenarios incorporating subsurface injection or targeted application timing, as well as an EU-style closure period. Through land use reorganization, we discovered that profitability could be maintained while achieving double-digit reductions in nitrogen, phosphorus, and sediment. Winter closure and injection methods resulted in the largest reductions in nitrogen and phosphorus. Furthermore, the manureshed concept identified new opportunities for manure reduction, such as centralized treatment leading to the production of value-added consumer fertilizers or local biogas digesters to promote energy independence. Moreover, both land reorganization and a manureshed approach to nutrient management helped identify landscapes with high-risk nutrient loss. Targeted critical source area management and designing innovative agricultural best management practices in these areas could offer additional benefits in further reducing water quality degradation. It is crucial to emphasize that innovative thinking and new business strategies will be necessary to assist farmers in the Chesapeake Bay watershed meeting the mandated USEPA 2025 TMDL (Total Maximum Daily Load) limits for while sustaining their livelihoods. Educating and engaging consumers and farmers through cooperative efforts and outreach programs will be essential to convey nutrient reduction benefits found in this study and promote strategies for preserving the Chesapeake Bay watershed.

Sediment and total phosphorus effectiveness of riparian mitigation (versus costs) accounting for concentrated runoff flowpaths

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Pollution trapping by riparian mitigation is fundamental to their use in protecting water quality and often predicted as load reductions against margin width using literature-derived relationships dominated by short-term experiments or by observations biased to (idealised) diffuse flow interception. We propose accounting for concentrated flow paths (CFPs) (relative to diffuse flow) that alter buffer sediment and total P trapping presents a significant improvement in effectiveness estimations. Here, we extend procedures developed earlier in the U.S. around the Vegetated Filter Strip Model (VFSMOD) to account for reduced sediment and P trapping.

Our method proposes that retention efficiency of the incoming pollution load is dependent not only on the margin width, but also on the ratio of the effective margin segment area (at the delivery point) to the contributing flow area from the field. We compared effectiveness for sediment and total P trapping in three fields within the Agricultural Catchments Program area of Ballycanew, a predominantly grassland farming area in Wexford, Ireland. We contrasted various riparian pollution mitigation interventions: a 2 m wide grass buffer (level 1); additional 5 m grass margins widened only at flow interception points predicted by Lidar (level 2); in-ditch and in-field sediment traps on major runoff pathways (level 3).

Net losses per field were 7 to 19 tonnes sediment/year and 3 to 15 kg total P/year. Due to CFP presence, level 1 grass buffers were predicted to retain only 2 to 16% sediment and 1% to 9% total P rising to 6% to 52% for sediment and 3% to 22% total P, with level 2 widened, targeted margins. Although poorly performing overall, the increase from 2 m to 5 m buffer zone grass margin width at delivery points enhanced effectiveness for only localised extra land take and costs/effectiveness approximately halved. Level 3 scenarios retained up to 34% to 49% of the sediment and 23% to 33% of the total P losses, showing benefits of enhanced measured built into grass margin space targeting CFPs.

Where pollution retention effectiveness can be coupled with simple annualised cost metrics (land area taken, installation and maintenance) the resulting effectiveness versus cost estimations present a powerful way to compare intervention levels. This is especially so where realistic functioning of the measures is provided through the incorporation of CFP processes for specific fields using screening data via readily accessible spatial data such as digital elevation models and soil types and field survey.

Assessing the effectiveness of sediment ponds at reducing excess nutrient concentrations through agricultural drainage ditches

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Agricultural drainage ditches, which may comprise of open surface drains or subsurface pipes, can act as a conduit for nutrient and sediment transport into receiving freshwater systems. The impact of this pathway on water quality is dependent upon the hydrological connectivity of ditches to freshwater systems, and sources of nutrients and sediment from yards and fields. In Ireland, drainage ditches are primarily installed as a means to quickly and efficiently transport excess water from agricultural land, resulting in a complex network of drainage ditches, each with different levels of connectivity. In terms of mitigating against this issue, it is important to identify the most effective place to install the right measure. Drainage ditches with a direct connection between farm yards and freshwater systems pose the greatest threat in terms of their ability to transport high concentrations of nutrients and sediment. Therefore, targeting these types of ditches to install a mitigation measure offers the best opportunity to minimise losses to water.

This study examined the efficiency of sediment ponds installed to reduce nutrient loss from agricultural drainage ditches with a direct connection between farm yards and freshwater systems. Case study farms in Cork and Wexford with sediment ponds installed along a drainage network in 2021, with sampling commencing in December 2022. Grab samples were collected for nutrient analysis from multiple locations at each site upstream and downstream of the sediment ponds and analysed for nitrogen, phosphorus and dissolved organic carbon, with sampling campaigns conducted weekly for the site in Co. Wexford (farm W1), while the two sites in Co. Cork (farm C1 and C2) were sampled fortnightly. Overall, initial results would suggest that attenuation of nutrients is somewhat limited, however there are some nutrients which have significantly reduced downstream of the sediment ponds. This was observed for ammonium (p=0.04) and Ortho-P (p=0.03) at farm C1, particulate P (p= 0.1) at farm C2, and total oxidisable nitrogen (p=0.0004) at farm W1. While further research is ongoing to collect samples across a longer time period, this study offers a greater understanding into the effectiveness of sediment ponds as a mitigation measure, and provides an interesting insight into nutrient dynamics within drainage ditch networks.

Nutrient impacts of on-site wastewater treatment systems on stream catchments with low permeability subsoils

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This research estimated the phosphorus (P) and nitrogen (N) loadings from domestic wastewater treatment systems (DWWTS) into small streams in low permeability subsoil catchments in Ireland. Four small catchments, each containing a high density of DWWTS (16 - 33 DWWTS km^2) and underlain by either poorly permeable subsoil or shallow, impermeable bedrock, were selected for study. The catchments were located in counties Cavan, Longford, Wexford and Wicklow. The primary stream in each catchment was monitored upstream and downstream of the main cluster of DWWTS for nutrients (N and P), as well as Total Coliforms, *E.coli* and Enterococci. In addition, a number of mid-catchment monitoring points were also sampled in order to observe changing water quality patterns throughout each of the catchments. A catchment P loading conceptual model, describing DWWTS-P and -N loading under low flow conditions was developed. The P loading arising from DWWTS was found to represent between 1.5 % and 9 % of the annual P loading from the four study catchments. Likewise, between 10 % and 29 % of the annual N loading was estimated to arise from catchment DWWTS. These results were found to be in close agreement with those generated by the EPA's Source Load Apportionment Model (SLAM) modelling software for the same catchments which incorporates the SANICOSE sub-model for contaminant transport and attenuation from DWWTS. In addition to the estimation of annual loading, general water quality in each catchment was characterised with respect to P and N fractions and sub-clusters of DWWTS located in close proximity to the stream, were found to result in 'hotspots' of severely impacted surface water. A number of models were examined with the aim of estimating the P contribution of a given DWWTS as a function of its distance from the stream. Across the four catchments studied, a power inverse model was found to provide a good description of DWWTS-P loading with distance, describing a gradual decrease in P loading to the stream with increasing distance. This has potential use in future mitigation strategies relating to the impacts of DWWTS on surface water.

Estimating slurry spreading opportunities based on soil moisture deficit

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Application of slurry and soiled water to land is used to cycle nutrients within the grazing platform, and as a secondary function, disposes of waste liquids generated in a holding. In Ireland, application is subject to both regional closed periods and also weather-based restrictions. Previous research has revealed that trafficable spreading conditions frequently occur within the closed period, based on weather and soil moisture. The objective of the present research is to examine potential slurry/soiled water spreading opportunities based on soil moisture deficit. Considering the prime goal of maintaining soil fertility and supporting crop demand, consideration of spreading opportunities is confined to soils which exhibit deficient nutrient indices and require build-up of reserves. Soil moisture deficit was calculated for three drainage classes using long-term meteorological data from fourteen synoptic weather stations. Monthly potential spreading days were subsequently determined using various threshold and calendar-based rules, and combinations thereof. Further, calculation of grassland area required to distribute slurry and soiled water volumes is presented.

Phosphorus Bioavailability and Speciation dynamics within fluvial suspended sediments

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Eutrophication of agricultural catchment streams remains a global problem despite increasingly stringent regulations. Release of bioavailable phosphorus (P) from legacy P stored within fluvial sediments can have significant and prolonged negative impacts on downstream water quality, hence detailed information is required regarding P speciation dynamics and potential release mechanisms from fluvial sediments to the water column. This study applied complimentary techniques including sequential chemical P fractionations (SCF), Dual Culture Diffusion Apparatus mesocosm experiments (DCDA), X-ray fluorescence spectroscopy (XRF) and X-ray Absorption Near-edge Structure (XANES) spectroscopy to investigate the various dynamic P fractions, speciation and bioavailability of suspended fluvial sediments from two geologically contrasting agricultural catchment streams (Ballyboughal (BB) and Tintern Abbey (TTA)). Results from the SCF of fluvial suspended sediments pre- and post DCDA microcosm experiment's illustrated loosely bound P (P_{H2O}), exchangeable P against OH^- ions (P_{NaOH}), and organic P (P_{Org}) are the major P fraction contributors to the bioavailable P fraction which would promote algal growth. Other P fractions including acid-soluble P principally associated with calcium phosphate compounds (P_{HCl}) and ferric bound P (P_{CBD}) showed relatively lower mineralisation to bioavailable P. Significantly, P K-edge XANES spectra enabled identification of seasonal and spatial P speciation dynamics and the existence of major P fractions including Fe-P and Ca-P associated mineral phases along with organic P compounds. Additionally, SCF, XRF and Ca K-edge XANES show contrasting Ca associated phases between both catchments, with calcite dominant in the BB sediments and Ca humic-complexes predominant in the TTA sediments. Contrasting Ca-P fraction transformation mechanisms of the two catchments are indicated by P redistributions in SCF and the reduction of elemental Ca amounts from XRF analysis. Calcium (Ca) K-edge XANES shows the BB catchment has a large amount of calcite while TTA was shown to contain organic Ca compounds, likely in the form of Ca-humic-complexes. This study provides a conjunctive method for future studies and validation of P speciation and bioavailability assessment associated with fluvial suspended sediments from agricultural catchments streams. The results contribute to future catchment scale sedimentary fluvial P modelling and enhanced catchment management strategies to improved water quality.

Identification of soils potentially vulnerable to losses of dissolved phosphorus in Sweden

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Eutrophication is an important threat to aquatic ecosystems worldwide, and reliable identification of areas vulnerable to phosphorus (P) losses from diffuse sources is essential for high efficiency of mitigation measures. In this three-step study we investigated (i) relationships between the agronomic (Olsen-P and P-AL) and environmental soil P tests (P-$CaCl_2$) with molecular techniques (31P NMR and XANES) followed by (ii) rainfall simulation experiment on topsoil lysimeters and (iii) comparison to long-term field measurements of water quality. Soil samples were collected from seven sites indicated to be vulnerable to nutrient losses due to underlying geology. High P release was positively correlated to standard agronomic P tests (Olsen P, r = 0.67; and P-AL, r = 0.74) and negatively to low P sorption capacity (r = -0.5). High content of iron-bound P compounds indicated more labile P and higher release of dissolved P (r = 0.67). Leaching experiment showed that three out of four soils with high initial soil P status had both higher P leaching concentrations before fertilization (0.83 – 7.7 mg P l^{-1}) compared to soil with low initial soil P status (0.007 - 0.23 mg P l^{-1}), and higher increase in P concentrations after fertilization. Higher soil P sorption capacity reduced P leaching losses. Finally, long-term monitoring data show no significant trends in P losses in a field with low initial P content and moderate P fertilization rates whereas high and over time increasing P losses were recorded in a field with high initial soil P content and repetitively high P fertilization rates. Combination of evaluation of long-term monitoring data with soil surveys and lysimeter leaching studies can increase our understanding of complex systems and help us identify soils vulnerable to losses of dissolved P.

A cross-scale understanding of efficacy of conservation measures for reducing phosphorus losses from agricultural land to water in Norway and Sweden

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Phosphorus (P) loss from agricultural land is an important contributor to the eutrophication of both downstream lakes in Norway and Sweden, and the Baltic Sea. While problems with eutrophication and enhanced P concentrations are identified at the large scale (in lakes, estuaries and sea bays), processes and mitigating options of P losses from soil to water are studied experimentally at smaller scales ranging from soil samples, topsoil columns and drain-depth long lysimeters to plots, fields and catchments. The findings have been used as foundation for developing simulation models and decision support tools. Furthermore, many of the findings have been used by agricultural and water quality managers for developing relevant regulations and recommendations, and for prioritizing subsidies. Still, there is a need of information synthesis for a better understanding of the connections and disconnections across the scales in influencing the efficacy of mitigation measures. In this presentation, we will discuss Norwegian and Swedish experiences from scaling up P mitigation efforts by combining studies at different scales or by using P models and P risk assessments.

The fear of missing out – how long high-frequency water quality time series do we need?

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High-frequency water quality measurements are becoming more common and unsurprisingly the number of long-term datasets from around the globe is rising quickly, adding to the improved understanding of complex catchments and process interactions. Many research projects obtain high-frequency instruments for a specific purpose, and once this is completed, ideally with a number of publications to follow, the question arises – what do we do now? The obvious answer is to continue measurements, as running costs are usually a fraction of the original purchase amount, but is there a good time to stop these measurements at a given site? The water quality hoarders in us will say –there is a great value in the long-term high-frequency measurements and we can capture both typical and atypical hydrologic conditions like the summer of 2018. But the more pragmatic part of us will opt for moving the instruments to a new catchment to gain new high-frequency insights there rather than keep catching yet another 'figure 8' storm event at the old site. So, when do we have enough information about the catchment, transport pathways and their mobilisation during storm events, when have we seen it all and it is time to move on? Is it simply the fear of missing out that drives the long-term high-frequency pursuits or is it an evidence-based decision? I will answer this and other questions in relation to research, management, and operational perspectives in my presentation using high-frequency examples from diverse catchments and geographical settings.

Three decades of regulation of agricultural nitrogen losses: Experiences from the Danish Agricultural Monitoring Program

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Excess nitrogen (N) losses from intensive agricultural production are a world-wide problem causing eutrophication in vulnerable aquatic ecosystems such as estuaries. Therefore, Denmark as one of the most intensively farmed countries in the world has enforced mandatory regulations on agricultural production since the late 1980s. We demonstrate the outcome of the regulations imposed on agriculture by analyzing decadal trends in nitrate (NO_3^-) concentrations and loads in streams using 29-32 years of detailed monitoring data and survey information on agricultural practices at field level from five intensively cultivated headwater catchments.

The analysis includes the importance of four main drivers (climate, land use, agricultural practices, and biogeophysical properties of catchments), each divided into different factors that may influence stream NO_3^- loads during three subperiods defined by the time of introduction of different mitigation measures: i) 1990-1998, ii) 1999-2007, and iii) 2008-2018.

Significant correlations with annual flow-weighted stream NO_3^- concentrations and/or loads were found for factors representing all of the four main drivers including precipitation, large scale climate fluctuations, runoff, previous year's runoff, baseflow index, number of annual frost days, agricultural area, livestock density, field N surplus, catch crop cover, manure storage capacity, method and time of manure spreading, and time of soil tillage.

Changes in the four drivers were reflected by the load-runoff (L-Q) relationships for each of the three subperiods within each of the five headwater catchments. The five catchments experienced large but catchment-specific downward shifts in the L-Q relationship attributable to changes in land use and agricultural management within the catchments. The documented large downward shifts in NO_3^- loads demonstrated for the five catchments (30-52%) as a consequence of mandatory regulation over a period of nearly three decades are a unique example of how agriculture can reduce its environmental impact.

Estimation of annual nitrogen losses by runoff based on long-term catchment monitoring data in Norway

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Since decades, inland water bodies and coastal waters of Norway are suffering from too high nutrient and sediment losses from agricultural areas, among other sources. After the start of a National Action Plan for measures, the Norwegian Agricultural Environmental Monitoring Programme (JOVA) was established to monitor nutrient, sediment, and pesticide losses of selected catchments representing typical agricultural areas in Norway (for details, please see abstract 1047). In addition to this water runoff quality and quantity monitoring at the outlets of the catchments, field-level management practices were recorded. Using the data collected in the first ten years of monitoring of five catchments, an equation with best predictors was developed based on stepwise multiple regression analyses. The ultimate objective of the initial equation was to estimate nationwide nitrogen losses from agriculture-dominated catchments with less than 20% grassland area. The predictors in this equation were annual runoff, soil organic matter content, positive field nitrogen balance of tilled fields, runoff from January to April, the number of days with mean temperature above zero from soil tillage until 1st of May, the sum of daily mean air temperature above zero between May and August, and autumn to spring runoff from grassland area. During the past 20 years, these annual estimates of nitrogen losses from Norwegian agriculture have been used to evaluate the efficiency of agricultural mitigation measures to reduce nutrient losses. Meanwhile, the monitoring dataset comprises around 210 site-years from seven catchments. With this valuable dataset the equation is being revised following the same procedure as for the first one. This takes also into account the availability of input data on national scale so that the equation can be used to estimate annual nitrogen losses of all agriculture-dominated catchment units across Norway. The results of the new equation will be presented and discussed.

Agricultural nutrient losses in Sweden during 25 years – monitored catchments compared to modelled leaching regions

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The losses of nitrogen (N) and phosphorous (P) from arable land to root-zone in Sweden have been calculated with the NLeCCS modelling system, for four different years, 1995, 2005, 2013, and 2019. NLeCCS (Nutrient Leaching Coefficient Calculation System) is a system for calculating standard leakage rates of N and P from arable land. The calculation included a matrix of 22 leaching regions, 13 crops, 10 soil types, soil P content in topsoil, slope (only for P). The different years were represented by different data on crops, harvests, fertilization and other cultivation measures. The data used are from Statistics Sweden and the Swedish Board of Agriculture. The changes between the different years and leaching regions have been evaluated with respect to changes in crop acreage, fertilization-harvest response, catch crops, buffer zones, and the occurrence of fallow. In the calculation a 30-year long period of weather, data representing a normal climate in each leaching region, have been used for all calculated years. Nutrient losses to surface waters have been monitored in small agricultural catchments (2–35 km^2) for more than 25 years in Sweden. The catchments have been intensively monitored with stream water sampling, yearly crop management surveys and soil characterisation. The catchments are located in southern and central Sweden, representing different agro-climatic, crop-soil management and soil texture conditions. Annual losses of total N at catchment stream outlet vary from 6 to 32 kg ha^{-1} yr^{-1}, with the largest losses from sandy loam soils in south-west Sweden, where precipitation is high. Losses of total P vary from 0.1 to 2.0 kg ha^{-1} yr^{-1} and are largest in catchments with clay soils. The leaching regions and the monitored catchments were compared in terms of time series in nutrient losses and agricultural management for the same period (1995-2019). The catchments reflects the mix of agricultural systems, other sources, and the weather during the monitored period whereas the modelled data reflects the changes in the agricultural system between the years. The modelled results from the leaching regions can contribute to explain changes in nutrient losses in the monitored catchments.

Modelling pathways to a 50% reduction in nutrient loads from agricultural catchments under different climate trajectories

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Under persistent eutrophication of European water bodies and a changing climate, there is an increasing need to evaluate mitigation measures for reducing nutrient losses from agricultural catchments. In this study, we set up a daily discharge and water quality model in Hydrological Predictions of the Environment for two contrasting agricultural catchments in Sweden to forecast the impacts of future climate trajectories on nutrient loads. The model predicted a slight increase in inorganic nitrogen (IN) and total phosphorus (TP) loads under RCP2.6, likely due to precipitation-driven mobilisation. Under RCP4.5 and RCP8.5, the IN loads were forecasted to decrease with 16%-26% and 21%-50% respectively, most likely due to temperature-driven increases in denitrification and evapotranspiration. No distinct trends in TP loads were observed. A 50% decrease in nutrient loads, as targeted by the European Green Deal, was backcasted using a combination of mitigation scenarios, including i) a 20% reduction in mineral fertiliser, ii) introducing cover crops between growing seasons, and iii) stream mitigation by increasing the size of floodplains and wetlands. Target TP load reductions could only be achieved by stream mitigation, which is likely due to legacy effects and the strong effect of secondary phosphorus mobilisation within agricultural streams. Target IN load reductions were backcasted with a combination of stream mitigation, fertiliser reduction, and cover crops, wherein the required measures depended on the climatic context. Overall, the diverging responses of nutrients to climate change and mitigation scenarios indicate that water quality management needs to be tailored to the catchment characteristics, and to the spatial and time specific effects of climate change. This study has demonstrated the potential of catchment water quality modelling as a first step in decision support to find the most effective ways to mitigate nutrient loads in agricultural catchments.

Simulation of the Impact of Nature-Based Solutions on Diffuse Pollution in Ballycanew Co. Wexford

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The Environmental Protection Agency's 'Water Quality in Ireland Report 2016-2021' revealed that the overall water quality in Ireland has continued to decline. The intensification of agriculture in the South and Southeast of the country has increased the pressure on Ireland's water resources. Nature-based solutions (NBS) utilising soil and runoff management can play a major part in improving Ireland's water quality.

The Catchment Runoff Attenuation Flux Tool (CRAFT) is a parsimonious rainfall runoff model that can be run at the catchment scale using hourly data. CRAFT is used to simulate the effect on water quality and quantity of changing hillslope flow pathways. It is designed to investigate the impact of different flow pathway management strategies on nutrient and sediment fluxes in the three main flow pathways: the fast near surface flow, subsurface flow, and slower groundwater flow. Soil management is represented in the model using infiltration capacity of the cultivation zone and runoff management is simulated as a sediment trap store with a specified sediment removal rate, to which phosphorus removal is directly linked.

The 11km^2 Ballycanew catchment in Co. Wexford is presented as a case study. The catchment is dominated by grassland (78%) and tillage (20%). The heavy soils are prone to runoff, which means phosphorus and sediment are the main sources of pollution during storm events. Using 10+ years of high frequency water quality and flow data, CRAFT has simulated the following scenarios: (1) existing conditions with low infiltration rates and high runoff rates, leading to high levels of diffuse pollution;

(2) soil and land use management generating higher infiltration rates and suppressing near surface flow; and (3) the potential to mitigate pollution using flow attenuation features such as buffers, sediment traps and wetlands. CRAFT shows that a significant proportion of the phosphorus export is in the near surface, creating the opportunity through (2) and (3) to greatly reduce diffuse pollution. Results show that changing flow pathways using NBS features can significantly reduce the diffuse pollution levels leaving the catchment.

High expectations and open questions: using high-frequency proxy data to calibrate catchment-scale phosphorus transport models

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High-frequency (HF) data from in-situ sensors is commonly used to better understand catchment processes and to capture temporal variability in proxy measures of water quality, with HF turbidity being used as a proxy for total phosphorus (TP) and total suspended solids (TSS) concentrations. It is not yet common to use HF proxy data with catchment scale water quality models, which are normally calibrated to low frequency (LF; biweekly or monthly) grab samples. The rationale for combining high-frequency data and water quality modelling is twofold (1) it is management relevant to explore all possible applications of in-situ sensor data sets, and (2) it is scientifically interesting to expore how present-day models and protocols work with this kind of data. This study aims to provide new insights into the use of HF data for model calibration using INCA-PEco, a process-based, catchment-scale water quality model. A LF data set including monthly grab samples of TSS and TP was compared to a HF data set using turbidity as a proxy for TSS and TP. The model was set up for a Swedish mixed land use catchment using data from 2012-2017. Effects of using different calibration data sets on model performance were evaluated by (i) multi-objective calibration strategies, (ii) varying hydrological input compared to calibration data sets, (iii) parameter sensitivity analysis and (iv) assessing concentrations and loads. The results show large differences dependent on the different calibration data sets (LF/HF) but only minor differences due to hydrological submodel parameterizations. The HF data set is more variable and includes higher concentrations of both TP and TSS compared to the LF data. This results in generally higher concentrations and loads (TP and TSS) when calibrating to the HF data set. It was harder to obtain a good fit between observed and simulated data for the HF data, which could depend on the high variability and the larger number of observations. These results raise questions about the theoretical and practical implications of using turbidity from in-situ sensors as a proxy for TSS and TP. With HF data, we achieved a good description of temporal variation in the modelled output, but the results are still uncertain due to the proxy relationships.

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 km^2) 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 geo regions, 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.

How transferable are Bayesian Network models between diverse agricultural catchments? Representing and understanding catchment processes

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Phosphorus (P) pollution originating from agriculture poses a significant challenge to maintaining and improving water quality in the Agricultural Catchments Programme (ACP) catchments. This programme was created to evaluate the Good Agricultural Practice measures implemented under the EU Nitrates Directive, and extensive monitoring and research have been carried out into the drivers and controls on nutrient loss in these catchments. Managing P pollution and deriving catchment-scale understanding requires a systemic modelling and assessment approach. Bayesian Belief Networks (BBNs) support system-level thinking as they can represent complex systems (such as rivers and catchments) integrating disparate information sources while representing uncertainty, aiding decision-making around pollution risks.

A previous study reported the development of a BBN parameterized for a 12 km^2 ACP catchment with flashy hydrology on poorly drained soils and grassland as the dominant land use (Ballycanew). Seven years of hourly turbidity and discharge measurements at the catchment outlet, in addition to mapped soil P content were used for the parameterization. Literature data and expert opinion were included to complement the dataset when information on point-source pollution (farmyard and septic tank nutrient losses) was lacking.

In this study, the BBN is developed further and is parameterized using a monthly time-step for three additional diverse ACP catchments: two arable land-dominated catchments with contrasting hydrology (well-drained vs moderately drained, Castledockrell and Dunleer) and a well-drained grassland catchment (Timoleague) to test model transferability. In a step forward from the previous model, we quantify potential P losses from a sewage treatment plant in Arable A, and we consider biota in-stream P removal in all catchments as an additional process, informed by expert elicitation. Total Reactive Phosphorus (TRP) concentrations are compared to BBN predictions using percentage bias as an objective function for model calibration.

Results showed that the model can predict the mean TRP concentration for the target catchment, performing relatively well for the other three, while representing the variance less accurately. Here, we show that the BBN best captures the processes in the surface pathways-dominated catchments compared to the groundwater-dominated catchments and discuss the reasons for any discrepancies. Testing the model transferability to other catchments is important to (a) inform on the differences in P loss between catchments, and (b) inform model testing in data-sparse catchments. Future research will focus on integrating climate change scenarios in the model to inform the targeting of mitigation measures under future change, foster discussion with stakeholders, and support decision-makers.

Modelled impact of water and nutrient retention measures using a new routing approach in SWAT+

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Natural/small water and nutrient retention measures (NSWRMs) have been identified as a strategy for reaching agri-environmental policy objectives, including good chemical and ecological status of water bodies, balanced water quantity, protection of natural resources, and climate change adaptation and mitigation. The OPTAIN project (www.optain.eu) proposes a social and scientific journey towards increasing and better understanding the multiple benefits of NSWRMs. The benefits they provide depend on the type (e.g. grassed waterways, constructed wetlands, conservation tillage, or controlled drainage) but also on the specific location, implementation design, and combination with other measures. 'Optimal' implementation schemes would respond best to the characteristics of the catchment and efficiently retain water and nutrients with minimal trade-offs with other societal and economic objectives, such as maintaining agricultural yields.

In order to explore such schemes in scenario simulations, OPTAIN developed a novel method to set up the 'Soil and Water Assessment Tool' (SWAT+). Based on terrain properties, all land and water objects are connected with their contiguous neighbour objects to enable different types of fluxes between them, such as surface runoff and lateral flow. With this approach, each individual landscape feature in a land cover layer is considered as a unique routing object. This allows studying the impact of NSWRMs with respect to their individual site-specific allocation within the catchment. The new method is applied in 14 case studies across Europe. In this presentation, we will show first results from the German case study (Schwarzer Schoeps catchment, 135 km²), critically reflecting and discussing ways to represent a set of different NSWRMs (hedgerows, riparian buffers, grassed waterways, retention ponds, and conservation tillage combined with cover crops) in the model, as well as showing their modelled efficiency to retain water and nutrients.

Impact of soil map resolution on SWAT+ modelling, case study of Petite Glâne, Switzerland

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When local or regional soil data are lacking, modelers using the Soil and Water Assessment Tool (SWAT) must rely on freely available but very coarse soil maps, such as the Digital Soil Map of the World (DSMW). Up to now, the significance of soil map resolution in SWAT modeling has been relatively neglected compared to the attention given to DEM resolution. The few studies conducted on the matter have demonstrated that the key impact of soil map resolution is the number and size of the Hydrologic Response Unit (HRU), ultimately affecting the results. However, as for the impact of the resolution on the model's performance, opinions are divided as to whether the coarser or the finer resolution performs better.

This paper explores impact of soil map resolution on SWAT+ (a completely revised version of the SWAT model) modelling with the Contiguous object Connectivity Approach (COCOA) model se up. SWAT+ COCOA was developed within the Horizon2020 OPTAIN project and contrary to former SWAT/SWAT+ model setups, HRUs are not attributed internally by overlaying the input soil map and land use map but defined solely by the land use map. With this approach, each land use object is attributed with the dominant soil based on the soil input data, consequently, the influence of soil maps can be more thoroughly assessed.

Based on the Horizon2020 OPTAIN case study in Switzerland, the Petite Glâne watershed (100 km^2), the SWAT+ COCOA model is used with three different soil maps: the DSMW with a resolution of 1:5’000’000, a soil map based on the Swiss Soil Suitability Map with a resolution of 1:200'000, and a high-resolution soil map based on local soil profile data (1m resolution). The assessment of the simulated flows with the three different soil maps is done by comparing them with measured runoff and water quality values before and after calibration.

Emergence of a climate change signal in Irish meteorological observations?

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Detecting emergence of a forced anthropogenic climate change signal from observations is critical for informing adaptation responses across sectors, including agriculture, ecosystems and water. By regressing local variations in climate onto annual Global Mean Surface Temperature (GMST) we track emergence of an anthropogenic signal in long-term quality assured observations of temperature and precipitation for the island of Ireland. Analysis of station-based observations, together with island scale composite series is undertaken for annual and seasonal means, together with 16 indices of extremes, with the derived signal to noise ratio classified as normal, unusual or unfamiliar relative to early industrial climate. More than half of indices show the emergence of at least unusual conditions relative to early industrial climate.

The Effect of Cover Crops on Nitrate Loads in an Irish Catchment under Climate Change

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Nutrient loss to streams degrades the water quality of European rivers, and these problems may be amplified by climate change. Climate-smart mitigation strategies are required, and these call for understanding of the underlying processes of nutrient loss under future weather conditions. The objective of this study was to assess how climate change and cover crops collectively impact the nitrate load in an agricultural catchment in Ireland.

The studied catchment (ca 11 km^2) is part of the Agricultural Catchment Program (ACP) at Teagasc. The focus of this study is on the Castledockrell catchment, which predominantly has arable land use with freely draining soils, making is particularly susceptible to nitrate losses. The extensive high-frequency monitoring of hydrological and chemical parameters conducted by the ACP for over a decade makes for an excellent foundation for applying the Soil Water Assessment Tool (SWAT). The SWAT model is a process-based eco-hydrological model that is capable of simulating stream flows and water quality based on climate data, topography, soil properties, land use and management practices. SWAT can be used with past, present and future meteorological conditions as input, making it a widely adopted model for simulating both present and potential future conditions and processes within a catchment.

In this study the SWAT model is used to examine the risks of nitrate export from agricultural catchments. SWAT was used to simulate daily streamflow and total nitrate load. The model is calibrated and validated over the period of 2010-2021, and model performance is evaluated using KGE, R2, and PBIAS.

To simulate the effects of climate change, localized climate scenarios provided by the WaterFutures project were used. These scenarios were developed by running downscaled Global Climate Models (CNRM-CM5, ECEARTH, MIROC5, and MPI-ESM-LR) to simulate two future climate scenarios - one with an intermediate emission pathway (RCP4.5) and one with an intensive emission pathway (RCP8.5). The scenarios were used to estimate NO_3 loads for the coming century and the effectiveness of cover crops as a climate-smart mitigation measure is evaluated by simulating different management scenarios.

Empirical modelling of elevated nutrient losses caused by extreme weather events under future climate change scenarios

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The degradation of water quality has been enhanced by changing weather patterns. Drastic changes in the concentrations of nutrients have been observed following prolonged droughts and heavy rainfall. Hence, it is important to identify the trigger events in order to assess the implications of the occurrence and timing of these extreme weather events in the future.

In this study, we used empirical modelling to 1: Investigate historical extreme weather events that have triggered pulses of Nitrate (N) and/or Phosphorus (P) losses over a 12-year study period, and; 2: Predict changes in the frequency and timing of occurrence of such pulses using projected climate change scenarios. The impact of two emission scenarios of RCP4.5 and RCP8.5 during three time periods comprising 2010-2040 (P1), 2040-2070 (P2), and 2070-2100 (P3) were investigated in a poorly drained grassland catchment (Ballycanew) in SE Ireland, and a well-drained grassland catchment (Timoleague) in SW Ireland.

The analysis of 12-year high-temporal resolution data revealed that air temperature exceeding 18 °C for three consecutive days followed by an effective rainfall of >5 mm in one day would cause an increase in N concentrations of ditch water leaving the catchment outlet and entering the surface water. For Ballycanew, the model predicted 0.8%, and 26% increasing chances of having trigger events in RCP4.5 during P1, P2, and P3, whereas these probabilities increased to 1%, 23%, and 185% for RCP8.5 during the same time periods, respectively. In Timoleague, the corresponding estimates were predicted to equate to a 0%, 5%, and 16% increase for RCP4.5, compared with a 2%, 37%, and 256% increase for RCP8.5 during P1, P2, and P3, respectively.

As for P triggering events, cumulative effective rainfall >5 mm over five consecutive days followed by effective rainfall >15mm in a day were identified as triggering an increase in P concentrations. The RCP4.5 emission scenario in Ballycanew projected an 18%, 11%, and 27% increase in P-triggering events during P1, P2, and P3, whereas for RCP 8.5, the corresponding increases were 25%, 33% and 50%, respectively. For Timoleague, the corresponding estimates were predicted to be a 59%, 66%, and 95% increase for RCP4.5, compared with 49%, 80% and 144% for RCP8.5 during the same future time periods.

The climatically-driven increases in nutrient concentrations are likely caused by a build-up of the nutrient pool available for mobilization due to reduced plant growth and mineralisation as a result of increased temperatures, and flushing driven by extreme rainfall. The differing responses of nutrients to the projected changes in weather patterns indicate that management decisions and practices need to be tailored to catchment characteristics in order to ensure proper water quality protection. Long term water quality monitoring data capturing current weather extremes can assist in estimating nutrient losses under projected climate change scenarios in order to help develop appropriate climate-smart adaptation measures at catchment scale.

Phosphorus mobilisation and delivery in a changing climate

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Climate change is likely to exacerbate land to water nutrient loss, causing a degradation of water quality in rivers. Therefore, planning for mitigation measures requires insight into the underlying processes of nutrient loss under changing weather conditions. The aim of this study was to assess how a changing climate might influence phosphorus (P) mobilisation and delivery in six intensively managed agricultural catchments (*ca* 3-30 km^2) in Ireland, selected to represent contrasting hydrological controls (mostly groundwater-fed *vs*. hydrologically flashy catchments).

Changes or stability of P transfer processes were estimated using projected far-future scenarios of river discharge. The river discharge was derived using the SMART model, driven by downscaled climate scenarios (RCP4.5 and RCP8.5), and Mobilisation and Delivery indices for total P (TP) and total reactive P (TRP) were estimated using the existing links between the hydrological regime and transfer processes.

Comparing data from 2080 (2070-2099) with 2020 (2010-2039) and 2050 (2040-2069), suggests that mobilisation processes, such as soil P detachment and solubilisation, are expected to be relatively stable in the different catchments. There was, however, a slight decrease of the mobilisation index in the groundwater-fed catchments and an increase in the hydrologically flashy catchments in 2080. The delivery processes, on the other hand, are expected to increase in all the catchments by 2080 for both RCP4.5 and RCP8.5. The highest increase in P delivery indices were in the groundwater-fed catchments for RCP8.5 (up to +27.5%). There were, however, also high increases in P delivery indices in the hydrologically flashy catchments. An increase in inter-annual variability of delivery processes is also expected.

Future risks of P loss are likely related to increases in hydrological connectivity and/or reduction in P retention within the landscape. The underlying processes for P losses associated with climate change were different for TP and TRP and for catchments with different hydrological controls. Such information will help to target more resilient mitigation strategies and further design these for scenarios of future weather conditions and land use.

This work was undertaken as part of the WaterFutures project and the Agricultural Catchments Programme.

Climate induced changes at the riparian reactive interface: Might this be the Achilles Heel for Global nutrient cycling and how can we assess this?

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Riparian zones are the highly dynamic interfaces between terrestrial and aquatic ecosystems, ultimately governing cycling and transfers of key macronutrients, such as carbon (C), nitrogen (N) and phosphorus (P), between the land and the oceans. These zones are critical for hosting an array of biogeochemical interactions that control the onward mobility of nutrients through river systems and which, in turn, drive aquatic ecosystem functioning and biodiversity, water resource quality, and global nutrient cycles. Whilst riparian areas are already recognised as being key *active zones*, it is reasonable to hypothesise that certain riparian locations may become *hyperactive* zones under future climate change scenarios, but there is little hard evidence for this, yet. Our overarching hypothesis is that functions relating to macronutrient (CNP) storage, filtration and fluxes in river riparian zones are going to be significantly altered by climate change, manifested in changing temperatures, shifting water table dynamics and river morphology. In turn, we hypothesise that changing functions at this critical interface will govern large shifts in global CNP cycles between land and oceans. This paper will be delivered as an oral presentation from a newly formed collaborative team of biogeochemists, soil scientists, and modellers working on sites in northern England, Scotland, Sweden and Germany. We will use this short paper to share our hypotheses and emerging conceptual typologies of riparian zones based on their functioning, and provoke thought on the way ahead, for ourselves and the wider community.

From challenges to solutions: Implementing nature-based solutions for water quality and quantity management

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There is an urgent need to adapt to current and future water-related environmental pressures; both water quantity (managing hydrological extremes) and quality. These issues continue to be a concern in Ireland and internationally and recognizing the severity of this, many governments have prioritized the development and implementation of strategies to tackle agricultural diffuse pollution and the impact of hydrological extremes. However, progress with implementation remains slow and many water related issues still exist and will likely worsen with climate change. With this, nature-based solutions (NBS) have been identified as one solution to many water related environmental pressures. However, further evidence and guidance is needed to support implementation. Also, greater focus must be given so that these solutions can provide many more ecosystem services. Importantly, any solutions need to work with agricultural practices (*e.g.* through agri-environmental schemes, win-win approaches).

Therefore, this talk will look at the role of measure design and placement for managing water quantity and quality issues. To achieve this, first we explore how common management approaches (e.g. grass buffer strips, ponds) could be best designed to attenuate storm runoff (*e.g*. re-designing existing measures or using combinations of measures). In order for measures to function effectively during storm events, it is necessary to examine the key design criteria for slowing down and disconnecting fast erosive flow pathways. Using Irish and international case examples, we will demonstrate approaches for optimising the function of these measures in agriculturally managed landscapes – both the uplands and lowlands. Secondly, we explore strategic placement of measures to achieve wider benefits. For this, we outline a three-tier measure placement framework whereby the third tier considers a greater range of augmented measures (*e.g.* engineered buffers, in-ditch sediment traps, wetlands). The hierarchical framework provides an approach for selecting and placing measures in a catchment, considering the specific challenges and characteristics of each location. For example, where converging flow pathways exist, using measures such as bunds on field margins and sediment traps may require less land and deliver a greater benefit for flood management and sediment capture than traditional grassed margins. Examples of these approaches will be shown Ballycanew catchment, Co. Wexford and this will form part of a practical fieldtrip/workshop discussion session during the conference.

In conclusion, the successful implementation of measures in agricultural landscapes necessitates considering the right measure in the right place. By adopting a holistic approach that either integrates different NBS approaches or more bespoke measure designs then we can effectively address water-related challenges and pave the way for sustainable water management in the future.

OPTAIN - Optimal strategies to retain and re-use water and nutrients in small agricultural catchments in Europe

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The increasing number of droughts and heavy rainfall events are aggravating 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 and more resilient agriculture and society. Moreover, these measures contribute to the achievement of different Sustainable Development Goals and environmental targets formulated in several water- and agriculture-related policies of the European Union. Despite the existence of a 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 that allows the 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 their 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 are involved during these steps to identify NSWRM practices considering both environmental and socio-economic indicators. We will present the first results from these different steps, such as the actor-based identification of promising measures, including customized environmental and economic performance indicators, the state-of-the-art of the harmonized modelling and optimization approach and the policy analysis across 14 case studies.

Suite Sixteen: Expert evaluation of environmental effectiveness of riparian mitigation measures

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The pollution of surface and ground waters represents one of the primary environmental challenges facing agri-ecosystems. There is an urgent need to halt declining water quality and habitat condition in farmed landscapes and the riparian interface between land activities and the water environment is a key location for management. Riparian buffer zones are patches of land adjacent to rivers, streams and drains, removed from intensive production. Coupled with benefits for water quality, these areas can provide a variety of environmental and ecological services, including a habitat for biodiversity, alleviating flood threat, greenhouse gas exchanges and aesthetic and recreational services.

Riparian mitigation measures have been widely incorporated in European agri-environment schemes. However, despite their widespread implementation, uncertainties remain in relation to the multi-functional effectiveness of riparian mitigation measures. This study reports on an assessment of the effectiveness of sixteen riparian management measures to maintain and enhance water quality and additional ecosystem services.

The study employed an expert-based process of generating effectiveness and confidence estimates, undertaken with national and international academics and practitioners. Experts were invited to complete a bespoke online questionnaire, assessing the effectiveness of each of the sixteen mitigation measures. Each mitigation measure was assessed in relation to the delivery of fourteen individual ecosystem services (covering provisioning, regulating, supporting and cultural services). Following initial scoring, all responders were invited to join an on-line workshop to discuss the effectiveness scores and given the opportunity to again score the effectiveness of each measure.

Key results indicated that wooded buffers were the highest rated mitigation measure, and the top performing mitigation measure for half of the 14 individual ecosystem services. Integrated buffers was the second highest ranked mitigation measure (across all ecosystems services). The results indicate that although widely implemented, grass buffers consistently scored low in their effectiveness at delivering a range of ecosystem services, and ranked lowest for phosphorus, and nitrogen benefits (key stressors in aquatic ecosystems).

Information gleaned from this study (*i.e.* SMARTER_BufferZ) will facilitate policy-makers to target the most cost-effective riparian management measures to support the delivery of multiple ecosystem services and in particular help surface waters achieve Water Framework Directive targets.

Identifying and testing adaptive management options to increase catchment system resilience using a Bayesian Network

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The cumulative impacts of future climatic and socio-economic change threaten the ability of freshwaters to provide valuable socio-ecological services at the catchment scale. Stakeholders who manage freshwaters require decision-support tools that increase their understanding of catchment system resilience and support the appraisal of adaptive management options. Our research aimed 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?

We used the predominantly arable River Eden catchment (320 km^2), in eastern Scotland as a case study, where water quality is impacted by both point source and diffuse phosphorus sources. We applied participatory methods to develop a BN model that 1) mapped the catchment system to determine the multiple phosphorus source pathways, 2) investigated the impacts of multiple future climatic and socio-economic change pathways on water quality conditions to a 2050-time horizon to inform the identification of management strategies and 3) tested the effectiveness of identified management strategies in improving water quality conditions and increasing catchment system resilience.

We applied a hybrid equation-based model to measure the uncertain impacts of both climatic and socio-economic change, which was a novel way of considering 'what if?' scenarios within a BN model. Model outputs informed the identification of management options during stakeholder workshops. Management options were grouped into management scenarios and their effectiveness in improving water quality conditions was tested using the BN model. Two optimal management scenarios that addressed water quality issues in the Eden catchment both now and to 2050 were identified. The first optimal management scenario focused on predominantly nature-based management options such as wetland wastewater treatment methods and rural sustainable drainage systems. The second optimal scenario focused on resource recovery, including phosphorus recovery from wastewater treatment works and constructed lagoons for crop irrigation.

The BN model was in effective decision support tool, demonstrating that conventional management actions and regulatory measures would not improve water quality conditions in the Eden catchment now and or in the future. Instead, innovate and collaborative adaptive management scenarios were required to achieve water quality improvements in the Eden catchment. Our participatory methods facilitated the identification of innovation and collaboration across different sectors, which considered wider environmental, social and economic benefits to increase catchment system resilience to the impacts of future change.

Mitigating eutrophication in small agricultural catchments – long-term efficiency of two constructed wetlands

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Constructed wetlands (CWs) are mitigation measures that can reduce nitrogen (N), phosphorus (P), suspended solids (SS) and total organic carbon (TOC) losses from agricultural catchments to the aquatic environment. Since the 1990s, over 15 000 ha wetlands have been constructed in Sweden, but there is a lack of long-term evaluations of their effectiveness. Therefore, the long-term effectiveness of two small CWs (0.1 and 0.3 % of catchment area) targeting P retention in clay soil dominated catchments in Sweden, was assessed using flow-proportional water sampling. This was done directly after construction and for the following 10-12 years including maintenance. Area-specific nutrient retention increased with nutrient load in both CWs. However, despite higher nutrient load in CW2, mean annual retention efficiency in CW1 (38 % TP, 41 % SS, 26 % TOC, 37 % TN) exceeded that in CW2 (5 % TP, 8 % SS, 4 % TOC, 7 % TN). The double HLR in CW2 could be too high to satisfactorily retain nutrients. The varied nutrient capturing efficiency could be explained by different size, fertilising/management and maintenance routines. Annual N efficiency increased with age in CW1, while CW2 was affected by the maintenance. There was a release of N after sediment removal and TOC release in the two following years due to fertilising before heavy rain. Furthermore, the retention performance difference between the initial deep area compared to the shallow vegetated area in CW2, indicates a need to even perform maintenance in the shallow area every few years. Our study confirms that long-term high-frequency monitoring of multiple nutrients is needed for reliable assessment of nutrient retention efficiency of wetlands, maintenance effect and avoidance of pollution swapping. The varying performance of these two CWs, suggests that implementation of future wetlands needs clear size and placement guidance and maintenance plans. To be able to improve performance and determine the optimal dimension and maintenance needs, HLR should be calculated. This also further emphasizes the requirement for long-term monitoring of several mature CWs with a range of critical HLR rates on different soil types.

Trade-offs between nitrogen and phosphorus mitigation in remediated agricultural streams

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Losses of agriculturally-derived nitrogen (N), phosphorus (P) and sediments to aquatic ecosystems continue to exacerbate eutrophication and negatively impact stream water quality and ecology. Pollutant transport is mediated by agricultural headwater streams, but their high potential for nutrient and sediment processing remain at large untapped. To improve stream corridor pollutant processing and reduce downstream export, lateral floodplains have been constructed as a stream remediation measure. This measure relies on fluvial and biogeochemical controls to reduce the export of N, P and sediments.

In this study, we investigated the potential of floodplain sediments to remove nitrate by microbial denitrification and the concurrent risk of reactive P release through desorption. Further, the capacity of particulate P reduction through floodplain sedimentation was quantified. The study was conducted in 10 floodplain remediated streams in Sweden, paired with upstream trapezoidal control streams. Denitrification rates and nitrous oxide yields were measured in channel and floodplain sediments, using acetylene incubation assays. Sediment P sorption in floodplain sediments was determined with P isotherm incubations. Net deposition of sediments was measured biannually using sediment plates and analysed for TP. Water chemistry were analysed monthly and flow discharge continuously.

Firstly, we found that floodplains increased denitrification of the entire system, contributing with 30 % of total denitrification in addition to stream sediments. More frequent inundation led to a beneficial increase in denitrification and a reduction in nitrous oxide yields in floodplains. However, these reducing conditions also promoted reactive P release, exposing a trade-off between solute N and P mitigation governed by inundation and soil properties.

Secondly, P sedimentation rates on floodplains also increased with inundation but were not sufficient to influence P concentrations along reaches. Instead, reduction in particulate P concentrations was controlled by bank stabilization, facilitated by floodplains on both sides of the inset channel (-54 µg/L) as opposed to one-sided floodplains (27 µg/L) and control streams (47 µg/L).

These results show that remediated streams can increase N and particulate P removal, but also reveals a trade-off between solute N and P. Thus, targeting of N, P and nitrous oxide mitigation, guided by appropriate floodplain design, needs careful consideration in water quality management before implementing remediated streams.

Assessing trade-offs between agricultural ditch remediation strategies

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Drainage ditches play an important role in agricultural water management, removing excess water from fields. Traditional ditch designs are effective for this purpose, and also minimize their land footprint. However, these ditches act as transport pathways for nutrients. During high flow events, their steep banks are also susceptible to erosion. This can be a source of additional sediment and phosphorous mobilisation in river systems. Ditch remediation, through the construction of two-stage or shallow slope ditches, has been proposed as a solution to reduce nutrient exports and hydromorphological pressures, while maintaining good drainage. In Sweden, ditch remediation actions have taken place, with encouragement and funding from agricultural agencies. However, there is limited research on the factors controlling the effectiveness of ditch remediation strategies. Additionally, the potential benefits and trade-offs to aquatic ecosystems resulting from remediation have not been assessed. To fill this knowledge gap, we conducted a synoptic sampling campaign of traditional and remediated ditches to analyse and compare channel properties, stream chemistry and macroinvertebrate communities. The aim was to assess the effect of ditch remediation on both pollution reduction and ecosystems. The obtained data has been used to model the effectiveness of various remediation strategies. Through the integration of hydrological and ecological methods we aim to increase our understanding of ditch remediation and ultimately support farmers, landowners, and authorities in the design of cost-effective mitigation measures.

Catchment vulnerability ranking for losses of pesticides to surface water: development of methodology and WaterProtect webtool

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Continued and intensive use of pesticides has resulted in the wide-spread presence of pesticides in the environment. While pesticides are typically applied on crops or the soil, different transport mechanisms lead to elevated concentrations of pesticides in ground- and surface waters. Detailed monitoring and/or modelling studies of pesticides in surface waters have been conducted to investigate the potential sources and pathways of pesticides to surface water and assess the impact of mitigation measures taken.

In order to apply the findings of these studies to other sites it is important to put these catchments into context and to assess how vulnerable they are for the presence of pesticides in surface water. Such a vulnerability ranking index can furthermore be used as a decision tool for the selection of catchments for new detailed monitoring studies or to identify the locations where mitigation measures might be most appropriate.

To that end, a catchment vulnerability ranking method has been developed for the presence of pesticides in surface waters. The vulnerability of catchments is assessed based on a hybrid GIS approach which considers both the pesticide emissions from surface runoff and soil erosion and explicitly takes into account land use and the connectivity of the landscape. This method has been applied to Flanders, a region characterized by frequent exceedances of pesticide environmental limits in surface waters and where a number of detailed monitoring studies, as well as data from a broad monitoring network, are available.

The catchment vulnerability ranking index will be added to the WaterProtect Belgium webtool, a tool for geospatial analysis of pesticides in groundwater and surface water. Inclusion in the tool will allow users to easily identify catchments that are prone to the presence of pesticides in surface waters and to guide them in selecting locations for priority monitoring and mitigation while also providing the currently available monitoring data in an easily interpretable and applicable way.

Water quality benefits and legacies of reducing MCPA spraying in river catchments using an incentive scheme

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On the island of Ireland, the herbicide 2-methyl-4-chlorophenoxyacetic acid (MCPA), which is highly soluble in water, poses a significant threat to surface water quality because of its widespread use to control common rush on grassland soils. Over 99% of Northern Ireland's, and 80% of Ireland's, drinking water is sourced from surface waterbodies and, in some areas, MCPA concentrations exceed the EU drinking water limit of 0.1 µg/L in treated drinking water.

The INTERREG VA Source to Tap project implemented a pilot Land Incentive Scheme (LIS) in the cross-border Derg catchment (Co. Tyrone and Co. Donegal) between April 2020 and October 2021. This scheme encouraged farmers to alter agricultural practices, including swapping boom spraying of MCPA for contractor-provided weed wiping with glyphosate, through 100% grant aid. In order to explore the impacts of the LIS on pesticide concentrations in surface water, a high-resolution (7-hourly to daily) monitoring program has operated in the 384km^2 Derg catchment, and in the comparable Finn catchment (but with no LIS) since May 2018. This provided nearly two years of baseline data, 18 months of data during the LIS and two years since the LIS concluded, offering an opportunity to assess the impact and legacy of the LIS.

Additionally, a spatial sampling campaign was carried out in the Derg between March and June 2018 and between March and June 2023. This allowed identification of sub-catchments with high MCPA levels and to explore localised impacts of the LIS.

Before the LIS, 37% of MCPA concentrations in the Derg and 49% in the Finn exceeded 0.1 µg/L during the spraying seasons (April-October). During LIS implementation, this was 34% and 47% respectively, but after the LIS conclusion, only 26% of MCPA concentration in the Derg were over 0.1 µg/L compared to 45% in the Finn. Likewise, calculated MCPA loads in the Derg were substantially lower than those in the Finn by the end of 2021 and this change was maintained throughout 2022. Whilst there was a slight positive trend in glyphosate concentrations in both catchments through time, there was no significant difference between the rate of increase in the Derg and Finn, indicating there was no pollution swapping. These results will be updated with summer 2023 data and will be complemented by preliminary results of a behavioural study of farmers in the Derg catchment focused on the impact of the LIS on farmer awareness of, and engagement with, the impacts of MCPA use on water quality.

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Quantifying nutrient and sediment erosion and valuing mitigation at riverbank cattle access points

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In agricultural river catchments, excess instream sediment deposits can be attributed to eroding riverbank soil from unrestricted livestock access. This can lead to elevated turbidity, siltation of riverbeds, nutrient enrichment and increased bacterial pollution. Agri-environmental schemes with water quality objectives often include riparian management options such as fencing. While unrestricted cattle access to rivers is recognised as an important pressure on water quality, there is a lack of data on the order of magnitude of its contribution to soil transfer from riparian zones and the cost-effectiveness of fencing as a mitigation measure.

This study addressed this research gap by using high resolution aerial photogrammetry and terrestrial laser scanning (TLS) to measure cumulative, seasonal and annual erosion rates from nine unmitigated cattle access points in two river catchments. These data, combined with bulk density and deep soil core sampling of exposed and adjacent bank faces, gave estimates of total mass sediment, fine sediment and total phosphorus (TP) transfers from riverbanks at cattle access points. An initial analysis of cost-effectiveness of fencing was based on the cost of replacing total soil/sediment loss compared to the cost of installing riverbank fencing per metre.

Eroded cattle access points had cumulatively lost 0.19 – 2.16 t m^{-1} of soil expressed as mass per linear length of riverbank, mostly as fine sediment (<2mm). The analysis also showed that cumulative TP losses were 0.134 – 0.587 kg m^{-1} of linear riverbank. The TLS measurements of annual soil losses from cattle access points were 0.19 – 0.21 t m-1 yr^{-1} corresponding to a TP transfer of 0.065 – 0.087 kg m^{-1} yr^{-1}. Most losses occurred in the presence of cattle during the grazing period.

Based on annual total sediment losses, livestock exclusion fencing is proposed as a cost-effective measure. For example, on a per unit length of bank, fencing costs would be 13 % - 14 % of the cost of importing topsoil for repairing bank faces when calculated over the 5-year term of an agri-environmental scheme. This decreases to 4 % - 5 % over the 15-year lifetime of a timber post and wire fence. Costs, however, scale to the length of field boundaries with cattle access scars. These results are important to farmers and policy makers and will be discussed in the context of agri-environmental schemes which aim to improve water quality in grazed grassland catchments.

Effect of Plantain Inclusion on Nitrate Leaching from a Grass Clover Sward across Five Soils

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A recent report published by the Department of Housing, Local Government and Heritage stated that 47% of river sites in Ireland have unsatisfactory nitrate concentrations. Water quality, including nitrate levels in the water, is a key factor being considered by the EU Commission relating to Ireland's organic N stocking rate limits. Free-draining soils are particularly susceptible to nitrate loss with a high potential for nitrate to leach into the groundwater during times when water is moving through the soil profile such as the autumn, winter and spring periods. For Ireland to achieve its targets set out by the Water Framework and Nitrates Directives, tools to mitigate against nitrogen leaching in pasture systems are needed. Plantain is a plant species with good agronomic and nutrient uptake characteristics. There is growing scientific evidence that plantain inclusion in swards may mitigate against nitrate leaching in pasture systems, in particular by reducing leaching from urine patches, which are zones of high nitrogen concentration.

In the current study, nitrate leaching was measured from five soils each with three sward treatments in soil lysimeters of one meter in depth. The treatments were (1) perennial ryegrass & white clover, (2) perennial ryegrass, white clover & 30% plantain, and (3) perennial ryegrass, white clover & 50% plantain. Leaching measurements commenced in autumn 2021 and are scheduled to continue until autumn 2023. The soils of the lysimeters covered a range of drainage classes' varying from a poor-draining clay to a very well-drained sandy loam. An initial application of cows' urine was applied to the lysimeters in autumn 2021, followed by a further one in winter. In the summer of 2022, a slurry application was applied and repeated in winter. A final urine patch was applied in the early summer of 2023. The preliminary results indicate reduced nitrate leaching in the lysimeters where plantain was included in the sward for some soils giving a preliminary indication that plantain has potential to reduce nitrate leaching in pasture systems. Full results will be presented.

Improving water quality through catchment science and advisory engagement with farmers

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The EPA monitored bathing waters in Lough Ennel at Liliput were identified as being as risk of losing its designated bathing water status due to elevated levels of pathogens (E.Coli) in 2018 and 2019. A contributing water body to the lake, Dysart_010, was selected as a Priority Area for Action (PAA) in the River Basin Management Plan for Ireland 2018-2021. This waterbody was identified as having agriculture as a significant pressure on water quality and came under the remit of the ASSAP* programme.

The ASSAP programme is a collaborative approach to addressing agricultural pressures on water quality and works closely with LAWPRO**. It involves a catchment science approach to identify pressures on water quality from agriculture and other sources, and an advisory service to help farmers to adopt practices or measures that will reduce the loss of contaminants to waters.

The LAWPRO catchment scientists undertook a comprehensive local catchment assessment process in the Dysart_010 to establish the necessary scientific evidence to identify the significant pressure(s), the pathways, the locations and potential actions to mitigate contaminant losses from agriculture. This information was referred to the ASSAP advisors who in turn contacted farmers in the areas identified and assessed farms for issues that may be impacting on water quality.

In the Dysart_010 the ASSAP advisors identified a number of issues on farms based on LAWPRO referrals that were impacting on water quality in the Dysart Stream and the bathing waters at Liliput. These included cattle access to the stream for drinking and the incorrect use of buffer margins for organic manure spreading. These practices were contributing to the pathogen load in Liliput. Advisor/farmer engagement in 2020 led to mitigation actions being put in place to minimise pathogen losses to waters. This resulted in the levels of pathogens dropping in mid-2020 to levels compliant with bathing water requirements.

This case study is an excellent example of science, knowledge exchange and stakeholder engagement working together to realise water quality improvements.

* ASSAP – Agricultural Sustainability Support and Advisory Programme

**LAWPRO – Local Authority Waters Programme

Behavioural approaches to water quality improvement – findings from WaterMARKE

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As part of the WaterMARKE project, the project team worked closely with ASSAP advisers in order to make recommendations on how to achieve wider adoption of water quality improvement measures. This largely involved using a number of behavioural approaches to examine the adoption of water quality improvement measures. The studies ranged from (a) the implementation of the COM-B (Capacity, Opportunity, Motivation-Behaviour) psychology approach in undertaking separate focus groups with ASSAP farmers and advisers, to reveal the COM-B drivers of behaviour relevant for water quality, (b) classification of ASSAP measures in relation to their behavioural attributes e.g. knowledge required/ease of use, costs involved and the acceptability of measures to farmers and (c) using the Theory of Planned Behaviour to develop a generalised model of the behavioural attributes of a suite water quality improvement measures. This paper describes the methodologies and data used and the findings of the studies, presenting recommendations for advisory and policy users.

Investigating bottlenecks hampering the adoption of water quality-enhancing practices for sustainable land management in Ireland

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Across the European Union (EU) agriculture is the biggest source of water pollution today, which predominantly contributes to the non-point pollution of water in the EU. Sustainable land management practices are necessary to mitigate the water quality challenge. Multiple actors are advising farmers about the adoption of these practices. This research aimed to investigate the bottlenecks hampering the adoption of advised sustainable land management practices.

The scaling of adopted measures on farms is often proposed however, the factors that inform the non-adoption of advised measures are typically overlooked. A better understanding of these factors could offer important insights for overcoming the bottlenecks for adoption and therefore offer important potential with respect to addressing agri-environmental challenges. We investigated the factors hampering the adoption of sustainable land management practices advised by the main agricultural extension service of Ireland.

A large dataset (N=760) containing farmers' reasons for rejection of advised practices was analysed to identify bottlenecks for adoption. To do so, a qualitative approach was utilized where farmers' reasons for not adopting were categorized into the theoretical framework based on social judgement theory and the layers of acceptance. Our research showed that rejection can be explained by different underlying reasons.

Overall, it can be concluded that the adoption of advised sustainable land management practices aiming at water quality improvement are most impeded by the diverse consequences perceived by the farmer, the aging farmer population and land ownership challenges. In the acceptance of the diverse consequences especially the costs and practicality associated with the advised practice were considered barriers for adoption. While subsidies exist for implementing sustainable land management practices, incentives to implement are insufficient and costs remain the main barrier for adopting sustainable land management practices.

Next to an analysis of the reasons for rejecting all advised practices, we investigated the three main sustainable land management practices advised in-depth. The differences in barriers for adoption between these practices showed the need for nuanced communication to enhance uptake. In order to reach water quality targets through enhanced uptake of sustainable land management practices, advice should be framed and tailored to farmer objectives.

Catalogues of agro-environmental measures – for communication about effect and functionality

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In many research and collaboration projects, the production of catalogues that describe environmental measures and their efficiency and functionality is included. The catalogues gather knowledge among partners and contribute to the sharing of experiences. The catalogues are published as reports or in web-based interfaces, or in a combination of both. When the project ends the information in the catalogue is seldom updated.

Information about environmental measures is required in the whole scale from farm to EU-level. The farmer and agricultural advisor want to know about applicability on the farm, the national authority need information about environmental efficiency for the planning of policy measures as regulations and subsidies but also for the evaluation of already implemented measures. In parallel, the business sector requires the information for environmental accounting on their products.

Here, the potential to combine various needs and information into an active and continuously updated catalogue is explored. Measures from field to stream will be included, for example in soil and crop management, in drainage systems, and in streams as wetlands and buffer zones. Main focus is water and nutrient retention but also aspects as soil carbon balance, climate gas emissions, increased landscape diversity and biodiversity. The information is evidence based but experiences from landowners and users will also be included. A matrix systemize all aspects and show existing gaps.

The catalogue framework is developed with partners in national and international projects, and in collaboration with Swedish stakeholders at local and national level. The expected outcome is a web-prototype showing a selection of measures that could be linked to the Swedish national water management system.

The establishment and use of local coastal water boards is tested in Denmark to find bottom-up solutions for RBMP 2027

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The Danish EPA has drafted a 3rd River Basin Management Plan (RBMP) under the Water Framework Directive setting target nitrogen loads for each coastal water and overall plans for how to reach the reduction needed from coastal catchments. This RBMP was in a public hearing in spring of 2022. The Danish Government has also initiated four projects which engages stakeholders around four of the 109 coastal waters and catchments in Denmark to help finding local solutions for the RBMP to be implemented in 2027 under the WFD. One of these new projects areas are focusing on the Hjarbæk estuary situated in Limfjorden being one of the coastal water bodies in Denmark that needs the highest reductions in nitrogen loadings to be achieved before 2027 (ca. 65 %) as compared to the status loading (2016-2018). This new project involving a coastal water board with all main stakeholders in the region being represented was initiated in February 2023 and has to deliver proposals for 1-2 scenarios before the end of 2023 that can assure that the Hjarbæk estuary reach the target of achieving good ecological conditions. The organizational structure of this new coastal water board project includes a coastal water board with 18 stakeholder representatives for the region, a secretariat lead by municipality of Viborg and the Limfjord Council and a technical working group with representatives for the stakeholders, the secretariat and representatives for experts being affiliated to the project in different work packages.

The requirements under the present River Basin Management Plans (RBMP) for the EU Water Framework Directive (WFD) are to reduce the total nitrogen (TN) loadings to the Hjarbæk estuary in Denmark from the present (2015-2019) annual status loading of ca. 1730 tonnes N to a modelled target loading of 637 tonnes N in 2027. The catchment area to the estuary represents a total of 1177 km^2 and the catchment is drained by four major streams. The Danish national monitoring programme has established gauging stations covering 969 km2 of the catchment area the remaining 208 km^2 being ungauged areas. Modelled data on N-leaching from the root zone on agricultural fields and surface water monitoring data on N-export losses are available from the 1980'ies and onward. A detailed mapping of nitrogen (N) attenuation in the catchment have been conducted at a scale of ca. 15 km^2 (ID15 sub-catchments) including mapping of both N-retention in groundwater and surface waters as well as N-delays in groundwater in Karst sub-catchments. The mapping shows huge differences in N-retention in groundwater within the ID15 sub-catchment (<20 % to >80 %) and the same large variation is seen for N-retention in surface waters (<20 % to >80 %). An analysis of delays in the transport for N from fields to surface waters have shown that especially one of the four monitored catchments experiences a long delay in N responses (> 10 years).

The local engagement of stakeholders representing all sectors in the catchment and estuary will work setting up a minimum of two scenarios that includes: i) marine mitigation measures such as mussel farming and improving water exchange through the diked estuary; ii) reductions in point source loadings; iii) use of a new portfolio of N mitigation measures to be adopted at source (e.g. catch crops, early seeding, set a side, afforestation, etc.); iv) use of transport mitigation measures from field to surface water (several types of constructed wetlands, riparian buffers and restored wetlands); v) the possible use of different phosphorus mitigation strategies in the catchment (lowering bank erosional P-losses, buffer strips, afforestation, etc.).

Farmer's attitudes towards growing catch crops in a catchment with high stream water concentrations of $N0_3$-N

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In tillage farming, catch crops are shown to be effective in reducing nitrate leaching to groundwater through the uptake of N during the fallow period between crop harvest and subsequent planting of the next crop. Catch crops sown currently in Ireland are used to meet agri-environmental scheme requirements such as schemes such as the Green Low-Carbon Agri Environmental Scheme (GLAS) and the Agri-Climate Rural Environment Scheme (ACRES). This study aimed to investigate and analyse farmers' knowledge, experience, and perspectives on catch crops in order to understand how extension services can improve and encourage increased adoption of catch crops to address the water quality issue faced by agriculture in Ireland. A mixed methods approach was adopted, including a literature review, key informant interviews, a questionnaire, and semi-structured interviews with farmers. The study found that catch crops are viewed positively by farmers, with a significant proportion motivated by their positive impact on soil health and structure. Incentivizing farmers through schemes such as GLAS can have a positive impact on their motivation to continue growing catch crops beyond the time horizon of financial incentives. Participatory extension approaches such as discussion groups and demonstrations, collaboration with industry representatives, public agencies, and policymakers, and ongoing support and guidance were identified as important in promoting the adoption of new practices. The study recommends discussion groups as an effective way to provide farmers with the support and guidance they need throughout the year. The study concludes that catch crops have the potential to provide significant environmental benefits on tillage farms in Ireland, and that participatory extension approaches can be highly effective in promoting their adoption.

Land leases and the implementation of structural agri-environmental measures (AEMs)

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In many EU member states (MS) a significant portion of agricultural land is leased out by landowners to farmers, who in turn manage this land. In Sweden, around 40% of all agricultural land the right of use belongs to the leaseholder and not the owner. In Germany, this figure is closer to 50%. Similar values are seen in other MS and are increasing (although in some MS and EU regions for historical reasons shares of leased land can exceed 75%, but are decreasing). Adoption of structural AEMs, e.g., wetlands, buffer zones, two-stage ditches, regulated drainage among others may have a negative impact on agricultural productivity through higher water levels, reduction in available land and other factors. Reductions in agricultural productivity can lead to lower economic returns for the farmer but not necessarily for the landowner. Therefore, implementation of structural AEMs on leased agricultural land will depend on the national legal rights and responsibilities assigned to land owners and those leasing land. The legal ramifications of land leasing need to be understood to better comprehend barriers that may limit the potential for implementing measures. This study analyzes the legal framework of leasing contracts in Sweden with respect to the possibility of implementing land based structural AEMs on agricultural land. Although legal rights are country specific, the analysis in this study illustrates the complex relationship between landownership, right of use, land use management and the adoption of structural measures beneficial to the environment and society.

Collaborative approach to identifying and removing the barriers to water quality improvement

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The implementation of mitigation measures by farmers to minimise the loss of nutrients, sediment, pesticides and toxic substances to waters is key to improving water quality. These measures need to be the 'right measure in the right place, (at the right time)' and the ASSAP* programme engages with farmers to identify what the most appropriate measure is. While farmers engaged positively with the ASSAP programme and agreed to implement suggested mitigation actions 93% of the time, when it came to implementing measures on the ground the data recorded by advisors indicated that farmers declined to implement certain measures.

Advised measures range from implementation of existing regulatory measures to the implementation of supplementary measures; measures that go beyond regulatory requirements. Data from the ASSAP programme, gathered from discussions with farmers, identified a number of barriers to the implementation of supplementary measures. However, the cost to the farmer of implementing supplementary measures was identified as being a significant barrier to the carrying out of certain key measures.

A review of ASSAP, commissioned by the funding departments, DAFM** & DHLGH***, and conducted by an independent expert panel, identified as a key recommendation that 'financial support, external to the ASSAP, needs to be available to enable farmers implement agreed actions recommended by ASSAP advisors'. This provided the impetus for ASSAP to explore options for securing funding for farmers for measures recommended by advisors.

A process of engagement with stakeholders and discussions with both DAFM & DHLGH identified that the most appropriate mechanism for provision of funding to farmers to implement supplementary measures to improve water quality was though a Water EIP**** with €60 million in funding being provided over 5 years.

The journey from farm yard discussions between advisors and farmers identifying a barrier preventing water quality improvements to the successful securing of funds through the Rural Development Programme and CAP Strategic Plan for a Water EIP is a positive reflection on the strength of the collaboration and commitment of all stakeholders concerned with achieving national and EU water quality targets.

*ASSAP – Agricultural Sustainability Support and Advisory Programme

**DAFM – Department of Agriculture, Food and Marine

***DHLGH – Department of Housing Local Government and Heritage

****EIP - European Innovation Partnership

The role of innovation in Nitrogen Use efficiency on Irish Dairy farms

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Irish dairy systems are primarily a grass based production system with cows grazing outside for most of the year. Grassland management is therefore an essential element of Irish dairy production systems, and Irish dairy farmers are reliant on Nitrogen, both chemical and organic, to ensure an adequate supply of grass during the grazing season and to produce grass silage for the housing period. However, excess application on N fertilizers can have an adverse effect on the environment, in particular, high Nitrogen surpluses have the potential to run off into watercourses and have a negative effect on water quality. Using National Farm Survey data from 2013 to 2021, the role of innovation including low emission slurry spreading, the percentage of slurry spread between January and April, and the percentage of Nitrates in feed concentrates are found to be highly significant drivers of Nitrogen Use Efficiency on Irish dairy farms

Actions required to adhere to Irelands 5th Nitrates Action Programme: Farmer preferences and policy implications

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This research investigated how Irish Dairy farmers will respond to a significant policy changes under Irelands 5th Nitrates Action Programme (NAP). While the changes required at farm level are mandatory and legally binding, there are a number of different pathways that farmers can choose that will ensure overall compliance with the policy. These different choices involve decisions around farm management practices, farm investment, farm labour decisions and changes around existing farm systems. Costs associated with each choice may also differ so farmers will also need to consider whether to increase capital investments and increase debt levels on the farm. Key informant interviews were carried out in order to rank the eleven significant changes in Irelands 5th NAP and identify the top three changes that experts considered the most important in terms delivering water quality improvements. The key informant ranking forms the basis for farmer surveys around decision making at farm level. Key findings from this research include a lack of awareness prior to the introduction of the new measures. Supports in the form of knowledge transfer and financial aids will be required by farmers, and concerns that non-compliance by some farmers is leading to stricter rules for all.

Assessing circularity on mixed crop and livestock farming systems

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Given the present circumstances of a growing global population and the rising need for food, coupled with limited resources and the effects of climate change, the concept of the circular economy (CE) offers a promising approach to promote the development of environmentally sustainable agricultural systems. The concept of the circular economy (CE), or circularity, describes a process in which elements form closed loops or cycles, an alternative to the linear process paradigm. While the implementation of CE strategies has gained traction in various industrial sectors over the last decade, the adoption of circularity principles in agricultural systems and practices is relatively less developed. Indeed, the linear structure of agricultural production poses a challenge to defining circularity at the farm level, and there exists ambiguity regarding the specific conditions that constitute circularity. Inspired by the circular bio economy principles developed by Muscat et al. (2021), this research paper aims to address this knowledge gap and devise a farm-level index for evaluating circularity on mixed farm systems for dairy production.

Data to develop the circularity index will be attained from case study farms in seven partner countries collaborating with the DairyMix project. A data collection survey was finalised in February 2023, incorporating a wide array of variables and questions pertinent to economic, environmental and social attributes for the mixed crop and livestock systems on the case study farms. A literature review identified studies from academic works on the subject of the circular economy for agricultural systems, with the purpose of identifying representative indicators aligned with the five bio-economic principles of Muscat *et al*. (2021), namely safeguarding, avoiding, recycling, prioritising, and entropy. Comprising of both qualitative and quantitative elements, each indicator was critiqued and validated by the project partners prior to inclusion in the survey, to ensure their relevance and efficacy for farm level circularly assessment. Data is currently being collected from case study farms, with data analysis due to start in June 2023. Following this, the results from the circularity index, as well as additional models and tools examining carbon and nutrient utilisation will be incorporated into the DairyMix information platform. This multi-actor knowledge hub is designed to increase understanding and knowledge of sustainable dairy production systems, and to enhance the communication and dialogue between farmers, science, stakeholders and policy.

Investigation of farmer's willingness to adopt anaerobic digestion in Ireland using a questionnaire

Mahony S., Deasy M., Moran B., Thorne F.

The reduction of greenhouse gas (GHG) emission for agricultural activity by 25% by 2030 is targeted in climate action plan. Anaerobic Digestion (AD) has been identified as a technology that can produce renewable energy from agricultural waste along with silage, while also reducing GHG emission. AD would improve Irish farmer's management of waste, produce a more effective fertiliser from organic manures and provide an extra source of revenue for farmers.

A questionnaire was provided to farmers that are involved in the TEAGASC, National Farm Survey (NFS), to seek their point of view on adopting AD, as farmers would be the primary adopters for the supply of feedstock for this new technology. An information flier with a brief description of the AD process was provided to farmers to get a better understanding of the technology. The farms in the NFS are weighted to be nationally representative across Ireland for different farm sizes and systems.

The initial finding showed that over 62% of farmers were not willing to participate in adopting AD. Whereas, 20% of farmers were willing to adopt AD. The majority of farmers were not willing to supply slurry, silage or join a co-operative. However receiving the fertiliser, in the form of digestate that comes from the AD plant had a higher percentage uptake of 46%.

Analysis was carried out to investigate the results from the survey and identify the key factors that are effecting or influencing farmer's willingness to adopt AD. A broad range of factors were assessed including; farm size, system, profitability, age, formal education level, production of silage and previous capital investments.

The low willingness to adopt AD in these results may be due to a lack of awareness of the process and benefits of AD for farmers, which was observed during trialling the survey. Different farm systems and sizes were examined and the preliminary results showed no differences. A better insight into the factors is needed to understand the barriers and obstacles farmers face in adopting AD.

POSTER PRESENTATIONS

On farm evaluation of catch crop biomass yield and crop nitrogen uptake

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All farming sectors in Ireland have to reduce nitrogen (N) loss and improve N use efficiency, in order to restore all water bodies to a good status by 2027. On free draining, nitrate leaching prone sites, research has shown that overwinter green cover can substantially reduce nitrate leaching to ground water from fallow crop land. The Agricultural Catchments Programme has been monitoring a tillage dominant river catchment in Castledockrell, Wexford since 2008 and has in recent years been focusing on winter green cover research. Ireland's 5th Nitrates Action Programme (NAP), requires in all circumstances that 75-80% of harvested crops be shallow cultivated or sown with a crop within 14 days of harvest. In 2021, four on-farm sown catch crops in the Castledockrell catchment were selected with a range of sowing dates for sampling, the dates of which were as follows: 10th August, 20th August, 4th September and 10th September. Three of the crops followed spring barley and one followed a crop of winter barley. All catch crops were a forage rape (*Brassica napus* L.) and leafy turnip (*Brassica rapa* L.) mixture sown at 8kg per hectare (ha). At each site four random above ground biomass samples were taken at six time points between September 30th and December 20th for dry matter and nitrogen concentration determination. Results show that August sown crops yielded much more biomass than the September sown crops throughout the sampling period. In addition those that were not grazed, had a peak uptake of nitrogen of 48 kg/ha N and 43 kg/ha N for the 20th August and 4th September sowing dates. In conclusion, this on farm study shows the importance of sowing catch crops as early as possible after harvest in order to get a peak crop yield of over 1000 kg DM/ha.

Assessing the Mineral Fertiliser Nitrogen Replacement Value of Dried Poultry Manure in Spring Barley Cropping

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In 2020, the number of poultry in Ireland was 16.5 million (CSO, 2020); a significant source of manure. The fertiliser replacement value (FRV) of manure impacts the economics of transport and determines the mineral fertiliser balancing requirement. In cereals understanding the nitrogen (N) FRV is particularly important to avoid lodging, yield loss or to produce grain with protein meeting requirements. The MRFV of a dried poultry manure was tested at a well-drained experimental site (52°48'51.16" N 6°8'39.56"W). The experimental design was a randomised complete block with four replicates per treatment. The poultry manure was from a modern poultry house with manure drying facilities. The manure dry matter (D.M.) was 88.1% and manure contained 38.1, 11.3 and 22.9 kg of N, P and K, respectively per tonne D.M. Ploughing, treatment application and sowing were completed on 31 March. P, K, Mg & S to ensure this nutrients were not limiting was applied to all plots. Poultry manure was applied at six N rates. The mineral fertiliser treatment N was calcium ammonium nitrate (CAN) (50 to 250 kg N ha^{-1} in 50 kg increments). Crop yield, grain protein and total crop N recovery were measured at harvest. Spring barley grain yields responded strongly to mineral fertiliser N and to manure application reaching maximum yields of 10.2 and 10.3 t/ha, respectively. In comparison the zero N control yield was 6.0 t/ha. The N in poultry manure was currently assumed to be 50% available in the season of application. Results from this trial indicates that the N-FRV of this dried poultry manure exceeded 50%. Results will be presented. Poultry manure, particularly dried manure, is a concentrated nutrient source relative to other manures/slurries. It's relatively high nutrient concentration lends itself to transport over longer distances than liquid slurries.

Assessing the socio-economic impacts of soil degradation on Scotland's water environment

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Soil degradation leads to a loss of natural capital and ecosystem services such as: flood prevention, pollutant removal, drinking water availability, crop yields and carbon sequestration.

We will present preliminary findings on the on-site and off-site socio-economic, and environmental costs of the physical, chemical and biological soil degradation of Scottish soils including compaction, sealing, contamination, loss of organic matter and soil biodiversity.

We review the processes and impacts of soil degradation and how they can be linked to costs including income forgone due to yield loss and the replacement value of lost nutrients, willingness to pay for public infrastructure to protect against flooding and market costs of carbon loss, particularly from organo-mineral soils and peat.

We will use this to build a framework for the assessment of costs and the Scottish data and methods available to identify the likely spatial distribution of soil degradation and the impact of these on water quality and quantity and the wider environment.

We will show how this wider framework builds on and links to previous work on calculating the cost of soil erosion to the Scottish economy, assessing the extent of soil compaction and its impact on runoff and mapping the pathways of diffuse pollution. We will also demonstrate the use of Scotland's soil risk mapping in the assessment of degradation and outline some of the challenges in dealing with double counting in the assessments of the costs.

Effects of grassland management intensity on nitrate leaching losses

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Nitrate leaching from intensive grassland systems is an important contributor of nitrate contamination of water resources in Ireland. The aim of this study was to determine nitrate ($N\text{-}NO_3^-$) leaching losses as affected by different grassland management intensity by establishing lysimeter monitoring sites on different farms within the selected catchment. The study catchment represents one of the most intensively managed agricultural areas with predominant well drained soils (Brown Earth/Cambisol) vulnerable to nitrate leaching. Twelve ceramic cup samplers were installed at each site to collect drainage at 90 cm depth. Drainage samples were collected for 2 years during the winter drainage period. Two sites were monitored in year 1, while additional 2 sites were added in year 2. The sites differed in terms of stocking rate (0.66 - 2.66 LU/ha), N input (50 - 192 kg N/ha) and grassland management (grazing paddock, silage + grazing, zero grazing). The seasonal $N\text{-}NO_3^-$ leaching losses during year one were 18.4 and 53.6 kg N/ha for low input pasture and intensive grazing paddock, respectively. Mean nitrate concentrations in drainage were 5.8 and 14.1 mg $N\text{-}NO_3^-$/l. Year 2 results are still to be processed fully and the results are therefore inconclusive. However, early results suggest significant differences between the monitoring sites in terms of both nitrate concentrations in drainage and the total amounts of $N\text{-}NO_3^-$ leached. $N\text{-}NO_3^-$ losses will be plotted against effective rainfall, stocking rate, grazing duration and N input in order to determine the main driving factors of nitrate leaching.

Conceptual framework on using DNDC model for informed nitrogen management strategy in Irish dairy farm pastures

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Nitrogen (N) is one of the major nutrients applied in organic and inorganic forms for grass production in grazed grasslands under Irish dairy farms. Surplus N can be lost from soil to water and air, resulting in economic losses and environmental consequences such as eutrophication, and global warming. Reducing N loss from agriculture and increasing N use efficiency (NUE) is a key ambition for Irish agriculture in line with national and EU policy targets. This research proposes that current nutrient management planning within the NMP Online tool can be refined by better accounting for diverse soil, weather and management regimes. Process-oriented models that connect soil, climate, weather and management with N dynamics can be useful to support such refinement. DNDC (*De Composition and De Nitrification*) is one such process-oriented model that processes inputs on soil, weather and climate, and management to simulate carbon (C) and N dynamics. It has been shown to provide good simulation for N dynamics in intensively managed Irish grasslands. Conversely, there is limited research directly in relation to its performance in modelling grass growth rate and annual grass yield in an Irish context. In addition, the best spatial resolution for DNDC simulation, between paddock and farm level, and level of generalization of soil inputs with which DNDC can provide acceptable simulations, is unknown. If found to be reliable, DNDC can be used to support informed N management in Irish grasslands through: (i) identifying the possible impact of N fertilizer application rate and timing, grazing intensity on N loss under different soil and weather conditions during different meteorological seasons and grass growth phases, and (ii) identifying the key factors regulating grass yield and N loss through sensitivity analysis for modelling optimum N requirement for desired grass yield. In this work the performance of DNDC and its potential use for sustainable N management in grasslands is assessed. The results from the current stage of this research indicated that DNDC can provide good simulation of grass growth at paddock and farm level, both under specific and Irish Soil Information System based soil inputs. Farm level simulations were found to be better than paddock level under both soil input scenarios. In general, this indicates scope for broader replication in Ireland and elsewhere.

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Effect of land management on carbon dioxide fluxes

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In Ireland the Department of Agriculture, Food and the Marine (DAFM) monitors the implementation of NAP through the Good Agricultural Practice (GAP) regulations. The DAFM has funded the Agricultural Catchments Programme (ACP) to monitor the effectiveness of GAP measures since 2008. More than a decade later, the ACP has expanded its baseline data collection to include the monitoring of greenhouse gas emissions (GHG) and soil carbon sequestration to align with national and European policy. To do this, a network of five eddy covariance flux towers were established to monitor net ecosystem CO_2 exchange (NEE), gross primary productivity (GPP) and ecosystem respiration (Re) in three grassland types (intensive dairy grazing, drystock grazing and zero-grazing) and one arable site in geographically distinct agricultural catchments in Ireland. The initial results show larger magnitude of NEE, GPP and Re in intensively grazed and zero-grazed grasslands that are subject to frequent grazing/defoliation followed by recovery of photosynthetic potential. The continuously grazed drystock grassland exhibited lower NEE and GPP rates but smaller seasonal fluctuations in daily fluxes which may reflect the reduction in nutrient availability to support higher GPP. However, the drystock grazed grassland had significantly higher soil water content which may stimulate higher soil CO_2 respiration resulting in lower NEE over time. The arable site showed that greater NEE corresponded with increases in leaf area to DOY140. There was sustained C uptake during grain filling, however, ecosystem respiration exceeds net photosynthesis ~3 weeks before harvest date. Management practices involving defoliation and nutrient supply influenced affected season CO_2 exchange but longer-term flux monitoring is required to assess the net ecosystem carbon budgets of each system.

Effect of forest restoration on greenhouse gas emissions from a small headwater stream, Eifel/Lower Rhine Valley

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Riverine systems are distinct components of the natural environment which have significant roles in storing and processing terrestrial carbon. While processing organic matter, rivers release large amount of greenhouse gasses to the atmosphere. In this light, headwater streams are particularly interesting. Due to their high connectivity with the surrounding landscapes, these small streams are strongly influenced by terrestrial inputs of carbon and groundwater inflow. The first order streams have a disproportionate effect on terrestrial carbon budgets. The amount and character of carbon inputs to headwater streams are highly dependent on vegetation types, especially between spruce and beach forests.

The aim of this research is to characterize dissolved organic carbon (DOC) and greenhouse gas emissions (GHG) in two headwater streams from a spruce and newly restored beach forest.

The present study is carried out in the Wüstebach stream, Eifel/Lower Rhine Valley (Germany). This headwater stream is a part of the Terrestrial Environmental Observatory (TERENO) network. The stream flows through the forest, the site of a restoration project in which 9ha of planted Norway spruce was cleared in 2013 and has been replanted with original beech. The sampling strategy of the study considers collection of three GHG (CO2 CH4 and N2O) samples weekly, at eighteen sampling points in Wüstebach, for a year. In October-November 2022 a preliminary sampling campaign was carried out. The poster presents results of this study.

The results show spatial variation of CO2 CH4 and N2O concentrations along the main stem of the Wüstebach and influences of organic inputs from the tributaries. There is a clear decreasing pattern of CO2 concentrations along the river gradient. There are three methane “hotspots”, which can be explained by low flow velocity and visible higher amounts of organic matter. There is no noticeable trend along the stream, but generally, N2O concentrations are decreasing further from the source. The preliminary conclusions are:

- The Wüstebach and its tributaries are net sources of GHG to the atmosphere.
- The concentrations of CO2 decline along the 500m study reach from the source, indicating a significant source of groundwater to CO2 in the stream and physical control on CO2 evasion along the reach.
- In contrast, CH4 shows more spatial variability with hot spots corresponding to a wider, vegetated pool, suggesting localized controls.
- CH4 concentrations were higher in the control stream compared to the clearcut area, CO2 concentrations were higher at clearcut area and N2O concentrations did not differ much.

Effectiveness of afforestation for carbon sequestration in Ireland and influencing factors

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This paper provides a comprehensive analysis of afforestation as a carbon sequestration policy in Ireland by reviewing scientific and grey literature. The examination incorporates findings from various studies encompassing forestry science, land use change, soil science, ecology, and hydrology to explore the role of afforestation in carbon sequestration across Ireland, Britain, and New Zealand. Specifically, the review focuses on different aspects of carbon sequestration, including tree types, individual or small groups of trees, and trees within forested areas. Additionally, it investigates the impact of forest planting regulations and management practices in different soil types such as mineral or peatlands.

To assess carbon sequestration values, the review utilizes diverse methodologies such as eddy covariance, physiological approaches/algometric equations, revealed or stated preference methods, and value transfer techniques. Initial results estimate the carbon stock in forests to be around 3.36 t C/ha per year. However, employing eddy covariance, it is revealed that annual sequestration rates during the first Kyoto commitment ranged from 4-8 t C/ha per year by 2012.

The literature review suggests that broadleaf tree species have a greater potential for carbon sequestration compared to conifers. Nevertheless, a body of research reports no significant or negative change in carbon stocks resulting from afforestation. These contradictory findings contribute to the complexity and uncertainty surrounding the accurate assessment of afforestation's impact on carbon sequestration.

Considering various factors is crucial in interpreting the findings of impact assessments. Factors such as site characteristics (soil class, soil type), tree species (broadleaves or conifers), the duration of afforestation, and management practices (thinning or no-thinning) should be taken into account. However, accounting for these factors poses challenges, especially in Ireland where limited data availability hinders the precise calculation of carbon sequestration in afforested areas.

Therefore, further investigations are necessary to enhance understanding of the relationship between afforestation and soil carbon storage. This knowledge can contribute to optimizing carbon sequestration efforts and informing future policies and practices. Additionally, the study highlights the importance of long-term monitoring of soil properties at multiple sites to obtain a comprehensive understanding of changes in land use, land-use change, and forestry (LULUCF).

By conducting a rigorous examination of the existing evidence, this paper provides valuable insights into the effectiveness of afforestation as a carbon sequestration strategy in Ireland. Nonetheless, it underscores the need for continued research to fill knowledge gaps and refine our understanding of this important topic.

On the improvement of catchment scale simulations of nitrate transport through tile drains

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Nitrate transport from cultivated areas poses a significant risk to water quality of inland and marine water bodies. During subsurface transport nitrate may undergo reduction under anaerobic conditions. However, under temperate climate tile drainage are widely used in agriculture, which provides short-circuits between the root zone and surface water systems, with limited or no nitrate reduction. To identify areas most prone to loss of nitrate to the aquatic environment, it is thus vital to assess and quantify not only the transport out of the root zone, but also the fraction of nitrate being transport by tile drains vs. groundwater transport. Tile drainage can be estimated by use of physically based distributed hydrological models, but their construction and evaluation are generally challenged by limited data on drains, with respect to both the tile drain network and in particular with respect to the efficiency of the drains, i.e. the amount of recharging water that is transported via drains. To support water management, the models must cover relevant scales (100 – 1000 km^2) posing an additional upscaling modelling challenge.

As part of nitrogen usage regulation in Denmark, a national nitrogen model has been developed, which is currently under revision. An important task is to improve the description of drain transport. This is achieved through detailed hydrological modelling of fields with drain flow observations from which drain fractions, i.e. the fraction of precipitation being drained, are calculated for each model grid. A machine learning algorithm (gradient boosted decision tree) is then used to regionalise the results to the national scale at a 10 m resolution. Calibrating the national model in a fine grid resolution is practically infeasible. The model is thus calibrated in a 500 m grid resolution, while the final model results will be generated using a 100 m grid resolution. Up- and downscaling approaches will thus be developed to utilise the detailed drain fraction map in model calibration, and the downscaling of drainage from a 500 to 100 m grid resolution. While the drainage estimates are needed at a fine scale, preferably at grid scale, data to evaluate model accuracy in terms of nitrate transport at this scale is not available. At catchment scale, the seasonal dynamics of observed nitrogen transport in streams provide valuable information on the amount and temporal variation of the contributions from drains. Analyses of the observed time series will be used to further constrain nitrate drainage transport at catchments scale.

Hydrological Variability to Land Use-Land Cover and Management Changes in Data-scarce Gado Catchment, Ethiopia

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For the past three decades, an increase in population pressure caused change in the land use land cover (LULC) and land management practices (LMPs) in Gado watershed. Gado is a watershed found in North Shewa highlands of Ethiopia; Jemma sub-basin of Blue Nile; affected by human induced factors causing deforestation and improper (LMPs) which in turn affects the watershed hydrological components. This study is mainly focused on the assessment of variability in stream flow magnitude due to LULC and (LMPs) using ERDAS imagine and Geographic information system (GIS) integrated with soil and water assessment tool (SWAT). The assessment on LULC indicated that the forest cover decreased by 32.01% between the years 1987-2000 and it decreased by 82.16% between the years 2000-2014. Likewise, the dominant Bush/Shrubs cover in the mid 1980's around the upper most highlands and lower portions of the watershed greatly changed for the study period from 23.99% to 2.91%. The grass/grazing land rate of change followed similar trend (from 17.77 to 12.31% reduction) between 1987 and 2014. This was mainly due to the expansion of cultivated land and settlements from 19.2% to 68.96% during the period of 1987−2014. SWAT was applied to evaluate the change in stream flow magnitude due to LULC and land management practices and the results show that stream flow variability could be related to the change of the LULC and (LMPs) in Gado watershed. Based on model result, stream flow was analysed to evaluate if changes in LULC and management practices affected stream flow. The simulated mean annual discharge had changed from 19.62m^3/s to 20.09 m^3/s. This indicates that there was change in stream flow through time-periods of 1987 to 2014 due to change in LULC and (LMPs) in the study area.

Keywords: *ERDAS Imagine, Gado, GIS, Land Use Land Cover, SWAT*

Soil Nutrient Health Scheme: Developing a regional-scale risk map of hydrological source areas

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In agricultural settings, diffuse contaminant losses to surface waterbodies (e.g. fine sediment, nutrients and pesticides) are recognised environmental pressures. The deployment of effective mitigation measures to reduce the losses of these contaminants requires a fundamental understanding of both the contaminants themselves, and the way in which water moves in the landscape.

In Northern Ireland (NI), the predominant pathway for phosphorus loss from agricultural land to waterbodies is via overland flow from Hydrologically Sensitive Areas (HSA); a consequence of the wet climate, impermeable soils and undulating topography in the region (Thomas *et al.* 2016). In a study across multiple agricultural catchments, Cassidy *et al.* (2019) found a strong relationship between the proportion of a catchment with high HSA risk on soils above optimum for soil test P, and in-stream P concentrations. In order to develop effective mitigation and management, there is a need to develop and extend this approach to all areas of NI, but the simultaneous identification of HSA across areas of more than a few tens of km squared remains challenging, because of the computational, labour and data demands of the process.

The Soil Nutrient Health Scheme (SNHS) will, between 2022 and 2026, map the soil nutrient status of all agricultural fields across NI. At the same time a 16 ppm LiDAR topographic scan of the entire region will be used to develop sub-field scale mapping of HSA runoff risk for all fields, providing individual farms with the baseline information needed to implement on-farm nutrient management planning and to carefully manage those areas at greatest risk of nutrient loss to waterbodies.

In 2022/23, the focus of the SNHS project was south-east NI (Co. Down and eastern Co. Armagh), which covers 3,336 km^2, with elevations from sea level to 850 m, and containing over 6,800 farm businesses of varying intensity and type. This presentation will explore the 37-step workflow developed to digitise the 16,718 km of drainage pathways, to model HSA risk using the Soil Topographic Index, and identify those areas within in the 95^{th} percentile for risk of experiencing overland flow. Areas of ongoing research that will improve the workflow in future will also be explored.

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Buffer strips influence on soil phosphorus fractionation and risk of soluble phosphorus loss to rivers

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Buffer strips are commonly implemented in agricultural catchments to mitigate particulate phosphorus delivery to rivers. However, accumulation of organic matter and phosphorus in buffer strips can affect soil phosphorus fractionation and the risk of soluble phosphorus transfer to adjacent rivers. It remains unclear to what extent the implementation of a buffer strip modifies soil phosphorus fractionation and how this relates to changes in soil organic matter content. The objective of this study is to investigate these relationships at sites where ungrazed buffer strips have been implemented as water protection measures within an agri-environmental scheme in an agricultural catchment in Northern Ireland. Soil samples were taken at five sites prior to installation of the buffer strips. The sites were located in four grassland fields characterized by a range of soil Olsen P index (1 to 3) and slope (9 % to 15 %). At each site, composite soil samples were taken from 0 to 7 cm depth and from 7 to 15 cm depth. Soil was sampled along two lines parallel to the river: one line within the planned buffer strip and another line 3 m upslope and outside the buffer strip. In total, four composite soil samples were taken at each site. Soil organic phosphorus fractions (e.g., biomass organic phosphorus, labile, moderately labile and nonlabile organic phosphorus) were extracted from fresh soil subsamples and inorganic phosphorus fractions (*e.g.*, soluble and loosely-bound phosphorus, aluminium-phosphorus) were extracted from dry soil subsamples. Soil phosphorus sorption index, soil organic matter content and other soil physical and chemical properties were also determined. Further development of this work will include the sampling of composite soil samples after buffer strip implementation to investigate changes in soil phosphorus fractionation, and a longer-term soil monitoring program to investigate these changes over several years. This will help to refine understanding of the influence of buffer strips on soil phosphorus fractionation and the implications for phosphorus loss to rivers.

Potential human health risks associated with ingestion of heavy metals through fish consumption in the Gulf of Guinea

Mario Boateng

Heavy metal pollution of the marine environment has toxic implications for both the aquatic biota and human health. We examined the levels of Zinc (Zn), Lead (Pb), Copper (Cu), Cadmium (Cd), Arsenic (As) and Mercury (Hg) in muscles of *Sardinella maderensis*, *Dentex angolensis*, *Sphyraena sphyraena* and *Penaeus notialis* caught from the coastal waters of Ghana using inductively coupled plasma mass spectrometry method. Penaeus notialis recorded the highest concentrations of all the metals (Cu:12.08 ± 1.46 µg/g, Zn: 19.20 ± 2.27 µg/g, As: 8.46 ± 2.42 µg/g, and Cd: 0.03 ± 0.01 µg/g) except Hg. Mercury was relatively high in *D. angolensis* (0.14 ± 0.03 µg/g). Apart from As, all metals were within globally permissible daily limits for consumption by humans per meal. The estimated Target Hazard Quotient due to the intake of Hg through *D. angolensis* consumption exceeded the threshold value across all age categories. Carcinogenic risks due to As intake through *P. notialis* consumption far exceeded the 10−6 threshold for all age groups in Ghana. It is recommended that the consumption of these fish species particularly, the shrimp *P. notialis* be done cautiously to avoid possible future health challenges.

Creating a nutrient budget to understand catchment inputs to a lake SPA

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Hornsea Mere SPA is a shallow eutrophic lake and fringing wetland located in an arable catchment in north east England. Concentrations in the lake of total phosphorus (P) and total nitrogen (N) consistently exceed the water quality targets for the site, and it frequently suffers from dense algal blooms. The aim of this study was to create nutrient budgets for N and P in the lake, quantifying the relative importance of different sources, and to identify the precise location of nutrient inputs from the catchment. The study ran from 2014-16. Inflowing streams were sampled monthly for water quality and discharge, and nutrient loadings were calculated for each of the streams. An intensive survey of the three main streams gave further precision by taking water samples at appropriate locations on a single occasion. Early autumn and winter surveys of Hornsea Mere itself assessed lake water quality and enhanced understanding of the role of sediment as nutrient source. Rainfall traps were set at two locations to estimate nutrient input from precipitation.

The lake was well oxygenated and there was no evidence for nutrient release from the lake sediment. Precipitation was an unexpectedly high source of P inputs, with catchment runoff remaining a significant source of P and the dominant source of N. We were able to identify the locations along streams with the highest input of nutrients, enabling targeted mitigation measures to be implemented. We could also differentiate areas where agricultural inputs were the main sources from those where other sources (e.g. residential) were important, and by measuring ammonia identified a zone of probable septic tank contamination.

The lake nutrient budget gave an indication of relative importance of each stream to overall loading, so that catchment measures could be applied efficiently. The study succeeded in highlighting priority locations along each stream, where targeted intervention would have the greatest impact in reducing nutrient loads. Simplified maps were produced to help visualise the key locations of concern. The study also provided a detailed baseline for any future assessment of the effect of catchment management.

Nitrate concentrations of leachate underneath perennial ryegrass and plantain monocultures following the application of dairy cow urine. A lysimeter study

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Nitrate-N (NO_3-N) leaching from urine patches generated by grazing livestock can contribute to reductions in water quality. Thus, it is imperative to investigate strategies to reduce leaching from this source. Previous studies, have reported established swards of Ribworth Plantain (PL) as an effective method to reduce inorganic-N leaching from cow urine patches relative to perennial ryegrass (PRG). The objective of the current study was to investigate the impact of establishing PL and PRG monocultures in reducing leachate nitrate concentrations over the autumn/winter period across differing soil types. This study was conducted at Teagasc Moorepark. It was a two x two factorial design with two soil types; 1) a free draining Cambisol (FD) and 2) a poorly drained Gleysol (PD) and two sward types; 1) PL monoculture and 2) PRG monoculture with four replicates per treatment. The two swards where established in May 2020. Urine (equivalent to 704kg N ha^{-1}) from late lactation dairy cows grazing grass and white clover swards was applied in October 2020. Leachate was collected at two-week intervals from the time of urine application (October) until March 2021. Analysis of inorganic N components was conducted using an Aquakem 600A automated analyser. Nitrate was calculated by subtracting nitrite from total oxidised N. All data were analysed using SAS. There was no significant effect (P>0.05) of sward type on leachate nitrate concentrations. There was a significant effect of soil type on leachate nitrate concentration (P < 0.01), with the FD soil (13.4±2.1 mg/L NO_3-N) having a greater nitrate concentrate compared to the PD soil (6.7± 2.1 mg/L NO_3-N). This was likely due to due to greater levels of denitrification on PD soils. Sward type had an effect on leachate drainage (P < 0.05), with PL having lower drainage volumes compared to the PRG (355 and 310± 11.2 L, respectively). These findings suggest that PL and PRG have minimal impact on soil nitrate concentrations; however, plant species did have the potential to reduce volumes of drainage during the establishment period and thus reduce overall Nitrate-N loads to groundwater. There was no significant effect of sward type on total kg of NO_3-N leaching, however the NO_3-N was significantly lower on the PD soil (3.2±0.88 kg N ha^{-1}) compared to the FD soil (6.28±0.88 kg N ha^{-1}). The results of this study confirm the effect that soil type can have on nitrate concentrations during high-risk periods of autumn and winter.

Cultivation ridge genesis, fertility and potential localized effect on surface hydrology in grazing systems

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Cultivation ridges (CRs) are common landscape features found across areas of Ireland and the United Kingdom. A CR consists of a ridge and furrow surface feature typically created by the addition of an amendment to the soil surface (e.g. manure) followed by the flipping of turf cut with a tool (*e.g*. a loy [spade]). CRs have been referred to as lazy beds, famine beds, and raised beds too. Across Ireland, their extent is often confined to landscape areas where soils are, for example, too wet due to proximity to a river and shallow water table, restrictive soils over a dense till parent material, or shallow bedrock; soil drainage limitations are often the primary cause leading to their creation. CRs are often present today where sheep, beef or dairy cattle are grazing and thus the manure from grazing animals has the potential to follow topographic patterns and accumulate or be transported in furrows; such surface transport has the potential to contaminate adjacent water bodies. We present results of a study that examined three cultivation ridge systems in the Drumshanbo area of County Leitrim: riverine with shallow water table; drumlin system with dense till; and till over shallow bedrock. Within each system a site was chosen for geomorphic analysis with a DJI Mini 2 drone with Structure for Motion capability. A ridge through furrow to ridge soil profile was excavated by hand for description of soil characteristics, fertility, and total, trace, and rare earth element geochemistry. Results show that CRs on slopes were often found on a southerly to south-westerly aspect and oriented with the long axis in a downslope direction. The riverine system had a <1% slope, the shallow bedrock system had a slope of 4%, and the drumlin system a slope of 6%. In each system, evidence of surface saturation was present with oxidized rhizospheres always found in furrows and in the riverine system in ridges too. The riverine CR system was deepest with furrow to ridge relief ~40cm suggesting long-term use and surface additions of materials for fertility improvement or from local flooding. The drumlin and shallow bedrock systems were of similar thickness with a furrow to ridge relief of ~20 cm. Fertility characteristics support furrows as accumulation areas. Animal excrement was found at all locations. Future research will address differences in cultivation ridge systems by topographic position, soil drainage class, parent material, aspect, and amendment additions (*e.g.* seaweed).

Clear as mud: Insights into soil and carbon loss to water during a bogflow

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Landslides of peat have been recorded across Britain and Ireland for centuries. Whilst natural, and usually coinciding with heavy rainfall and erosion, certain anthropogenic factors can increase their likelihood. On 13th November 2020, a bogflow (i.e. a flow failure of peat) occurred at Meenbog on the Irish border. Although this event was ultimately triggered by supersaturation of the peat, it occurred in an area that had previously been partially drained, was afforested and was undergoing wind farm development. At least 20,000 cubic metres of peat was released, complete with solid rafts carrying upright trees, with much of this entering surrounding watercourses.

Whilst peat-related landslides are not uncommon, their immediate impacts are rarely documented. However, about 37 km downstream of the bogflow in the largely agricultural Derg catchment, water was being collected from the River Derg by a refrigerated autosampler on a 7-hourly basis. This enabled analysis of water samples for suspended sediment (SS), particulate organic carbon (POC) and dissolved organic carbon (DOC) for three days before, and 25 days after, the bogflow. These data were coupled with river discharge to estimate loads. Hourly measurements of turbidity and chromophoric dissolved organic matter (CDOM) were recorded *in-situ* at the sampling location.

The samples in the 24 hours following the bogflow were completely opaque with black sediment that did not settle. Concentrations in the first of these samples were the highest measured, with 825 mg/L SS and 346 mg/L POC. In contrast, the lowest measured concentrations of SS and POC were 1.9 mg/L and 0.85 mg/L. Over the 8 days in which the major impacts of the bogflow were apparent, an additional 1318 tonnes SS and 608 tonnes POC were transported at least as far as the monitoring point – this equates to 325% more SS than would be expected under similar flow conditions, and 925% more POC. There was no effect of the bogflow on DOC concentrations or loads. On the day of the bogflow, turbidity peaked at 60 NTU, although remobilisation events caused a peak of 119 NTU six days later. In contrast, CDOM decreased during the bogflow. CDOM also exhibited an unexplained 32% decrease just over three days before the bogflow, potentially giving an early warning sign. This opportunistic study provides insight into both the types of contamination that bogflows release into watercourses and their duration and effects on water quality.

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Building the evidence base for phosphorus Catchment Nutrient Balancing

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With increasingly tough phosphorus removal targets placed on water recycling centres (WRCs) in the UK, the case is building for offsetting a small proportion of load reduction, by funding the agricultural sector to reduce its phosphorus contribution above and beyond its own obligations. Phosphorus removal at WRCs has a high carbon footprint and can be disproportionately expensive to the customer particularly when tight consents are placed at small rural works. Through a regulator established framework – Catchment Nutrient Balancing (CNB), it is possible for water companies to set up schemes that allow farmers to apply for funding for mitigation measures. These mitigation measures are targeted to reduce delivery of nutrients to waterbodies at an equivalent or greater degree than would be achieved by phosphorus 'stripping' at the WRC. This may be achieved at a lower cost and carbon footprint, whilst also capturing additional benefits including biodiversity improvements and flood risk reduction. With a proven track record of delivering such schemes for nitrate, Wessex Water embarked on a programme of phosphorus CNB.

Quantification of baseline agricultural nutrient losses and the subsequent reductions in those losses following the implementation of mitigation measures is key to demonstrating the success of a CNB scheme. The phosphorus CNB schemes are heavily reliant upon modelled outputs to estimate these losses. However, a network of monitoring stations has been established across the Wessex region, in various farm settings, to sense check these estimates. For several years, the Wessex Water catchment management team has monitored leached nitrate losses using porous pots buried 90 cm below the surface. But as phosphorus CNB schemes have been introduced, different approaches to monitoring have become necessary due to greater phosphorus losses via surface flow and preferential pathways through soils.

The monitoring network consists of several edge-of-field surface runoff, tile drain discharge, farm track runoff and ditch monitoring stations. Each allowing the monitoring of hydrological discharge and water quality parameters, to calculate nutrient load losses. It's these load losses that are used to sense check the modelled outputs, providing Wessex Water and the regulators greater confidence in the impact of CNB schemes, or where necessary provide evidence to challenge the model output.

Preliminary results of this monitoring will be presented here alongside, for comparison, the modelled load losses.

How's the Water? Improving Recreational Water Quality Monitoring and Forecasting in the River Almond Catchment

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Recreational waters in Scotland are a vital asset to public well-being, environmental health, and local economies. However, many of these same waters receive sewage discharge, which degrades the aquatic environment and creates a public health risk. At present, there is increasing pressure from the public, regulators, legislation, and international environment agreements, to improve surface water quality in Scotland. However, monitoring is expensive and time-consuming, so often we are not aware of how much sewage is in the river, nor how long it can present a health risk to recreational water users. New and innovative methods are needed to improve the frequency of water quality monitoring in an economically feasible way.

The overall aim of this PhD project is to improve recreational water quality monitoring and forecasting. The research is focused within the River Almond catchment, one of Scotland's most polluted rivers. The River Almond - impacted by urban wastewater, agricultural runoff, and legacy mine water discharge - is one of Scottish Water's priority catchments, with ambition of achieving Good Water Quality status by 2027.

This presentation will highlight the proposed methodology for long-term, in-situ monitoring and modelling of microbial water quality in the River Almond catchment. The three main stages of this PhD research are to:

1) evaluate the applicability of using novel sensors to monitor water quality in real time;
2) Use the higher-resolution monitoring data to determine what drives water quality in the River Almond, and evaluate how variables such as time of day or adverse weather impact the extent and duration of poor water quality in the catchment; and
3) Use the in situ sensor data to improve forecasting of water quality conditions.

Increasing our understanding of surface water quality using innovative monitoring methods is fundamental to improving water quality management and environmental health.

Integrated assessment of CO_2eq flux from upland agriculture

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Peatlands are a predominant land cover type across the island of Ireland and globally store approximately 3 billion tonnes of carbon. However, when water tables are modified through drainage for agricultural or forestry use, peatlands then become a potential source of carbon, both atmospherically and fluvially, with fluvial exports accounting for approximately 35% of the overall carbon cycle within peatlands. With the rate at which carbon is accumulating in the atmosphere increasing in recent years, it is extremely important to monitor carbon exports from peatlands at different stages of restoration, and investigate how these rates are effected seasonally and by different weather events.

In this study, in situ proxy measures (YSI EXO3 sondes) have been installed to monitor dissolved organic carbon (fDOM as a proxy) and particulate organic carbon (turbidity as a proxy) exports at high frequency intervals on the CAFRE Glenwherry Hill Farm in Co. Antrim, Northern Ireland. The study area comprises of three peatland micro-catchments with stream flumes; an open-moorland site that will be restored in the future, a forest-to-bog site restored in 2020, and a control site that will not be restored. With high frequency hydrological and water quality monitoring stations, changes in fluvial carbon flux will be monitored to investigate how rates of dissolved organic and particulate organic carbon changes seasonally, along with how extreme weather events affect these rates. The fluvial carbon flux data collected during this project will be compared to flux tower data installed on the moorland, which provides daily to yearly data on the gaseous carbon flux measured on the moorland, to compare the carbon loads exported from the hill farm.

Initial results show higher dissolved and particulate organic carbon concentrations in the forest-to-bog site than the control and open moorland sites. Larger dissolved and particulate organic carbon concentrations have also been recorded after periods of heavy rainfall and increased discharge at all sites.

Few studies have implemented in-situ high frequency monitoring to investigate how seasonality impacts dissolved and particulate organic carbon exports during different stages of peatland restoration, and even fewer compare this fluvial carbon load to the gaseous carbon load to achieve a complete peatland carbon budget. With both the annual fluvial carbon flux data and the annual gaseous carbon flux data, the total C flux from the peatland will be the most complete in Northern Ireland at different stages of restoration.

Thirty years of Agricultural Environmental Monitoring Programme in Norway

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Too high nutrient and sediment loads are threatening the water quality of inland water bodies and coastal waters since decades in Norway. Main sources of nitrogen are wastewater, aquaculture, industry, agriculture, and forestry and rural areas. The first national action plan to reduce losses from agricultural production was introduced in 1985. In 1992, the Norwegian Agricultural Environmental Monitoring Programme was established. The aim of this monitoring is I) to measure losses from the main agricultural production systems and typical geographical areas in Norway and II) to evaluate the effect of environmental measures as introduced by agricultural policy. Catchment areas were selected, representing cereal production in the east and mid of Norway, vegetable production in South Norway, intensive and extensive dairy farming including grass production in the west and north of Norway. Water monitoring stations are constructed at the outlet of the defined water catchment areas. There, runoff rate is measured, and composite samples are taken flow proportional which are analysed fortnightly. Water samples are analysed spectrophotometrically for total phosphorus after an ammonium molybdate method application (NS-EN ISO 6878) and for total nitrogen after persulfate digestion (NS 4743). Suspended sediments are quantified by filtration using a fibreglass filter (NS-EN 872-1/GF-C Whatman). Also, several different pesticides are analysed. In addition to these analyses, detailed agricultural management data are documented. This includes dates and types of tillage, sowing, fertilization, harvest, and pesticide applications. The 30 years of monitoring compiled important knowledge on hydrological regimes, agricultural management, and sediment and nutrient losses from typical agricultural production areas in Norway. Only a few significant one-way trends in losses were found. Rather the trends varied over time, reflecting policies at different times through the 30 years of monitoring. On-going impacts of nutrient and sediment loads on water bodies and coastal waters call for decades continuing, thorough monitoring. This is of special importance regarding effects of the changing climate on drivers for nutrient and sediment losses from agriculture.

NEW-HARMONICA: Modelling nutrients and mitigation measures across the Neagh Bann catchment

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In 2015 the ecological status of the vast majority of surface waters in NW Europe was reported to be less than "Good" status under the Water Framework Directive (WFD). The overall objective of the NEW-HARMONICA research project is to assess and develop a systematic, harmonised approach both to setting environmental targets and then identifying the methodology to reduce catchment nitrogen (N) and phosphorus (P) loadings in order to meet these targets in three large trans-border catchments: the Neagh-Bann (Ireland and NI), Wye (England and Wales) and Meuse (Netherlands and the Flanders region of Belgium). Currently these targets are quite variable by jurisdiction both in terms of what nutrient species is assessed and the threshold for "Good" status of the nutrient's concentration. A second key objective is to harmonise the selection of an effective suite of mitigation measures to reduce N and P loadings to achieve the overall objective. Catchment modelling is required to estimate the fluxes and concentrations of N and P in each of the three study catchments.

This study will focus on the estimation of N and P fluxes in the Neagh Bann catchment, covering over 3000 km^2. There are two strands to the modelling work, the first one uses a novel Materials Flow Analysis (MFA) approach to estimate the loadings of N and P in a full regional scale balance which includes fluxes to air and water (where these can be quantified). The second strand will focus on catchment modelling using the CRAFT model to model the N and P dynamics (concentrations and exports) under the existing land use in the 6 main Neagh-Bann sub-catchments. Previous studies using the CRAFT model in the Blackwater catchment (the largest of these) have assessed several different scenarios of land use management and P mitigation, and these will be assessed on a larger scale. The two strands will be combined in terms of an assessment of the overall loads of N and P in the catchment, the required load reductions to meet "Good" status objectives, and priority areas (in terms of both the nature of these loads and the geographic areas that require the most urgent mitigation) will be identified.

Catchment scale computational platform from an interdisciplinary research project “MAVELA”

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An innovation contest was arranged by the Drainage Foundation aiming to find new ideas for promoting sustainable agricultural water management to better adapt to climate change and extreme weather conditions. The winner of the contest was an idea to create a catchment scale computational platform using open access data in Finland. The award encourages the winning group to develop the idea further. The platform is based on a hydrological model, FLUSH, that has been developed in Aalto University for over a decade. FLUSH has been applied to simulate field water balance at several experimental fields. Open data resources such as digital elevation models and meteorological time series can be used as input data for the model applications. Data on soil properties is rarely available without laborious soil sample analysis. An idea to also establish a soil properties database of Finnish agricultural soils was emerged. The database would be based on already existing soil data and complemented using pedotransfer functions. Originally the idea came from Aalto university, but it also intrigued researchers from Natural Resources Institute Finland (LUKE) and Finnish Drainage Association. An interdisciplinary research project was established, and funding was applied at the end of the year 2022. The Drainage Foundation granted funding for the project in late 2022 and the Ministry of the Environment granted funding for the project in the spring 2023. The project is called MAVELA (Computational platform for catchment scale agricultural water management). MAVELA project consists of two work packages: (1) development of the FLUSH model and (2) establishing of the soil properties database. The development of FLUSH aims to create a computational tool to simulate regional agricultural water management solutions by using open data resources and the new soil properties database. The objective is to enable field water management simulations without time-consuming field monitoring campaigns and use the soil database in conjunction with other open data for setting up the model application at different sites and at varying scales. The tool aims to study different water management solutions implemented in open ditches and streams as well as in subsurface drainage systems on a regional scale in agriculturally dominated areas. The project will continue until the end of the year 2025.

Land use/Land Cover (LULC) Change Response to Urbanization in Ireland

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Distribution of land use/land cover (LULC) plays a decisive role in governing the regional climate dynamics and catchment hydrological behaviour to great extent. Rapid urbanization induced industrialisation process pose severe threat to natural environment of developed countries. In general, the spatiotemporal distribution of LULC change is greatly affected by the explicit and implicit anthropogenic activities. Hence, timely monitoring of historical LULC change over a region is essential for decision making in policy formulation. The conventional Global Positioning System (GPS) based field survey method of LULC change mapping is not feasible enough over larger spatiotemporal domain. This study proposes a remote sensing-based methodology by using the readily available satellite imageries for mapping the distribution of different LULC classes in given period. Variation in the four major LULC classes, viz., vegetation, barren land, waterbodies, and urban area were analysed during the period 2001-2021 across 43 major catchments of Ireland. To ascertain the accuracy and reliability of the study, the raw satellite imageries were subjected to atmospheric correction by the ACOLITE algorithm. Maximum Likelihood (ML) based supervised image classification approach was adopted to classify the imageries for the concerned period. Majority of the chosen catchments have experienced exponential growth in the urbanization with more intense growth is confined to the period 2017-2021. Consequently, based on the historically mapped LULC scenario, a regression based mathematical model was developed to predict the plausible future population growth scenario. Certainly, the developed methodology will assist the policy makers in planning a ubiquitous sustainable management framework for maintaining the water quality and quantity in the best possible way.

Application of a Parsimonious Phosphorus Model (SimplyP) to Two Hydrologically Contrasting Agricultural Catchments

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The Agricultural Catchment Programme has compiled an extensive dataset, encompassing hydrological and chemical parameters within various agricultural catchments, which provides a robust foundation for modelling studies aimed at assessing long-term hydrochemical dynamics. This study investigated phosphorus export dynamics from agricultural catchments by examining the use of a parsimonious water quality model, SimplyP, in two ACP study sites. These sites are similar in size and are in close proximity to each other but differ significantly in their physical characteristics and hydrochemical behaviours. Ballycanew is characterized by grasslands with heavy soils, presenting a high risk of P export, while Castledockrell has predominantly arable land-use with lighter soils, resulting in a lower risk of P export. These sites were selected due to their contrasting attributes, to evaluate the applicability of the SimplyP model in different conditions.

Modelling was conducted at the catchment scale with a daily temporal resolution over the period 2010 to 2021, with sequential optimization of hydrology, sediment, and phosphorus components. In instances where parameters were not determinable based on catchment characteristics, a set of free parameters were optimized during calibration, including 6 for hydrology, 2 for sediment, and 4 for phosphorus dynamics. The Kling-Gupta Efficiency objective function served as the criterion for calibrating the model against observed records of streamflow, suspended sediment, particulate phosphorus, and total dissolved phosphorus.

Results indicate that the SimplyP model produces a good representation of hydrological, sediment, and phosphorus fluxes in the Ballycanew catchment. Notably, it enables an accurate simulation of total phosphorus export dynamics, which indicates it could be a valuable tool for assessing the impacts of catchment modifications on TP exports. By contrast, in Castledockrell catchment the model fails to provide an acceptable representation of phosphorus dynamics, primarily due to limitations in the model structure. Specifically, the model cannot adequately capture groundwater-driven phosphorus dynamics in this catchment. As it stands, the SimplyP model appears well-suited for deployment in catchments primarily governed by surface flow pathways but encounters constraints in adequately addressing groundwater-driven systems.

This research underscores the importance of considering catchment-specific attributes and hydrological dynamics when applying phosphorus models, while also highlighting the potential utility and limitations of the SimplyP model in distinct agricultural catchment scenarios. Further investigations are warranted to refine and expand the model's applicability, particularly in catchments where groundwater-driven processes play a substantial role in phosphorus dynamics.

Climate change impacts on phosphorus emissions in four Irish catchments: a Bayesian Belief Network approach

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Climate change is anticipated to have significant implications for phosphorus (P) emissions in Northern Europe, driven by the increased likelihood of weather extremes. The WaterFutures project aims to improve our understanding of these impacts on Irish catchment hydrology, by deriving downscaled climate change projections for several Irish catchments, including those within the Agricultural Catchment Programme (ACP). The downscaled projections contain daily time-step series of rainfall, air temperature, discharge, and potential evapotranspiration available up to the year 2100 for the ACP catchments under RCP4.5 (intermediate emissions) and RCP8.5 (intensive emissions).

This preliminary study adapted the climate change scenarios to a pre-existing probabilistic model based on a Bayesian Belief Network (BBN). This BBN was designed to predict in-stream P concentrations in four ACP catchments using high-resolution datasets, literature, and expert opinion using the 'source-mobilisation-transport-continuum' concept. Consistent with previous studies, we divided the scenarios into three thirty years blocks, and we used Monte Carlo methods to adapt the discharge time series to monthly distributions that could be used in the BBN.

Preliminary results shed light on P losses under both climate change scenarios in the four catchments exhibiting contrasting agricultural land use and hydrology. The findings provide insights into the potential impact of climate change on future P emissions across Ireland's landscape.

Assessing climate change impacts on streamflow and hydrologic extremes in the Pra river basin

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The Pra river basin (PRB) provides important ecological services, including municipal water supply, agriculture (irrigation), and water for use in mining institutions in Ghana. The PRB has significant agricultural activities with cash crops such as cocoa and oil palm plantation scattered within the basin. The challenge in water management within the PRB is constantly becoming a topical issue owing to the influence of climate variability. Also, recent scenarios in climate change exacerbated by anthropogenic activities have resulted in changing temperature and rainfall patterns thereby threatening water resources in three dams that source its water from the river basin. This has also negatively impacted river flow attributable to a high rate of pollution, increased runoff, and high evaporation. It is therefore important to have an understanding of the consequence of variation in climate change on current and future hydrologic regimes and hydrologic extreme events through a modelling approach.

Hence, in this research, we investigated the response of hydrological regimes and hydrologic extremes in relation to climate change in the river Pra basin by employing five (5) new Coupled Model Intercomparison Project (CMIP6) GCM for two-time slices, near future (2030s; 2015-2044) and mid future (2050s; 2045-2074) under two emission SSP2-4.5 and SSP5-8.5 scenarios. Preliminary analysis revealed bias-corrected CNRM-CM6-1 as the best and suitable climate model for climate change projection and further assessment of climate change impacts on streamflow and hydrologic extremes. SWAT model calibrated and validated data results compared with observed flow data were deemed satisfactory for future flow simulations over the Pra basin.

We found a continuous increasing trend for predicted mean temperature while precipitation is predicted to increase in the 2030s and then decrease in the 2050s under SSP2-4.5 and SSP5-8.5 scenarios. Also, we may see a decrease in the mean annual discharge for the 2030s and 2050s period. Overall, we may observe an increase in the mean projected precipitation and temperature under the two simulation periods. The projected changes in low flows under all SSPs may see a decrease, hence the magnitude of drought may likely increase at certain periods in future. On the other hand, we predicted an increase in extreme flows (Q1) at about 10.56% and 13.47% under SSP2-4.5 and SSP5-8.5 respectively in the study periods. Hence flood mitigation measures as well as proper water resources management strategies must be ensured by stakeholders to avoid any catastrophes downstream of the basin.

Evaluation of changing climate on agricultural water resources and adaptation on the island of Ireland

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Global warming leads to changes in air temperature and precipitation variables and can have a major impact on agricultural water resources, environmental ecology, agricultural systems, and human lives. These joint anthropogenic and natural activities may have a substantial indirect impact on the socio-economic development status of the country. Particularly, the impact of changing climate on seasonal agricultural water resources, is significant and can transition to agricultural productions and water supply, mainly due to both seasonal trends and short variabilities of climate variables. Therefore, quantifying the influence of climate change on agricultural water resources using SPI and SPEI is essential to evaluate possible adaptation and mitigation measures for enabling seasonal agricultural suitability and sustainability. Here we examine changes in the monthly climate water balance, aridity index, and drought characteristics using standardized drought indices for the island of Ireland derived from bias-adjusted CORDEX simulations for the 2080s (2070-2099), forced with a high (RCP8.5) and moderate (RCP4.5) emissions pathway. Summer and spring show the greatest increase in drought magnitude and frequency, most marked in the east of the island. By contrast, multi-seasonal droughts, assessed using 6-month accumulation periods show more modest changes in magnitude and duration. The resultant impacts of climate change on drought for Ireland would require considerable adaptation given the vulnerabilities exposed by the 2018 drought. From the climate water balance (precipitation-pet) point of view, the seasonal increase in precipitation variability and potential evapotranspiration will reduce water resource surplus in the future, particularly in the summer season. Overall, increases are considerably greater for the standardized precipitation evapotranspiration index (SPEI) than for the standardized precipitation index (SPI), emphasizing the importance of using metrics that capture potential evapotranspiration in monitoring and assessing future drought risk.

Assessment and impact of deposited sediment in rivers in Irish agricultural catchments

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Freshwater ecosystems represent hotspots for global biodiversity, containing almost 10% of all described species. However, these habitats are experiencing even more rapid rates of biodiversity loss than marine or terrestrial ecosystems, in what has been described as 'an invisible tragedy'. While sediment is a natural component of freshwater, anthropogenic activities have increased its input and storage and have turned it from a necessary part of river ecosystems to a 'master stressor'. In Ireland and worldwide, agricultural activities have been recognised as one of the main drivers of excessive deposited fine sediment in rivers.

Numerous techniques can be used to assess the different attributes of deposited sediment. These different techniques, along with a lack of agreement on standard methods, make intra-research comparisons difficult. In addition, there are no clear guidelines on what level of deposited fine sediment will negatively impact aquatic life and little guidance on what impact changing climate scenarios will have on deposited sediment dynamics.

This study aims to:

- Investigate and experimentally assess the various assessment methods for deposited fine sediment, and refine methods to produce a stakeholder-specific, biologically relevant, rapid assessment method that would be suitable for use in Ireland.
- Establish an ecologically relevant threshold for deposited fine sediment in Irish agricultural catchments.
- Assess river flow dynamics for sediment deposition in present and future climate scenarios.

Investigating hydromorphological restoration in low-order, intensively farmed catchments under a changing climate

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This study aims to provide a robust evidence base for the restoration and enhancement of low order catchments in Ireland that have been subject to historic hydromorphological alteration and intensive agricultural land use. This study will use a range of methods to reconstruct the historic geomorphological response of two grassland catchments: Ballycannew, Co. Wexford, and Timoleague, Co. Cork. Both catchments are intensively grazed and contain low order streams that have been altered through channel straightening, deepening, and re-sectioning, and are representative of many small catchments across Ireland which are failing to meet their WFD objectives. Both catchments are similar in size, share similar histories of channel modification and agricultural land use management, but differ in their geological and hydrological regimes, which provide an opportunity to understand the impact of historic channel modification under differing baseline environmental conditions. Using the conceptual understanding of historic change as a baseline, the study will model the future channel process-form relationships using landscape evolution modelling (LEM), using scenarios of climate change established under the WaterFutures project, and scenarios that simulate established river restoration methods. It is anticipated that LEM will simulate future geomorphological processes and response within management time frames, predicting the impact of river restoration methods on physical geomorphological response. The final output will be a series of recommendations to restore instream geomorphological processes without the need for ongoing channel maintenance. This study will establish the benefits and limitations of applying river restoration measures to address the pressures of both climate change and intensive agricultural land use.

Assessment of green cover requirements: Implications for farmland birds

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The management of agricultural landscapes requires balancing practices aimed at maximizing production with those that support ecosystem services including water quality and biodiversity. Freshwater bodies pose significant challenges due to the potential loss of agricultural nutrients to surface and groundwater receptors, contributing to a reduction in water quality. European Union agri-environmental policies, for instance, the Nitrates Action Programme (NAP), aim to reduce these impacts on ecosystems by regulating practices and implementing targets to protect and improve water quality. The current NAP includes measures to reduce the loss of nutrients post-harvest, by promoting management of winter stubbles (i.e., stalks and tillage remains) that enhances green cover, through shallow cultivation or the planting of cover crops. Winter stubbles, however, are a key resource for farmland wildlife species (e.g. seed-eating birds, small mammals). Concurrent with declining water quality in agri-ecosystems is a stark decline in farmland bird species, which are in turn protected by the Birds Directive. Member States are obliged to take appropriate actions to maintain bird species at appropriate ecological, scientific, and cultural population levels. Challenges thus arise, how should practitioners proceed when the management requirements to achieve the objectives of concurrent EU policies potentially diverge from one-another. The new AGRI_Birds project (2023-2027), seeks to answer this question. AGRI_Birds aims to understand the role of winter stubbles as a resource for wildlife on farms, assessing different tillage practices and modelling agri-environmental data to disentangle the effect of these practices on water quality and bird diversity. AGRI_Birds will work closely with stakeholders across the country, to identify synergies and tradeoffs in achieving environmental and biodiversity policy targets.

Occurrence of microplastics in wild oysters (*Crassostrea tulipa)* from the Gulf of Guinea and their potential human exposure

Mario Boateng

The high dependence on plastics in Ghana has resulted in the generation of large quantities of plastic waste which are poorly managed and improperly disposed into the aquatic environments. This study assessed the spatial distribution and abundance of microplastics in mangrove oysters (*Crassostrea tulipa*): a major fishery resource of commercial importance in Ghana.

The results showed that 84.0% of all individuals examined had ingested microplastics. A total of 276 microplastic items were recovered from the 120 individual oysters. Densu (100%) and Volta (93%), two estuaries situated in urban areas, had a greater incidence of microplastics than Whin (77%) and Nakwa (66%), estuaries situated in peri-urban and rural settlements, respectively. The mean microplastic abundance ranged from 1.4 to 3.4 items/individual and 0.34 to 1.7 items/g tissue wet weight. Fiber accounted for 69% of microplastic shapes, followed by fragments (27%) and films (4%). Polymer analysis showed polyethylene (PE), polypropylene (PP) and polystyrene (PS) as the most common types in oysters. The estimated microplastic intake per capita per year was one magnitude higher than the mean for other countries. This high rate of human exposure to microplastics requires an eminent policy formulation to guide the use, management and disposal of plastic waste in Ghana.

Waters of LIFE Integrated Project

Anne Goggin

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The Waters of LIFE is a European Union funded Life Integrated Project which aims to help reverse the loss of Ireland's most pristine rivers. The ongoing loss of high-status waters is a worrying trend for water quality in Ireland. The protection and restoration of these waters is one of the key underpinning principles of the EU Water Framework Directive.

The project aims to develop, test and validate effective catchment management measures to reverse this declining trend. Six project catchments have been selected, five demonstration catchments and one control catchment. These are:

1. The Avonmore, Wicklow.
2. The Awbeg (Kilbrin), Co. Cork
3. The Graney, Co Clare.
4. The Sheen Co, Kerry. (Control)
5. The Islands, Co Galway/Roscommon
6. The Shournagh, Co. Cork

The locations and extent of these sub catchments can be seen here: https://www.watersoflife.ie/catchments/

The project's primary aim is to protect and improve water quality in high status objective river waterbodies. These waterbodies are frequently located in more remote, less populous areas. Measures will, where possible, aim to achieve multiple benefits for climate action and biodiversity. The project will include a 'Results Based Payment Scheme' (RBPS) for participating farmers and foresters in the demonstration catchments. Engaging and communicating with stakeholders and the public will be an important element of the project.

A project team has been established which will work in close cooperation with other River Basin Management Plan projects and implementation bodies such as the Local Authority Waters Programme (LAWPRO) and the Local Authorities' Blue Dot Catchment Programme. The project is expected to run until March 2028.

The DHLGH is the lead authority for the project and there are a number of project partners, including:

- *Dept. of Agriculture, Food and the Marine*
- *Teagasc*
- *Environmental Protection Agency*
- A number of LEADER Companies
- OPW
- *Coillte*
- *Local Authorities*
- *DAFM – Forest Service*

The total project budget is €20,206,605.

The project was officially launched by Malcolm Noonan, T.D., Minister of State at the Department of Housing, Local Government, and Heritage on 29th April 2022 at an event in Kilmallock, County Limerick. Practical implementation of measures will begin in 2024 and the project will run until 31st March 2028.

Bank erosion is as major phosphorus source in Danish catchments: how to find possible mitigation options

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A new national survey of bank erosion and phosphorus in bank material has shown that bank erosion is the dominant diffuse source for total phosphorus (P) to Danish streams contributing on average 60 % of annual diffuse source riverine P-loadings to Danish coastal waters. A new analysis of survey data from two Danish catchments where ca. 4000 erosion pins were installed in a total of 48 stream reaches has been reanalysed with the aim of finding possible ways to mitigate bank erosion, among others by planting native trees along the stream channels. The outcome show that planting trees has a huge impacts on bank erosion and the resulting P-loss but being dependent on stream size and landscape geology.

The outcome will be used in the official Danish plans for restoring stream channels and wetlands where the municipalities that are seeking funding to project areas will need to estimate the importance of bank erosion and P-losses in a before and after analysis. Moreover, the importance of bank erosion as a source of P to coastal waters and how to mitigate is a major component in the four projects established in Denmark where stakeholders in local coastal water boards will prepare bottom-up scenarios for how to reach good ecological conditions in the coastal waters. Here P reductions in coastal water loadings can serve as a substitute for lowering nitrogen loadings as there are established a N:P exchange rate for each of the P vulnerable estuaries in Denmark.

The results of the newly developed tool for bank erosion and P loss to streams as well as its potential use in projects involving planting trees along stream channels and restoration of rivers and wetlands will be presented. Moreover, the outcome of the P scenarios conducted at catchment scale under four new projects involving stakeholder driven coastal water boards in Denmark will also be presented.

Tracing the origin of sediments and C across the terrestrial-aquatic continuum

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Quantifying land use sources and understanding the dynamics of organic carbon (OC) in river catchments are essential to reduce both on-site and off-site impacts of soil OC erosion. Extensive data from Loch Davan catchment, Aberdeenshire, was used to find the effect of novel combinations of *n*-alkane concentration ratios, *n*-alkane compound-specific stable isotopes (CSSI) and short-chain neutral lipid fatty acid (SC-NLFA) biomarkers on land use source discrimination using a Bayesian un-mixing model. In comparison to using only *n*-alkane ratios, a combination of *n*-alkane ratios and CSSI improved discrimination between arable and pasture land uses and using a combination of *n*-alkane ratios and SC-NLFA reduced error when discriminating four land uses (arable, pasture, forest and moorland). OC source proportions were identified in both streambed and suspended sediment (SS) revealing different dominant land use sources for streambed and SS OC, together with seasonal changes in land use sources.

Soil erosion “hotspots” (i.e. where there is high risk of soil degradation) can be identified by modelling catchment erosion using a variety of different erosion models. The utility of these models in identifying hotspots, and guiding Best Management Practices (BMP), depends upon their accuracy and there is a need to assess model usefulness. A new method was developed and tested using streambed sediment land use -specific yields estimated using OC fingerprinting as a benchmark to determine which erosion model best identified the relative land use OC yields in streambed sediment.

Methods combining sediment fingerprinting and carbon loss erosion modelling lead to improved identification of processes driving spatial and temporal OC dynamics and evaluation of the role of riparian buffer zones in intercepting sediment delivery to streams. These techniques are now available to evaluate the effectiveness of land management interventions and river restoration schemes to improve soil health and reduce soil erosion.

The effects of an offline flood storage area (OSA) on peak stream flows, water quality and pasture health

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In recent years, the scientific community and public-sector environmental bodies have placed much emphasis on the potential of Nature-based Solutions (NBS) to mitigate hydrological and water quality issues in catchments throughout Europe. In Ireland, however, there are few studies which have both constructed NBS features for hydrological and water quality management and have investigated their functioning over extended time periods. Research recently completed on a farm in Co. Cork is presented here which illustrates the functioning of an NBS situated on an agricultural field: an offline storage area (OSA). The OSA is designed to attenuate flood peaks by diverting stream water to a field during the upper portion of the rising limb of a flood peak. Flood water is retained in the OSA until the flood peak has passed, gradually draining back to the channel in the wake of the flood surge (c.24 hours after the flood peak). The potential for the OSA to bring about changes in concentrations of important water quality pressures was investigated through sampling upstream, within and downstream of the OSA during these flood events. Results show that the OSA, through retaining flood waters during flood events (n = 11), can achieve appreciable attenuation of the peak discharge within the channel downstream of the feature (18% Std Dev = 16) and bring about significant attenuation ($p < 0.05$) of suspended solids and nitrate. The OSA also appears to act as a source of total phosphorus and soluble reactive phosphorus during flood events – a consequence of flood storage which should not be over-looked. Additionally, the research examines the productivity of the sward in the OSA in response to repeated flooding. While appearing to be marginally reduced during the winter season relative to the non-flooded zone of the field, the sward is shown to potentially benefit from the flood events in achieving greater biomass during the summer months – a critical period for feeding animals on the land and the production of silage. This indicates that winter flooding of agricultural land may benefit sward productivity during the critical period for plant growth and allow greater resilience in the face of summer draughts.

Right measure in the right place – a StoryMap to reduce nutrient losses from arable land

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Lake Mälaren is the third largest lake in Sweden and a source of drinking water for more than 2 million people. In spite of very efficient reductions of nutrient emissions from point sources such as wastewater treatment plants, eutrophication remains an important threat to the water quality in the lake, mainly due to the considerable nutrient losses from diffuse sources in general and from arable land in particular. Reliable identification of areas vulnerable to nutrient losses from diffuse sources is essential for high efficiency of mitigation measures. Within the frames of LIFE IP Rich waters programme, an ArcGIS StoryMap (https://arcg.is/1HC001) was developed to support catchment managers, advisers and farmers in the efforts to reduce nutrient losses from arable land. The main goal of the tool to facilitate discussions between different stakeholders (authorities, catchment managers, extension services and farmers) by providing local information at field and catchment scale. The study area covers the whole catchment of lake Mälaren (22650 km2) and the StoryMap consists of high-resolution maps as well as instructions how to use the different maps, illustrative examples and further references. The StoryMap is available through an ordinary web browser and no skills in Geographic Information Systems (GIS) are required from the end users. Six map viewers are included in the StoryMap illustrating (i) waterways in the landscape, (ii) erosion risk, (iii) catchment characteristics (area and share of arable land), (iv) nutrient flows at landscape level, (v) optimisation of wetlands location and sizing and (vi) flooding risk. Possibilities, limitations, experiences so far and further improvements of the tool will be discussed.

Phosphorous Reduction Measures: quantifying the benefits of gypsum application and grassland subsoiling treatments on heavy agricultural soils

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As our understanding of the impacts of agricultural nutrient loss on the environment has developed, so has the necessity for implementation and quantification of field-scale phosphorous loss reduction measures to achieve Catchment Nutrient Balancing (CNB). Measures commonly involve reducing or interrupting surface runoff from fields using buffer strips, cover crops or arable reversion. To increase the range of measures available to farmers, proof of concept trials of novel phosphorus reduction measures were undertaken, namely gypsum application and grassland subsoiling.

Agricultural trials suggest the application of gypsum granules to the soil surface improves soil structural properties such as aggregate stability of clay soils and increase the soils electrical conductivity. For phosphorus reduction, the proposed benefits include erosion control and improved binding of phosphate on soil surface. Reduced erosion decreases the likelihood of sediment losses via overland flow pathways, thereby preventing transport of sediment bound phosphorus. Grassland subsoiling is a mechanical soil treatment to break up compacted soil layers by drawing widely spaced tines through the soil, at the required depth, to produce a shattering effect. This increases infiltration, root penetration and reduces surface runoff, similarly reducing overland flow transportation of phosphorus into ditch and river networks.

Proof of concept trials of gypsum applications and grassland subsoiling were hosted by farmers in the Brinkworth Brook and River Stour catchments over the winter of 2022-2023. Gypsum granule application rates for the trials included distinct plots in combinations of one, three and five tons per hectare, paired with standard practice control portions of the field in all cases. Grassland subsoiling plots were similarly monitored against a standard practice control. Soil characteristics were measured in all plots, including saturated soil infiltration rates using automated infiltrometers, soil compaction using a penetrometer, soil quality sampling for phosphorous content and laboratory derived soil health indicators, and Visual Evaluation of Soil Structure (VESS). In addition, spot samples of drainage ditch water quality were collected.

The benefit of these efforts has been threefold.

1) Indicative baseline data that both suggests the merits of such treatments and validates the investment in repeated and scientifically robust trials in future

2) Highlighting the implications of various trial formats and where complementary datasets could be added through future trials

3) Development, through training and equipment familiarization, of technician monitoring capability and capacity in support of this and future trials.

Preliminary data of soil and water quality will be presented alongside lessons learned.

A decision support tool for selecting between sixteen riparian mitigation measures based on farmed landscape factors

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Edge of field measures may be an effective part of a chain of source and transport controls for controlling pollution from farmed land. However, the widespread application of relatively narrow grass margin means that in many situations riparian buffer zones can fail to deliver multiple benefits. Failure to apply a wider range of designs that suit the site-specific context (soil types, flow pathways, nature and severity of erosion) together with poor spatial targeting (or uniform narrow margins) often contribute to poor mitigation performance over a range of pollutants.

The Smarter BufferZ project (Irish EPA Research funded, 207-22) sought to introduce consideration and functional knowledge of a wider set of riparian measures and to help address their suitability against landscape factors. A synthesis of sixteen riparian pollution mitigation measures included commonly understood grass, wildflower and wooded buffers alongside novel, targeted measures for high erosion or runoff situations, and presence of artificial subsurface and open ditch drainage (available at: https://data.mendeley.com/datasets/ggc3pz78w4/1). Included was an effectiveness assessment undertaken by international experts for a range of pollutants and wider benefits.

To support decisions by catchment officers and advisors we developed a riparian mitigation measures tool (hereby referred to as 'the tool') to prioritise between the measures using a consistent framework within which to apply rules to reject vs favour some measures. The tool functions by guiding a user through a set of questions on the landscape, runoff and erosion pressures and pollution pathways to target edge of field mitigation measures. The tool acts as a screening and engagement tool amongst, for example, advisor and land-owner interactions at an initial stage prior to bespoke site survey, wider professional and policy advice, to reach final management decisions. The current version of the tool has been improved by stakeholder testing (Nov 2022) and is available openly at: https://measure-selection-tool.hutton.ac.uk/

Here we present an interactive poster display describing the sixteen measures and then some of the basis for the rules within the tool. Some basic instructions allow participants here a chance to explore the functionality of the tool 'live' by inputting either a couple of set scenarios (or their own chosen parameters) via the user input questions, exploring the mitigation recommendations as they change according to landscape and field scenarios.

Cover crops and nitrate leaching: a tool to determine over winter nitrate saving effectiveness

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Agricultural land is a major source of nitrates to surface and groundwater in the UK. Nitrate is necessary for agricultural productivity but can negatively impact water quality and is costly to remove during the drinking water treatment process. To alleviate nitrate leaching over winter, cover crops can be sown to provide ground cover thereby minimising the impact of rainfall. Research indicates cover crops can reduce nitrate leaching by accumulating and storing nitrogen which would otherwise be leached from the soil; however, not all cover crops will effectively prevent nitrate losses at the same rate or for the same amount of time. Consequently, the time cover crops are sown, and the choice of crop are influencing factors within the control of the grower that should be considered to reduce nitrate losses over winter.

The aim of this work was to establish a robust understanding of nitrate savings across various cover crop species and to identify how the nitrate savings efficacy of each cover crop changes over the winter soil drainage period (approximately September – April). A multi-annual dataset of cover crop nitrate leaching data has been established across the Wessex region and has been used in conjunction with Irriguide, a drainage calculation tool, to quantify the reduction in nitrate leaching gained from selected cover crop varieties. By sampling leachate in fields where cover crops have been sown and comparing to leaching from bare soils, the effectiveness of cover crop at preventing nitrate leaching has been established. Effectiveness curves for cover crop types were derived from the difference in leaching between bare soils and the cover crop against the sowing date of each cover crop.

Results indicate despite the oil radish (or turnip rape) category typically providing greatest nitrate savings at the start of the drainage period, the crop effectiveness degraded rapidly with no nitrate savings predicted from early October. Italian Rye Grass (or Westerwolds) and barley (or oats) presented lower starting efficiencies but maintained these values for longer and would be more appropriate crops to sow in later September than oil radish to attain greatest nitrate savings. Further analysis will investigate soil types as another influencing factor on cover crops and nitrate savings. Continued data collection to provide longer datasets will be necessary to assist in disentangling how previous harvest crop may influence the nitrate saving effectiveness of the cover crop and to identify how changing climatic conditions will impact nitrate leaching.

Smart farming technologies to enhance agricultural productivity and monitor environmental influence on Irish horticulture/tillage farms

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Irish horticulture and tillage farmers face a range of challenges such as weather variability, soil degradation, rising input costs, pesticide usage, sustainability practices and climate change impacts. Smart agriculture practices are evolving and transforming the farming practices through the integrations of sensor technologies via the data driven methodology to optimise the yields and monitor the environmental conditions.

Smart farming solutions, include soil sensors to facilitate the nutrient management, weather stations, to provide the real-time data for decision making, and remote sensing technologies to take decisions remotely, can be used to optimize resource management and crop yield. These sensors can also help to reduce the carbon footprint in the farming activities.

Smart farming with connectivity and remote monitoring by means of the Internet of Things (IoT) will allow farmers to manage operations remotely, using the real-time data alerts during the critical conditions. This approach not only improve the yields, but also helps to promote the sustainability by reducing the pesticide usage, water management and efficient energy management. Such data-driven decision-making approach with the help of smart technology, further contribute to climate change mitigation activities that are well aligned with the international climate goals. By exploring the challenges Irish farmers face, we will demonstrate how smart technologies could assist them.

WaterEIP Research Hub

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The Water EIP is the largest European Innovation Partnership project ever undertaken in the Irish Republic. This five year, €60 million project, aims to bring about improvements in water quality with co-benefits for climate change and biodiversity. €50 million will go in direct payments to farmers for measures delivered following approaches co-developed (e.g., ASSAP, Catchment Science, ACP, Teagasc Research, LAWPRO local catchment assessments, EIPs, High Nature Value and other initiatives) with the Agricultural sector under the 2nd River Basin Management Plan. The project will adopt innovative practices in nutrient management, the application of nature-based Natural Water Retention Measures (NWRM) and other measures at farm level following the principles of Integrated Catchment Management. Innovative approaches include the production of Rainwater Management Plans for farms and Nutrient Use Efficiency Plans for farms in nitrate vulnerable areas. Measures are being designed and implemented, in collaboration with farmers, and will be targeted specifically to address local challenges. Department of Agriculture, Food and the Marine and Department of Housing, Local Government and Heritage, An Bord Bia together with our project partners, are fully engaged in the delivery of this project to ensure learnings inform policy.

A Research Hub has been established to serve as a meeting space for the research community focusing on the EIP project. This community of researchers will leverage the opportunity provided by the project to facilitate high quality practical scientific research. The Research Hub will also advise on project evaluation, research findings and practices which may be adopted within the WaterEIP.

The Research Hub will facilitate input from the academic community and applied research, provide subject matter expertise on adaptive management trends, develop best practices and knowledge in key areas (e.g., adding High Nature Value concepts to pathway interception measures, rainwater management planning, nutrient efficiency opportunities, etc.), develop innovations to support water quality and flood risk management at the farm scale, upscale these from farm scale measures to catchment scale, leverage industry and project based specific insights, complement core project evaluation and inform national policy based on the practical innovations and social learnings from the project.

A key research area will be water quality protection efficacy of and multiple benefit potential of critical source pathway interception measures, across a range of farm enterprise (dairy, beef, tillage) and soil types.

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Clover150: reducing N on farm

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Ambitious targets of 350,000 tonne reduction in nitrogen (N) fertiliser have been targeted by 2025, recent figures have shown that there was a 14% reduction in N in 2022. There has been a growing awareness of the importance of legumes, in particular white clover integration into grassland systems and the reduction in N that accompanies. The 5 year Clover150 farm project was established in 2021 and has 35 farms across the country with a variety of enterprises, land types and geographic spread. There are four objectives of the program:

1. Maintain herbage production ≥ 14 t DM/ha grown
2. Reduce Nitrogen (N) Surplus <130 kg N/ha and an increase N use efficiency >40%
3. Reduce N fertiliser to ≤ 150 kg N/ha per year
4. Average sward clover content of 20 – 25%

The area of the farm in clover at the end of 2022 was 64% an up from 45%, an increase of 19%, in 2021, with an average sward white clover content of 18%, and increase of 6% from 2021. Sward clover content between reseeded paddocks and oversown paddocks was similar, at 15%, however, DM production, the paddocks that were over-sown had greater DM yield in the establishment year compared with reseeding (13.2 *vs* 9.9 t DM/ha), respectively. Chemical N fertiliser use in 2020, was 232 kg N/ha, with 14.4 t DM/ha of grass grown, while in 2021 chemical N use declined by 26 kg N/ha with an average of 14.1 t DM/ha of pasture grown. From 2021 to 2022 chemical N further reduced by 48 kg N/ha to 158 kg N/ha, and pasture grown was 13.2 t DM/ha. This reduction in chemical N resulted in a significant improvement in farm gate N surplus and N use efficiency (NUE) on the Clover150 farms. Farm gate N surplus and NUE were 194 kg N/ha and 31%, respectively in 2020 in the first year of the programme. By the end of the third year (2022), the farm gate N surplus had reduced by 55 kg N/ha (139 kg N/ha), while NUE had increased to 39%. This improvement in N surplus and NUE was largely driven by the reduction in chemical N fertiliser. White clover will play a key role in reducing the requirement for chemical N fertiliser and reducing farm gate N surplus on farm. A major focus in the coming years must be to increase the clover content in swards.

Signpost Dairy Farmers Progress Update

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The Signpost Programme is designed to support and enable dairy farmers to farm more sustainably. This paper aims to benchmark the GHG emissions for dairy farms (n=34 reported, 50 in total) in the programme and describe changes over the first 24-month period (2021, 2022). The Signpost dairy farmers are not representative of the "typical dairy farmer" and operate at a higher level of productivity and profitability relative to the national average. There was a high level of technical performance on the 34 Signpost farms in 2022 with an average milk solids output of 504 kg per cow using 186 kg of chemical nitrogen per ha and feeding 1,211 kg concentrates per cow with a stocking rate of 2.40 LU/ha. Total farm emissions (IPCC) increased by 2% on average across the 34 farms, with carbon footprint (emissions intensity, LCA) decreasing from 0.89 to 0.87 kg CO_2-e per kg FPCM. Analysis identified that 16 of the 34 farms reduced their total GHG emissions in 2022 (by on average 5%), with the same group of farmers also showing a 7% reduction in their carbon footprint (0.93 to 0.86 kg CO_2-e per kg FPCM). The remaining 18 farmers recorded a 9% increase in total GHG emissions and a 4% increase in their carbon footprint. The farms that decreased GHG emissions optimised mitigation technologies, reducing chemical N use per ha by 17% compared to 2021, applying 49% of their chemical nitrogen as protected urea and applying 90% of their slurry using LESS. Area of land farmed did not change on these farms but cow numbers and total milk output both increased by 1%. Of the farms that increased greenhouse gas emissions, area farmed increased by, on average, 2%; both cow numbers and milk output increased by 4%. Chemical N usage did not decrease in 2022 and 50% of the chemical N was applied as protected urea. Finally, the farms that reduced total GHG emissions saw a slightly higher increase in income per ha (+67% vs +51%). On farms where climate mitigations technologies have been adopted to a greater extent, and where herd size did not increase, there has been a reduction in GHG emissions.