CATCHMENT SCIENCE 2019

AGRICULTURAL CATCHMENTS PROGRAMME

Achieving quality water in diverse and productive agricultural landscapes under a changing climate

Clayton Whites Hotel, Wexford, Ireland

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

teagasc
Agriculture and Food Development Authority

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INTRODUCTION

Food production and environmental stewardship continue to be essential considerations from local to global scales. Food production for a growing world population and how this interfaces with the needs of a clean water resource and healthy biodiversity, and in the face of a changing climate is a challenge across the science-policy-producer-industry-consumer spectrum. For agriculture, the key challenge is for sustainable intensification.

The overall theme of **Catchment Science 2019,** hosted by the Teagasc Agricultural Catchments Programme in Wexford, Ireland, is **"Achieving quality water in diverse and productive agricultural landscapes under a changing climate".** This highlights some of the challenges we are currently facing within the scope of water quality management in agricultural landscapes. We draw on experiences from international science and policy programmes, and advisory and stakeholder engagement initiatives.

There are eight inter-related themes providing a framework for the oral and poster presentations of this international conference:

I. Soil analysis and nutrient management
II. Drivers, controls and time lags – meeting the expectations
III. Options for management approaches in reducing contaminant loss risk
IV. Long-term in-situ monitoring and modelling of water quality
V. Impact of multiple stressors on aquatic ecology
VI. Decision support tools
VII. Integrated management, stakeholder engagement and catchment economics
VIII. Knowledge transfer, water governance and policy implementation

The conference includes a choice of four field visits of different themes and an interactive workshop.

Catchment Science 2019

Agricultural Catchments Programme – Teagasc

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REFERENCES

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Achieving quality water in diverse and productive agricultural landscapes under a changing climate

Conference Schedule

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11.00 – 11.15:	**Noeleen McDonald [DAFM, IE]:** "Room for nutrient improvement: A Field scale audit of P management and soil P trends in two mixed-use catchments"
11.15 – 11.30:	**Sofie Van't Veen [Aarhus Univ, DK]:** "A nitrogen emission map for catchments based on stream measurements used to calculate nitrogen emissions from agricultural areas in three small Danish catchments"
11.30 – 11.45:	**Romain Hebert [Teagasc, IE]:** "Effects of manure type and soil properties on phosphorus bioavailability and environmental risk"
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09.45 – 10.00: **Ian Thomas [UCD, IE]:** "A next generation critical source area map of phosphorus losses in Irish agricultural catchments for decision support"

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11.30 – 11.45: **Michele McCormack [Teagasc, IE]:** "Factors influencing nutrient management practices on Agricultural Catchment farms"

11.45 – 12.00: **Mark Wilkinson [JHI, UK]:** "A margin of error? Assessing effectiveness and placement of grassed and raised field margins to enhance multiple benefits"

12.00 – 12.15: **Bertel Nilsson [GEUS, DK]:** "New methods for third generation river basin management plans under the Water Framework Directive-assessment o the impact of surface water from groundwater"

12.15 – 12.30: **Andy Vinten [JHI, UK]:** "Managing nutrient loads. Water levels and wetland ecology: opportunities and sticking points in the upper Lunan Water, Scotland"

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15.30 – 16.00:	Coffee

Poster Session Abstracts

Opportunity is knocking and we must answer. A path for farming and food production in the shadow of "big problems"

Drohan P[1]

[1]*Penn State University, USA*

One could argue that today is a good time in history to be alive given the abundance of fresh, safe, accessible food, which is readily available to so many. Yet as we look across the globe a subtle anxiety exists amongst many involved in agriculture. This anxiety is driven in part by the continued challenges of food production as farmers and governments adjust to global trade; climate change; population pressure; changing models of farming and intensification, and site-specific nutrient management; and the abundance of knowledge/information and rapidity of its sharing. Where do we look for solutions to these big, complex problems, and at what scale should we approach them? I use examples from several continents to briefly document how nations are coping with pressing issues surrounding food production. I then present a potential strategy for moving forward that argues for a scaled approach to food production. This approach embraces old and new ideas, but most importantly recognizes the necessity of understanding land ownership legacies, the evolution and stability of government in relation to food production, and the role of government in producing food but limiting corruption and checking the verticalisation of markets. I argue that essential to the success of 21st century, sustainable food production is the development and practice of critical thinking by constituents of all nations, and an assessment at all scales of government, of not just economic achievement, but also human well-being. I argue that more than ever, in this new world of rapid climate change, it is the absolute responsibility of "wealthier" nations to step forward and help those "less-wealthy" nations combat soil degradation; this is still one of the greatest threats to humanity. Checking soil degradation for all countries is essential to stabilizing fertility, economic markets, human health and political unrest, and is as important to the smallest villages in Ireland is it is to the most remote parts of Africa. I am hopeful and you should be too. We have solved many of the food production challenges the globe faces. Big, complex problems remaining, like climate change, are largely human behavior issues governments can address, but I believe only if their constituencies are educated to think critically. Big, complex problems we face are perhaps less a basic science issue and more an issue of ethics. I have no doubt that solving these problems requires far harder work than any of the soil and water sampling, or planting or harvesting we have done. We must change as individuals, as communities, as countries…and that is hard, requiring support from governments and a village, here in Ireland and in Africa.

Room for nutrient improvement: A Field Scale Audit of P Management and soil P Trends in two Mixed-Use Catchments

McDonald NT[1], Wall DP[2], Mellander P-E[1,2], Buckley C[3], Shore M[4], Shortle G[1], Leach S[1], Burgess E[1], O'Connell T[1] and Jordan P[5]

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[4] Local Authority Water Support and Advice Team, Limerick County Council, Co. Limerick, Ireland
[5]School of Geography and Environmental Sciences, Ulster University, Coleraine, N. Ireland

Accounting for the distribution of soil phosphorus within fields is crucial in identifying hotspots of agronomic underperformance and/or environmental risk to water as a consequence of inadequately managed P disruption. There is also a need to understand how P use and legacy soil P evolves under the Nitrates Action Programme (NAP) regulations from the European Union (EU) Nitrates Directive. In an Irish case study the aim was to provide a detailed audit of P balance and soil P responses and trends in two mixed land use agricultural catchments (Arable A-Castledockrell and B-Dunleer) across a four year study period. Driven by increased chemical P inputs the field balances in the Arable A catchment had an average surplus P, ranging from 1.9 to 7.5 kg ha^{-1} yr^{1}. However, during the study period 2010 to 2013, the average soil test P (STP) levels declined, with the area of excessive soil P concentrations decreasing by 8%. Similarly, in the Arable B catchment the average annual P inputs increased the surplus field P from -0.42 to 25.5 kg ha^{-1} yr^{-1}, but the area of excessive soil P concentrations increased by 4%. To some extent, this increase is attributed to some fields receiving excess applications of organic nutrient forms above crop requirements. Whilst, the legacy soil P (i.e. levels excess of crop requirement) declined in the Arable A catchment indicating a response to NAP, for both catchments it is evident that the distribution of P sources within farms was poor and P inputs often did not match crop and soil P requirements at the field scale. This study highlights the need for improved support to knowledge transfer mechanisms so as to deliver better farm and soil specific nutrient management planning strategies that offer dual benefits of improved water quality and increased crop outputs.

A nitrogen emission map for catchments based on stream measurements used to calculate nitrogen emissions from agricultural areas in three small Danish catchments

Van't Veen SGW[1], Kjeldgaard A[1], Tornbjerg H[1], Windolf J[1], Blicher-Mathiesen G[1] and Kronvang B[1]

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This study investigates the possibility to establish a local nitrogen emission map based on stream measurements. Nitrogen emissions from agricultural areas in three different Danish pilot catchments (200-1200 ha) have been determined by intensive daily monitoring of discharge and total nitrogen concentrations at a main gauging station and several synchronously monitoring stations placed within the catchment. The nitrogen emissions from agricultural areas were calculated utilizing a source apportionment taking into account nitrogen retention in surface water. The emission of nitrogen from agricultural areas within the sub-catchments was also used to investigate the local groundwater retention of nitrogen, which was compared to the groundwater retention from the Danish National Nitrogen Model. The different uncertainties involved in calculating sub-catchment nitrogen emission maps and retention in groundwater is discussed.

The nitrogen emission and retention maps were calculated based on two years of intensive measurement data from the three catchments covering different landscape types in Denmark. The outcome reveals that nitrogen emission varies a lot between the different catchments and within each catchment. Moreover, we found that the local groundwater retention in the sub-catchments in two of the pilot catchments showed large variations and was different as compared to the national mapping of nitrogen retention.

Our study shows that measurements of nitrogen emissions in streams provide a good opportunity for developing local nitrogen emission maps for agricultural areas. The map can give an overall picture of the spatial variability of the nitrogen loadings from agricultural areas within each sub-catchment and between the sub-catchments. This means, that the map can be used to get an overview of the local "hot spot" nitrogen emission areas which can be a help in order to better choose targeted mitigation measures.

Acknowledgements: This study is funded by a grant from the GUDP in Denmark.

Effects of manure type and soil properties on phosphorus bioavailability and environmental risk

Hebert R[1,2,3], Jordan P[3], McDonald NT[4], Vero S[5], Mellander P-E[1,2] and Wall DP[2]

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The application of phosphorus in organic manures can maintain soil fertility but a challenge is to avoid over application and risk of nutrient losses, potentially decreasing water quality.
To evaluate the effects of soil properties, time after application and fertiliser/manure type on soil P pools, a soil microcosm incubation study was undertaken using four soil types, each at low and high initial soil P concentrations. Five treatments, chemical P, cattle slurry, pig slurry and hen manure, applied at a rate of 100 kg P ha^{-1}, and a zero P control were investigated. The soils were sampled at three time points (0, 70 and 140 days) and analysed for Morgan's P (P bioavailability), water extractable P (WEP - mobility) and P saturation ratio (PSR - buffering). All treatments equilibrated within 70 days but different soil P pool responses were shown between treatments and between initial soil P concentrations. Pig slurry and hen manure induced the greatest increases in bioavailable P from all initial soil P concentrations providing good opportunity for immediate and longer term soil fertility. All manures also increased WEP following equilibrium but this was often significantly lower than chemical P, indicating lower longer term P loss risk, especially cattle and pig slurry. However, WEP increased significantly more for pig slurry and hen manure in the time before equilibrium and further work is required to determine the extent of environmental risk following application of these treatments. These findings should be considered in policy reviews that try to balance soil P fertility and crop requirements with environmental risk. These results can also underpin soil analysis and nutrient management advice for farmers to help decisions on the right manure choice, applied at the right rate, at the time in the right place.

Keywords: soil test phosphorus; water extractable phosphorus; organic manures; soil type; Morgan's P; environmental risk.

A comparative study of lipid extraction methods for the quantification of biomarkers within soil and cattle slurry

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[2]Agricultural Catchments Programme, Teagasc, Johnstown Castle Environmental Research Centre, Wexford, Co. Wexford, Ireland
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Potable water is a precious resource, so there are policies and programmes worldwide to protect and/or improve water quality. A key contributor to the decline of water quality is agriculture and associated faecal/nutrient pollution. Faecal waste causes excessive nutrient enrichment and one result is eutrophication. The latter problem has resulted in the EU Nitrates Directive and its associated Action Programme rules for managing amendments to agricultural land from fertilisers and slurry. The robust sourcing of these pollutants is important to be able to target the appropriate sector and to engage the corresponding managers. Biomarker technology has the potential to do this, particularly the biomarker suite of sterols. Sterols have been used in the differentiation of human and animal faeces; however, there is no unequivocal technique regarding their analysis. Some of the methods used include: Soxhlet extraction, Bligh and Dyer (BD) extraction, and accelerated solvent extraction (ASE). Whilst all have their inherent advantages and disadvantages, the less costly and time intensive technique of ASE is particularly attractive, but a current research gap concerns further comparisons regarding lipid extraction of soils/slurries compared with the more traditionally used methods of Soxhlet and BD extraction. Such a comparison has recently been undertaken in conjunction with a Teagasc Walsh Fellowship PhD studentship exploring the development of robust chemical methodologies and their correlation with conventional water quality datasets for confirming incidental transfers of farm slurries to watercourses.

Session II: Drivers, controls and time lags – meeting the expectations

Climate change is accelerating phosphorus transfer to catchments

Haygarth PM[1]

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The link between agricultural land and catchment science is now well established, but less so is the role that climate change plays in accelerating the transfers of nutrients like phosphorus. This paper describes a team effort that has been studying the extent to which phosphorus losses from agricultural land are being impacted by climate change. The paper will discuss the great challenge in determining this, with all the complexities, controversies and uncertainties in catchment science that surround it. By focussing on three UK catchments, we show that the effect of climate change on average winter phosphorus loads (predicted to increase by up to 30% by the 2050s) will be limited only by large-scale agricultural changes (e.g. a 20–80% reduction in phosphorus inputs). Achieving quality water in diverse and productive agricultural landscapes under a changing climate is going to be a massive challenge. It is less than a century since we started mining rock phosphate, but in the context of a 4.5 billion year old earth and the acceleration due to climate, we are living through a switching point for the earth system, and catchment science is at the heart of this. We urgently need to innovate systems to avert this and to raise these issues up the agenda.

Challenges in reducing nutrient and sediment losses in agricultural catchments

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Freshwater ecosystems are subjected to multiple pressures in agricultural catchments resulting in gradual deterioration of their chemical and ecological status. One of the major pressures is nutrient and sediment loss to receiving waters. These can be reduced by appropriate changes in land/crop/fertiliser management at farm and field scale and implementation of mitigation measures in the drainage and stream network. The drainage and stream mitigation measures aim at slowing down water flow (e.g. by increasing retention time) and increasing the rates of physical and biogeochemical processes removing nutrients and sediments from water. However, the effectiveness of drainage and stream mitigation measures shows a large spatial (between catchments) and temporal (between seasons and years) variation. In this paper we discuss the effects of changing weather and legacy sources on effectiveness of mitigation measures for a small clay-soil agricultural catchment in Sweden. We show how mitigating a single pollutant can lead to pollution swapping effects and how difficult it is to achieve satisfactory improvements in water quality in the short-term.

Major controls of base flow soluble reactive phosphorus losses in humid temperate headwater streams

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Long term low flow ortho Phosphorus (SRP) monitoring in headwater streams in central Europe revealed a seasonal variability of the SRP concentrations with highest concentrations in summer and lowest in winter. These seasonal concentration amplitudes often reach values above the eutrophication level. It is assumed that temperature dependent biogeochemical processes could lead to P release to streams during the summer low-flow period, where redox processes may be responsible for this increase. Several studies have highlighted the crucial role of reactive zones such as riparian wetlands in controlling solute export regimes. Moreover, and especially in forest headwater streams, in-stream assimilatory uptake shows a distinct seasonal behaviour because of varying shading conditions. These can also lead to seasonal SRP amplitudes. Furthermore sorption and desorption processes are temperature dependent which may alter in-stream SRP release during the year.

Often SRP concentrations are higher in the agricultural streams than in more pristine headwaters. It is not clear how land use (e.g. P status of soils) may impact the baseline SRP concentrations and which factors control the seasonal change in SRP stream concentration (riparian groundwater heads and redox processes, temperature, in-stream release and uptake processes). Therefore, the objective of this study is to disentangle land use impacts from hydrological and biogeochemical controls of low flow SRP losses. A comparative study on seasonal SRP concentration patterns will be presented comprising around 42 long term monitored headwater catchments in humid temperate climate of northern Europe and the United States. Based on hydrological and SRP headwater signals and catchment properties P release processes are discussed. The results of the study will allow to target SRP mitigation strategies based on knowledge of the dominating control of SRP loss from headwater streams.

Causes of phosphorus elevations during low-flows across three contrasting watercourses

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Elevated in-stream phosphorus (P) concentrations have been observed during periods of low river flow. These elevations can exceed Water Framework Directive (WFD) threshold (0.035 mg l^{-1}) during ecologically sensitive periods. This research identified source, mobilization and pathway factors influencing in-stream concentrations across the main watercourse and tributaries of three rivers during each of the spring, summer and autumn low-flow periods. Up to 50 water samples were taken in each catchment per season and analysed for total (TP) and dissolved reactive phosphorus (DRP). Bed sediment was sampled from a subset of seven points in each watercourse and P, Al, Ca and Fe concentrations were assessed (Mehlich extract). In each catchment, the greatest number of sampling points exceeding the WFD threshold occurred during summer (57% - well-drained grassland, 11% - well-drained arable, 71% - poorly-drained grassland). Concentrations declined during autumn but typically, did not return to spring baseline.

Different controls on P were identified in each catchment. The well-drained grassland exhibited diffuse transport through the groundwater pathway, coupled by lack of dilution. This manifested as similar concentration changes across most sampling points. The poorly-drained grassland showed a combination of identifiable point sources (agricultural and domestic) and cumulative loading across the watercourse. Mobilisation from in-stream stores occurred in the arable catchment, which typically exhibited greater Al:P ratios in bed sediment than the other watercourses. These sediments are more likely to attenuate P delivered from external sources (agricultural and wastewater treatment facility), which may potentially be released subject to in-stream conditions. This was the only catchment which returned to base concentrations at most sampling points by autumn. Assessment of stream P must take into account the flow of the watercourse, as measurements taken at low-flow may be elevated above typical concentrations. Longitudinal water sampling allows greater spatial accuracy in identifying potential sources and pathways.

Assessing the role of colloidal P in P delivery to surface water in two contrasting agricultural catchments

Fresne M[1,2,3], Jordan P[2], Daly K[3], Fenton O[3] and Mellander P-E[1,3]

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Belowground pathways can be important carriers of nutrients and other pollutants to surface water in groundwater-fed river catchments. The high sorbing capacity of soil colloids can enhance transport of phosphorus (P) from soils to groundwater but also the delivery of P to surface water via groundwater pathways.

The role of colloidal P in P delivery to surface water was studied in two agricultural catchments with well drained soils but with contrasting land use (arable and grassland) of the Agricultural Catchments Programme. Free soil solution, stream water and shallow groundwater were sampled on a weekly basis to monitor background concentrations of particulate, dissolved and coarse colloidal (0.20 – 0.45 μm) P fractions and P-related parameters (metals, TOC…).

In addition, high-frequency (2h) monitoring was carried out during rainfall events in stream water and in near-stream shallow groundwater to provide evidence on P fractions delivery to surface water via groundwater pathways. An automated sampler was deployed in the stream and an automatic and disturbance-free sampling set up was developed for groundwater.
Multi-parameter probes were also deployed to monitor stream water and near-stream shallow groundwater physico-chemical parameters (DO, temperature, conductivity, ORP). Stream discharge was measured using a flow velocimeter coupled with a water level logger and stream gauging campaigns in order to quantify the different P fractions loads and apportioned pathways.

Recent findings in the arable catchment showed that background stream P concentrations were comparable to shallow groundwater P concentrations, typical of groundwater-fed streams.
The relative importance of the coarse colloidal P fraction in the total P fraction was low and increased quickly but briefly during a rainfall event. Changes in P concentrations during rainfall events were also associated with changes in metals (Al and Fe) and TOC concentrations. Further monitoring in the grassland catchment is expected to show higher P concentrations and a larger colloidal P fraction.

Regional Constraints on Sustainable Livestock Production: Challenges and Opportunities

Doody DG[1]

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Increasing world population, changing consumption patterns and the agri-food industry's ambition for expansion, will drive an increase in outputs from Irish agriculture into the future. With spatial expansion of agriculture in Ireland limited by the availability of suitable land, increases in agricultural outputs will be driven by intensification of farming in existing areas through improvements in technology and resource efficiency. This will have to be achieved within the context of the targets established by EU environmental directives, such as the Nitrates Directive (ND) (91/676/EEC) and Water Framework Directive (WFD) (2000/60/EC). In 2017 the national phosphorus (P) surplus of Northern Ireland agriculture was 12.3 kg P /Ha, with 23,717 tonnes of phosphorus being return to land in the form of livestock manures. With an estimated 47% of soil in Northern Ireland above the agronomic optimum Olsen soil P value, continued application of manures to many soils is unsustainable if the targets of the WFD are to be achieved. However, there are significant constraints on farmers in terms of manure management and its redistribution across the region. In this paper we present a regional analysis of the challenges and opportunities of manure management across NI and consider the mitigation strategies that will need to be employed where P surpluses are unsustainable.

Field to catchment scale carrying capacities to limit soil P risk to water quality

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Soils with phosphorus (P) levels above the agronomic optimum are considered a risk to water quality, particularly if located in areas likely to generate surface runoff during rainfall events. Identifying and targeting management at these areas has the potential to reduce diffuse nutrient pressures on surface waters and, for farmers, to deliver greater on-farm nutrient efficiency.

To operationalise such an approach at field, farm and catchment scales a carrying capacity framework for soil P and runoff risk was developed and applied within catchments in Northern Ireland.

A soil P survey of 13 sub-catchments and 7,693 fields was undertaken in the 220 km^2 Upper Bann catchment, identifying fields at, below and in excess of the agronomic optimum, which is Index 2+ (21 - 25 mg Olsen P L^{-1}). Hydrologically Sensitive Areas (HSAs) were determined as the top 25th percentile risk from a runoff routing model that used a LiDAR digital elevation model and soil hydraulic conductivity properties. Comparisons of these spatial metrics with river soluble reactive P concentrations across 13 sub-catchments indicated that, for this landscape, the carrying capacity for above agronomic optimum soil P is no greater than 15% of sub-catchment areas and effectively no areas (<1.5%) of a catchment should have coincident high soil P and runoff risk.

The opportunities to redistribute these risks were analysed on fields with below optimum soil P and where HSA runoff risk was minimal. These areas, which could be utilised to redistribute organic nutrients away from high risk areas, ranged from 0.4 % to 13.8 % of the sub-catchment areas. This limited potential, unlikely to fully reduce the P pressure to over-supplied fields, would need to be considered in conjunction with lowering on-farm P balances and in-field P interception measures.

Ongoing work is extending the framework to other catchments in the region.

Designed riparian buffers improve functions and uptake

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Riparian zones are critical locations, at landscape to field scales, for management to enhance environmental functions and benefits. Riparian buffer strips between agricultural or developed land and watercourses can help alleviate pressures on the water environment and provide essential ecosystem services if correctly designed and sited. Although riparian buffers are amongst the most widely adopted diffuse pollution measures, their current adoption falls short of realising their full potential. For example, sediment or nutrient capture in surface runoff may at best be spatially variable, but for land where artificial subsurface drainage pathways exist, their functionality will be highly limited. Such uncertainty and lack of guidance for what works best and where, limits effective uptake.

This talk looks at the concepts of measures that can be applied in the riparian space that act to enhance functions (e.g. pollutant trapping and retention) required to 'buffer' against nearby agricultural field practices or to restore degraded functionality of river corridors (e.g. restoring canopy shading combating temperature extremes). The core concept is that innovative use of the riparian space, via designed features coherent with location, can reduce uncertainties in the way that buffers function for water quality and other benefits. The range of options includes vegetation change, tree planting, mini-wetlands intercepting drains, blind ditches, sculpted channel form, raised bunds and 'leaky' flood water holding areas. To examine the interactions of design, siting and the context of 'place' we introduce a range of designs aspects, examples of packages of measures that can be combined and demonstration examples of 'integrated buffer zone' approaches. These are considered against contexts of form of the field-riparian transition-channel zone, soil water table and differing pollutant pathways. We present an argument for moving away from linear fixed width buffers towards designed, spatially-targeted packages of measures to improve outcomes and, in-turn, uptake.

The Ditch of the Future: Managing Flow and Pollution Rates in Agricultural Systems

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Ditches within the agricultural landscape provide a key agronomic benefit by helping to improve land drainage in order to provide favourable soil conditions. However, the export of pollutants and possible contribution to local flooding associated with ditches is being largely ignored.

Sedimentation occurs naturally in ditches but is perceived as a problem due to a reduction in flow capacity of the channel. Thus, ditch management is often very active and can result in highly connected and polluting flow pathways. There are many modified drainage features and low order channels on farms that could be modified and managed in a new way. Ditch modification does not need to affect agronomic function, but could trap sediment and other pollutants, and lower flood risk, if designed appropriately. Ditches are already highly modified features and therefore further modification should not be an issue. Helping farmers to create, manage and maintain the 'ditch of the future' is vital for adding hydrological attenuation capacity to agricultural landscapes.

Here we will show several examples from UK farms that demonstrate how the typical ditch form can be modified, e.g., widened and flattened, to create 'zones' conducive to sediment (and associated pollutants) deposition, and the construction of within-ditch leaky barriers to temporarily store runoff. A 50m stretch of ditch draining 0.7 km^2 of arable land was shown to remove ca. 50% of the sediment and 30% of the total phosphorus concentration or a cost of 5000 euro. It is proposed that a network of barriers positioned along a ditch could yield a much greater impact than interventions in isolation. If space allows, then a ditch can be modified to retain significant volumes of flood flow. A scheme of this nature will be presented for an Irish Agricultural Catchments Programme research site.

Targeted drainage measures for improvement of water quality in Denmark

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The losses of nitrogen (N) and phosphorus (P) from point and diffuse sources to surface waters in Denmark have been reduced considerably during the last 3 decades. However, a further reduction in nutrient losses are needed to obtain good ecological quality in water bodies, a goal which is not easily achieved as the low hanging fruits for nutrient management already are fully exploited. Furthermore, farmers were again allowed to increase their fertilisation of crops to the economic optimum in 2017. This less stringent regulation of fertilisation in Denmark was implemented in exchange of farmers having to implement new collective and targeted regulations. One such targeted regulation is an open call for adoption of supplementary catch crops in areas where groundwater or estuarine waters are threatened by excess nitrate and where natural N removal in groundwater is reasonable low.

Furthermore, a limit for P inputs to fields was implemented in 2018 being set for different animal types and being stricter for farming in catchments of vulnerable lakes. The collective measures include larger schemes for wetland restoration, constructed wetlands (CW's), afforestation and taking organic soils out of production. A new scheme with catchment officers was at the same time implemented in Denmark with the aim to bridge farmers, municipalities and national agencies. Finally, a sub-catchment based targeted nutrient regulation will be adapted from 2019 and include a suite of new mitigation measures such as e.g. integrated buffer zones and biofilters, which have all being scientifically tested. Such a scientific documentation is essential to know the processes that control their local effects for N and P, their relative importance over time, need for management and their cost-efficiency. This presentation will provide an overview of the state of regulation of agriculture in Denmark as well as provide empirical evidence on the effectiveness of different targeted mitigation strategies and new ways of assisting in finding local placement with farmers to facilitate a local adaptation.

Pros and cons of grass buffer strips on Swedish arable land

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A field experiment with grass buffer strips was conducted in eastern Sweden to monitor leaching of nutrients from arable land. The study has been underway for 8 years, from 2011 to 2019 on a clay soil, 10 km south of Uppsala. The treatments included were: 1) control, usual tillage and cropping; 2) permanent grass; 3) Grass, which was harvested once a year. We measured the amount of surface runoff and drainage water and analysed the concentration of phosphorus and nitrogen in the leachates. Since the land was undulating, ca. 90% of water transport was through drainage systems. Permanent grass and harvested grass reduced the leaching of particulate phosphorus with erosion by 35% and 40%, respectively. On the contrary, the loss of dissolved reactive phosphorus was increased by 58% and 38%, respectively. The grass strips gave similar effects for losses with drainage water but to a lesser degree. Grass buffer strips reduced the leaching of nitrate nitrogen by 26% but harvesting increased leaching by 5%. This might be due to regrowth of the grass, which dies and decomposes during winter. We conclude that, on undulating Swedish arable fields, grass buffer strips are not sufficient to effectively reduced nutrient losses and supplementary measures should be taken.

Validation of soil erosion risk maps using legacy and agency farm assessment data

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For agricultural advisors, regulators and farmers to have confidence in risk assessment tools these tools require validation. While some soil erosion models have been validated using measured erosion rates from plot studies or inferred rates from sediment loads in rivers, many remain un-validated due to a lack of data. In Scotland we have applied a simple rule-based soil erosion risk assessment (Lilly et al., 2002) which uses soil runoff potential from the Hydrology of Soil Types (HOST) classification, slope and topsoil soil texture and has recently been adapted to take account of land management. We have used a novel combination of observed erosion events from research studies and regulatory data from farm assessments undertaken by

Scottish Environment Protection Agency (SEPA) staff to validate the risk assessment.
This approach ensures that the risk maps were salient to their end-users, credible for decision making and legitimate in their treatment of different views of risks associated with soil and land management with respect to protecting the aquatic ecosystem. This approach could be used as a key part of the SMARTER BufferZ project (funded by the Irish EPA) where we are developing both conceptual models of breakthrough points and a screening tool to assess areas of high risk of sediment and nutrient delivery to water courses.

Session IV: Long-term in-situ monitoring and modelling of water quality

Can the sediment pollution gap from intensive livestock farming be closed? Assessment using the North Wyke Farm Platform, UK

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Whilst much research in the UK on the impact of modern intensive farming on soil erosion and resulting externalities to water, including excess sediment loss, originally focussed on arable systems, there has, for some time, been a growing recognition of corresponding issues associated with intensive livestock farming. Ongoing research on the North Wyke Farm Platform in southwest England is monitoring sediment loss using 15 micro-catchments hydrologically -isolated by a network of French drains and instrumented in situ with equipment for discharge and turbidity measurements. The core monitoring work is providing a basis for estimating modern day sediment loss. In turn, these estimates are being compared with corresponding estimates of modern (pre-dating the post-World War II intensification of farming) back sediment delivery to rivers constructed using palaeolimnological evidence. The final part of the work is investigating the scope for closing the sediment pollution gap, characterised by exceedance of modern back ground sediment delivery to rivers, on the basis of increased uptake of best management practices applicable to lowland beef and sheep farming systems.

Quantifying components of the aquatic organic carbon cycle of a humic lake: a case study from the Burrishoole catchment, Co. Mayo.

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Directional climate change is proceeding rapidly. Assessing the impacts of the resulting changes in local climate on ecosystem function and formulating appropriate adaptation and mitigation strategies are the greatest scientific challenges that we now face. Warmer temperatures and shifts in seasonal precipitation patterns, as have been predicted for Ireland, will drive changes in the quantity and composition of nutrients, including organic carbon (OC), entering aquatic ecosystems. This has particular relevance for Ireland, where peatlands store between 53 and 62% of the national soil OC. Peatlands are acknowledged to be particularly important for current and future carbon cycling, due to their sensitivity to climate change, and the fact that they are hotspots for carbon storage. Interest in the carbon cycling of aquatic systems has increased internationally as evidence mounts that freshwater waterbodies can play significant roles as carbon sinks or sources. Peatland degradation represents a major transfer of OC from long-term stable terrestrial stores to more active and biological available forms and ultimately to the atmosphere. The role of aquatic transport from streams, ponds, rivers and lakes is central to this transfer. Over the last 20 years, considerable progress has been made on resolving the carbon budget of Lough Feeagh, Co. Mayo, primarily through the use of the long-term environmental monitoring data that are collected by the Marine Institute in the Burrishoole catchment. Burrishoole is a typical western peatland catchment and is an important index site for diadromous fish monitoring and catchment change. Here, we describe some of the outputs from several decades of data collection and research, including the historical context, seasonal patterns and drivers in dissolved OC export, CO_2 emissions from Lough Feeagh, and the role of allochthonous and autochthonous carbon in the foodwebs of Burrishoole.

Monitoring pitfalls: Aquatic environment

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Assessing the state of and impact on the aquatic environment calls for a strategic monitoring programme in order to give a sufficient assessment of the state of the environment in time and space. In addition, and not least, the monitoring has to include reliable data (sampling, laboratory analysis, statistical calculations and models). Especially when the trends in the state of the aquatic environment is analysed, the consistency of the time series of data is crucial.

In Denmark, a strategic monitoring programme has been going on for 30 years. During this period, changes in the number of monitoring stations, chemical analysis, sampling frequency, monitoring equipment and statistical calculation procedures have taken place. Some of these changes have led to problems when evaluating the state and trend of the aquatic environment. Examples of such problems will be given and include; changes in monitoring station network, sampling frequency, laboratory methods used for analysing total nitrogen, total phosphorous and as well as changes in gauging methods for calculation of precipitation and discharge in streams. Furthermore, it has become increasingly evident that the method for calculation and assessment of the transport of total phosphorus in minor streams is biased and is not sufficiently taking into account the dynamics of the concentration of phosphorus in such streams.

Combining high-resolution spatially distributed models with export coefficients produced by field-scale process-oriented model

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In Sweden, reduction of Phosphorus (P) losses from diffuse sources is recognized as necessary to improve water quality of impaired streams and lakes as well as the Baltic Sea. Different mitigation measures are continuously implemented but the targeting of critical source areas at higher resolution (field and subfield scale) is still poor, mainly because of the lack of reliable tools, which would make possible targeting at resolution higher than sub-catchment. Recently, high resolution erosion maps have been developed but the corresponding tools for P losses are still lacking. In the national pollution load compilations, P export coefficients are calculated using field-scale ICECREAMDB model for the 22 regions in Sweden, 15 crops, 10 soil textural classes and with consideration taken to field slope and soil P content. These export coefficients are thereafter used to estimate diffuse P loads from agriculture to surrounding seas, but the highest resolution of presented results of these calculations is sub-catchment level. In this study, we combine expert coefficients together with high-resolution elevation data, soil textural distribution and measured monthly flow to estimate P loads at scales varying from cell (2mx2m) to field and catchment scale. The approach has been tested with dynamic modelling for six small agricultural catchments included in the water quality monitoring programmes with available data on water flow and nutrient concentrations. In two of the catchments exists even monitoring results at one field within each catchment. The comparisons of P loads at field and catchment scale have shown satisfactory results and model was able to capture high variation between catchments. The possibilities, limitations and potential improvements of the suggested approach are discussed.

Understanding the hydrological dynamics of acid herbicides in river catchments using high-resolution data

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Surface waters from upland catchments are important for drinking water provision and, in both Irish jurisdictions, share these areas with agriculture and forestry. However, there is increasing evidence of pesticide concentrations exceeding the European Union limit (0.1 μg/L) in raw water and concern at the associated costs of treatment. The majority of these exceedances are caused by 2-methyl-4-chlorophenoxyacetic acid (MCPA), a selective acid herbicide primarily sprayed in upland areas to reduce rush (Juncus spp.) cover in grassland. MCPA is often sold in a mixture with other acid herbicides such as mecoprop-P, fluroxypyr and triclopyr, all of which can also be used alone in similar agricultural settings to improve grassland or crop yields.

A major initiative *(www.sourcetotap.eu)* has been monitoring acid herbicide concentrations in two large (>350 km^2) cross-border rivers since May 2018 to provide a baseline prior to introducing an incentive scheme. These high-resolution (7-hourly to daily) time-series demonstrate that the problem is greater than previously implied: over 27% of samples contained more than 0.1 μg/L of MCPA and concentrations did not fall below the limit of detection (0.0005 μg/L), even in winter when no applications were expected. Analysis showed that acid herbicide transfers to rivers were largely driven by short duration storm events in catchments, highlighting their highly soluble nature.

To further understand the transfer dynamics of the four acid herbicides, concentration-discharge relationships were analysed for selected storm events throughout the year to assess hysteresis magnitude and direction. The analysis showed similarities and differences in the sources, pathways and timings of transfer between the different herbicides and between the two catchments. We linked the hysteresis analysis to river flow and rainfall dynamics, which suggests how a predicted change in the climate could alter herbicide transfers to water. The implications of this for water quality and for agriculture are discussed.

Use of regulatory information and monitoring data to update pollutant loadings from Sewage Treatment Works across England at national scale

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Final effluent from Sewage Treatment Works (STW) has good connectivity to watercourses, continuous flow during ecologically-sensitive periods and emergent pollutants. These characteristics make their permitted management an environmental policy issue at national scale. Reliable quantification of STW loadings is essential for the development of targeted, cost-effective and equitable catchment management strategies for the improvement of water quality and ecological status. In this context, our recent work has integrated up-to-date information on consented discharge permits, data from the associated monitoring certification scheme (MCERTS) and archived water quality data in the Water Information Management System (WIMS) to estimate updated annual loadings of total phosphorus and suspended solids for STWs across England. While STWs managed by both water companies and non-water companies were considered, the current work has focused on those which record freshwater as their principal receiving environment. Statistical relationships between 1) permitted flow and actual daily flow, and 2) prescribed pollutant concentration limits and monitored data from regulatory sampling were explored. Annual loadings for individual STWs were calculated, and these exhibit a significant reduction (>80%) in the national scale total loads emitted to freshwater in comparison with our previous estimates for the period 2010-2012. Monte Carlo simulations have also been undertaken to quantify potential ranges for the load estimates. These estimates should, however, still be treated with some caution considering the issues of permit registration for those STWs with multiple outlets, the limited number of monitoring sites with good quality data (especially for total phosphorus) and the high variability of monitored concentrations recorded for any individual specified consented discharge. The updated STW loadings will contribute to ongoing cross-sector water pollutant source apportionment work as part of a strategic research programme exploring the cost-effectiveness of targeted on-farm intervention strategies for sustainable intensification.

Multiple stressors – a challenge for freshwater assessment and impact mitigation

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Most freshwater ecosystems are subject to more than one stressor acting simultaneously. These include a range of chemical pollutants but also physical stressors such as fine sediment that originate from drivers such as agricultural, forestry and urban land-uses, industry and transport. The various stressors can interact in complex ways, have different exposure pathways and impact different receptors as well as varying in intensity across spatial and temporal scales. The resulting impacts are complex, they are seldom simply the sum of the effects of the individual stressors, but can be greater (synergism) or lesser (antagonism), and can even lead to so called 'ecological surprises'. Furthermore, climate change is likely to superimpose other stress factors such as increased temperature and altered flow regimes. This is in addition to the growing number of contaminants of emerging concern.

The resulting 'stressor cocktails' challenge our ability to detect the impacting stressors, prioritise which stressors should be targeted and apply effective mitigation measures to protect ecological health and biodiversity but also the supply of essential ecosystem services. In the context of the Water Framework Directive this has implications for developing effective River Basin Management Plans and associated policy. This paper will introduce the issue of multiple stressors in freshwaters and highlight what research to date has shown in terms of stressor interactions. The results of multi-stressor mesocosm experiments carried out in Ireland will be included. The presentation will conclude with a summary of knowledge gaps, key questions relevant for multi-stressor management and options for using the available information to assess and manage the ecological health of freshwaters in a multi-stressor environment.

An integrated assessment framework for assessment of key ecosystem services and effect on aquatic ecology

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Ecosystems generate a range of goods and services important for human well-being, collectively called ecosystem services (ES). Services are often associated with high exploitation of the ecosystem; the risk is an unsustainable use of nature. The catchment is the appropriate scale to observe and quantify processes related to the water cycle. In the Karjaanjoki river basin, we aim to sustainable agricultural production that does not harm water ecosystems. Indicator species are trout and river pearl mussels. For that purpose we chained mathematical models to assess the threats of human activity in the catchment area to ecosystem services. These activities can influence water quality and thus living conditions of these species. As most of the decisions are made by individual farmers, we do sustainability analysis on farm level.
This is considered in the conceptual framework by including sustainability indicators, i.e. indicator combining capacity and flow. We created an integrated model chain to allow quantification of main ecosystem freshwater services and assessment of different loading scenarios from agricultural practices. The integrated model system will allow:

- assessment of nutrient and sediment loading from fields (load)
- identification of retention areas for nutrients and suspended solids (capacity)
- planning of reduction measures
- assessment of impacts on habitats of sensitive/protected freshwater species (benefit)
- analysis of sustainability performance of different agricultural products (flow)

Strong and recurring seasonality revealed within stream diatom assemblages

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The benthic biodiversity of freshwater streams is known to respond to multiple anthropogenic stressors, including excess sediment and nutrient delivery that is often modulated by climate-dependent flow, water temperature and event-driven transfers from catchments. Short-duration temporal studies have shown that benthic diatoms, single-celled algae that form a ubiquitous component of stream benthos, are impacted at daily timescales to variables including light, temperature, nutrients and flow conditions. However, knowledge of their seasonal resilience over multiple years is less well known, even in catchments actively managed to reduce pressures. Here, six years of monthly diatom samples from three independent streams, each receiving differing levels of diffuse agricultural pollution, reveal robust and repeated seasonal variation. Critically we highlight the importance of climate as an indirect variable that alters primary drivers such as nutrient concentrations in the water column and stream conditions. We recommend that future assessments of stream water quality must therefore capture the inherent seasonal variability of ecological communities and predicated seasonal changes in climate to understand the apparent resistance of stream ecosystems to pollution mitigation measures.

Cattle Exclusion from Watercourses: Environmental implications

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Nutrient enrichment and excess sediment inputs, are primary water quality issues for freshwater ecosystems. Anthropogenic activities, including land use and agriculture, are amongst the main sources of pollutants to freshwater systems. Intensive grazing by livestock can impact on water quality at local and landscape scales. Fenced riparian buffer measures are amongst the commononest mitigation measure to maintain and enhance the quality of freshwater ecosystems. However, few studies have evaluated their effectiveness, especially within Europe. The COSAINT project, Cattle access to watercourses: environmental and socio-economic implications, was a five-year (2014–2019), inter-institutional project funded by the Environmental Protection Agency (EPA).

Results from the COSAINT project indicate that cattle access points resulted in significant increases in fine bed sediment and the infiltration of sediment into the hyporheic zone. Increased stream sediments acted as reservoirs for faecal bacteria and phosphorus, which persisted when cattle were removed periodically from the field, but did not persist after cattle access pressures were fully removed. Increased sediment deposition was also a dominant driver of macroinvertebrate community change, although results here were more variable and site specific. Significant reductions in sediment sensitive taxa were encountered at points downstream of cattle access points, whereas abundances of sediment tolerant groups increased.

Results highlight that exclusion of cattle from watercourse can help improve the quality of environmental indicators over the short and long term. One year of exclusion resulted in improvements with regard to deposited stream sediment, phosphorus concentrations in sediment and macroinvertebrate communities. Improvements also persisted over a longer period of fencing (e.g. ten years post fencing), particularly with regard to macro-invertebrate communities.

Results from the COSAINT project will provide important information for policymakers in relation to the Nitrates and Water Framework Directives. It will also help guide agri-environmental policy and facilitate sustainable intensification objectives under Food Wise 2025.

Catchments of Conservation Concern: Sediment Flux and Provenance

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Sediment pollution is a potential factor in the decline of the freshwater pearl mussel, a sediment-sensitive species that has undergone dramatic population decline throughout its range in the 21st century. Although annual suspended sediment yields (SSYs) have been established for a number or Irish catchments, little is known regarding sediment yield in very extensive catchments, hosting populations of sediment-sensitive species. The aim of the study was to collect data on the flux of sediment in priority conservation catchments, and data on the provenance of the sediment.

High-resolution, continuous monitoring of suspended sediment concentrations in three freshwater pearl mussel catchments (the Bridia 22 km^2; the Kealduff 26 km^2; and the Owenroe 30 km^2), with varying levels of land-use and land-cover, and mussel recruitment was undertaken. Suspended sediment yield was calculated from calibrated turbidity, discharge and modelled data. Sediment fingerprinting, using natural soil and sediment characteristics, was used to identify sources of sediment.

Estimated annual suspended sediment yields were 2.7 t km^{-2} $year^{-1}$ for the Owenroe, 2.8 t km^{-2} $year^{-1}$ for the Kealduff catchment; and 5.6 t km^{-2} $year^{-1}$ for the Bridia catchment. These yields are low in the context of contemporary European yields, however results suggest that duration and timing of (relatively) high sediment concentrations may be more relevant to conservation strategies than overall yields.

Results showed seasonal fluctuations in sediment sources and yield in the study catchments e.g. 90% of the total yield in the Kealduff catchment was transported during <1% of the time. Forestry was a dominant source in the catchment containing a significant conifer plantation, while key sources in other catchments ranged from extensive areas to improved grassland and road verges.

The study can contribute to the development of ecosystem-based mitigation measures that both aid the restoration of endangered species and provide broader sustainable land management benefits.

Overseer, the story of a New Zealand decision support tool supporting sustainable farming practice.

Read C[1]

[1]Overseer Limited, Level 4, 2 Woodward Street, Wellington 6143, New Zealand

Agriculture is critical to a healthy New Zealand economy. This is because it is the largest trading sector in New Zealand, contributing approximately 5% ($NZ10.6 billion = €6.07b) to the country's Gross Domestic Product (GDP). In 2017, agricultural products made up 60% of merchandised exports valued at $NZ36b, of which pastoral farming made up $NZ21b. The sector is also one of New Zealand's largest employers, directly employing 136,500 people in 2012 with a large and growing service industry.

While we have traded off a "clean-green" image based on significant natural environmental assets (30% of New Zealand is in protected parks) and our rural landscapes, the intensification of farming since the 1990's has led to degradation of water quality over the last generation in rural areas.

The Prime Minister recently announced at the UN Climate Change Summit in New York that New Zealand would lead the way on international collaboration on agriculture and was "determined to show that we can be the most sustainable food producers in the world".

In New Zealand the approach to addressing environmental sustainability is based on a unique piece of legislation, the Resource Management Act, that uses participatory democracy and a permissive approach that deals with the effect an activity has on the environment.
Controlling diffuse nutrient losses from farmland is only possible if you understand what the losses are, what's causing them and how to reduce it. Until now, this information has not been easily available to farmers, and so change has been slow and sporadic.

Overseer was developed in the 90's to bring science to the process of recommending fertilisation levels for farms and making better use of nutrients in effluent. However, its value in identifying farm-specific options to reduce diffuse losses (nitrate leaching and greenhouse gas emissions) has taken a long gestation time, not until public perception around the impact on water quality of agricultural intensification has become a key tool in the management of water quality.

This presentation will describe the role of Overseer in supporting targeted management of farm losses and how it is now adding significant value as a decision support tool through connecting farmers and their advisers to the science they need to develop environmentally and economically sustainable farm systems.

Science tools to help get the right measure in the right place

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Catchments characterisation involves understanding how catchments work from the mountains to the sea. This includes assessing the impacts and risks of human activities on the water environment to help prioritise and target key pressures and highest-risk geographical areas for further investigation and inclusion in a programme of measures. A key change in catchment science and management in recent years has been the move from national, one size fits all measures to more localised action and the right measure in the right place.

The EPA carried out a national characterisation assessment of water bodies for the second cycle of the Water Framework Directive (WFD) which included evaluation of physical, hydrochemical and ecological characteristics, and a risk assessment of pressures, pathways and impacts. Diffuse sources of pollution are a major challenge and understanding the source-pathway-receptor linkages and the critical source areas (CSAs) is important for targeting measures. The assessments used results from water quality models including the national PIP-P (Pollutant Impact Potential for Phosphorus) map, the SANICOSE model for septic tanks systems and the SLAM (Source Load Apportionment Model), and an assessment of risk of water bodies not achieving their WFD objectives, to identify areas where local catchment assessments could be targeted for maximum positive impact. This is being further developed through the DiffuseTools Project to greatly improve the mapping of CSAs and the ability to pick out the areas of farms where buffers will be most effective.

The characterisation assessments support a collaborative nine step prioritisation process used to identify Priority Areas for Action. The Local Authority Waters Programme (LAWPRO) are working in these Priority Areas for Action to refine the understanding of the pressures and impacts at the local scale, and to work with others to get the right measure in the right place implemented. Where agriculture is a significant pressure, the Agricultural Sustainability Support and Advice Programme (ASSAP) provide farmers with a free and confidential advisory service to help improve water quality.

A next-generation national critical source area map of phosphorus losses in Irish agricultural catchments for decision support

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Farmers, catchment managers and policymakers can benefit from up-to-date, high resolution national maps of critical source areas (CSAs) of phosphorus (P) losses from agricultural land to waterbodies to improve land management decisions and enhance water quality. To achieve this for Ireland, the DiffuseTools project updated the existing Environmental Protection Agency's Catchment Characterisation Tool to improve CSA delineations and predictions of phosphorus losses via surface runoff and leaching. The tool now incorporates the latest nutrient source and mobilisation datasets/science. Furthermore, it uses a new national 5m resolution runoff risk map (soil topographic index), derived using a hydrologically corrected 5m digital elevation model (DEM), a new soil drainage class map for Ireland, and hydrological connectivity modelling. The national next-generation P CSA map was then generated and evaluated using water quality monitoring data from the Environmental Protection Agency and Teagasc Agricultural Catchments Programme. A new sub-model identified all delivery points across the country, where runoff and diffuse pollutants such as P enter the waterbody, and calculated attributes such as CSA size, risk score and receiving waterbody status, in order to further prioritise the targeting of mitigation measures, inform design requirements, and increase cost-effectiveness. The output of this research will contribute to functional land management and the growing evidence base to help ensure that agriculture is sustainable by reducing diffuse pollution to improve and protect water quality.

Risk-based modelling of phosphorus pollution in Irish Agricultural Catchments

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Phosphorus (P) pollution remains a major cause of surface water quality failures. Abating P pollution in agricultural catchments requires informed decisions about the likely effectiveness of land management mitigation measures and their spatial targeting. Furthermore, it's important to balance the environmental benefits of mitigation measures with their potential impact on farm productivity and profitability. Therefore, user-friendly transparent decision supports tools are required that allow the integration of uncertain information on potential effects and outcomes, whilst accounting for the uncertainty in the understanding of both the model structure and the data.

Bayesian Belief Networks (BBNs) are probabilistic graphical models that allow the integration of both quantitative and qualitative information from a range of sources (including data, other model outputs and non-scientific knowledge, such as expert opinion) in one model. BBNs allow system-level thinking, revealing possible causal relationships between controlling factors that may not be apparent otherwise and in situations where controlled experiments are not possible, such as diverse river catchments.

Here we present a spatial BBN to facilitate the understanding of the effects of land use on P pollution risk in Irish ACP catchments. The PhosphoRisk decision support tool facilitates the co-construction of the modelling outcomes by the academic and the stakeholder communities. The modelled scenarios will help to inform targeting of water quality mitigation measures in high risk areas, while the quantified model uncertainties will inform further research and data collection. The tool will provide a user-friendly interface with clear visual outputs that can be easily updated as new data and understanding become available.

NMP Online as a tool to support water quality improvement in Ireland

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The use of NMP Online as a decision support system with farmers in Ireland is focused on achieving three main objectives which are central to the development of a sustainable agri-food sector in Ireland. The objectives are:

- Improving soil fertility and crop nutrition to support improved crop/grass production
- Reducing nutrient losses to water
- Reducing gaseous emissions

In the past the main impetus for preparing nutrient management plans has been to meet statutory requirements arising from the Water Framework Directive, the Nitrates Directive and Agri-environmental schemes. However, the focus is shifting rapidly. Soil fertility has declined since the introduction of regulation. Improved understanding of the mobilisation and pathways of nutrients require a focus which is wider than just product and place to one which incorporates timing, soil type, awareness of critical source areas and an increased focus on farmyard and other point source losses. The requirement to reduce GHGs and Ammonia emissions require that nitrogen efficiency be improved and that particular emphasis is placed on technologies which can reduce emissions.

The best nutrient management system in the world is of very little benefit unless it can overcome two other challenges. These are (a) to develop a system where the professional supporting farmers can develop a plan for the farmer in the relatively limited time available and (b) to develop a system which can produce a plan for the farmer which can be implemented subsequently.

NMP online was first used to prepare plans in 2016 and since then plans have been prepared for over 60,000 Irish farms. Phased development over the next few years will focus on building on the ability to meet statutory requirements to an efficient system which can support the challenging range of sustainability goals which farmers face.

A new and integrated approach to catchment management in Ireland based on comprehensive stakeholder engagement

Crockett J[1]

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This second River Basin Management Plan (RBMP) outlines the new approach that Ireland will take as it works to protect its rivers, lakes, estuaries and coastal waters over the next four years. This plan also benefits from a stronger and more integrated approach to public consultation and engagement. The plan has placed a major emphasis on establishing the right governance and delivery structures for an effective catchment-based approach. Clear priorities are set out, which will ensure that all stakeholders are working together with a strong focus on delivering positive outcomes.

A key element of the plan has involved the establishment of a dedicated professional support structure aimed at achieving the objectives of the plan. There are a number of components;

- LAWPRO - the deployment of 43 local authority investigative assessment personnel, who will work in Prioritised Areas for Action;
- ASSAP - a new collaborative Agricultural Sustainability and Support Advisory Programme between Government (delivered by Teagasc) and dairy processing Co-ops (as part of the Dairy Sustainability Initiative) consisting of 30 Sustainability Advisors promoting agricultural best practice for water quality.

The two groups of professionals work side by side in 190 priority action areas (PAA). The local authority catchment assessment teams carry out detailed investigations in each PAA focused on identifying the pressures on water quality. The also work with non-agricultural 'pressure owners' to support them in resolving issues. The ASSAP advisors are working intensively with farmers in areas for action and assist them to reduce pressures identified in the catchment assessments. Achieving broad stakeholder support for the initiative has been challenging but has become one of the cornerstones of the rollout of the services and a key to delivery of individual and community actions.

BIOWATER systems attribute survey: Modelling Agricultural Land Management Scenarios in the Nordic Countries in the Year 2050

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This paper describes the development use and application of a survey conducted by the BIOWATER Centre of Excellence, a project financed by the Nordic Council of Ministers to examine the combined impacts of bioeconomy development and climate change on land use and freshwater quality and quantity. Assessment of the opportunities and limitations of bioeconomy development in the four Nordic countries is based on expected outcomes in the year 2050 of five Nordic Bioeconomy Pathways (NBPs). In the survey, qualitative descriptions (storylines) of the NBPs were presented and stakeholders were asked to link the NBPs to a set of land management attributes. The purpose of the survey was to allow stakeholders to share their views and expert opinions on how alternative bioeconomy pathways may influence land use and land management in the Nordic countries according to their knowledge about regional and sectoral constraints. The input from stakeholders serves as a guide for quantification of potential land use and land management changes in the BIOWATER study catchments. This methodology is easy to use, flexible, allows stakeholders to be involved in scenario development and provides support for researchers analysing impacts on the environment of events far into the future with uncertain impacts such as climate change.

Factors influencing Nutrient Management Practices on Agricultural Catchment Farms

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The Agricultural sector will play a key role in reaching the goals set out in The Water Framework Directive 2000/60/EC (WFD). Although some progress has been made the 2015 deadline for reaching the goals of maintaining "high" status waterbodies and increasing the status of all other water bodies to at least "good" water status has passed without success and the timeline for these objectives moved forward to the next two cycles 2021/2027. Now more than ever, policymakers need to understand the motivations of key participants of which farmers play an important role. This study investigates whether the use of a Technology Acceptance Model (TAM) can be useful in predicting farmer acceptance of two nutrient management practices, soil testing and nutrient management planning which have the potential to contribute to water quality improvements. Factor analysis on a survey of farmers involved in the Teagasc Agricultural Catchments Programme (ACP) reveals two specific variables which are hypothesised to be fundamental determinants of user acceptance: Perceived Usefulness (PU) and Perceived Ease of Use (PEOU). Both variables are found to be significant in predicting farmer intention to use and are subsequently included in a model to investigate key drivers of convergence to optimal soil phosphorus levels. The research suggests that farmers who converge to optimal P levels (soil P index 3) from soil P index 4 perceive soil testing and nutrient management planning "useful" and "easy to use" but there is no significant relationship on farms operating below optimal levels of soil P index 1 and 2.

A margin of error? Assessing effectiveness and placement of grassed and raised field margins to enhance multiple benefits

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Grassed field margins and riparian buffer zones have one of the highest uptake rates of any agri-environmental measure across Europe. However, progress remains slow in reducing catchment-wide agricultural diffuse pollution and storm runoff rates. Therefore, this measure needs to incorporate a greater range of technical advancements in order to further enhance the range of multiple benefits it delivers (e.g. management of hydrological extremes and soil erosion issues). There is a need to develop an evidence base for these enhancements at the headwater scales and generate guidance on placement and management of any modifications. In this presentation we demonstrate one such modification; the raising of field margins in specific locations through the creation of soil bunds to temporarily retain storm overland runoff.

We highlight findings from two UK cases where grassed field margins/buffers are widespread. The effectiveness of some of these buffers for mitigating storm runoff rates is limited.
In targeted locations soil bunds have been created to temporarily slow and retain storm runoff whilst still allowing landowners to farm the upslope landscape. The temporary storage areas hold approximately 200-400 m^3 and are designed to drain within 6 – 18 hours to ensure the farmland is not inundated for long periods, reducing the need for any compensation payment. To enable more efficient targeting of these bunds we demonstrate a novel GIS framework that can be used in an engagement process with landowners to suggest measure locations, length of bund and storage volumes/footprints. Raised margins can achieve a greater range of benefits than grassed margin when targeted at key hydrological flow pathways, for example, local flood peak reduction and capturing significant amounts of sediment (which can later be re-applied to the upslope farmland). Observations of trapped sediment are providing powerful messages to farmers of how much valuable soil can be lost in a storm.

New methods for third generation river basin management plans under the water Framework Directive - assessment of the impact of surface water from groundwater

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The Danish Environmental Protection Agency has initiated several research and development projects to provide knowledge and determine methods that can assess how and to what extent, the content of pollutants and water abstraction in a groundwater body can affect the state of associated targeted surface water bodies or groundwater dependent terrestrial ecosystems (GWDTE) in Natura 2000 areas.

The presentation will be focusing on the groundwater- lake sub-programme, where the interaction between groundwater and lakes is simulated with The National Water Resources Model (DK-model) for lakes with a surface area larger than 100 hectares. The spatial resolution of the DK-model is today too coarse to estimate the hydraulic contact between groundwater and lakes smaller than 100 hectares, thus a tool box of field site specific methods was developed to assess the quantitative impact on lakes smaller than 100 hectares.

A new method consisting of a five step approach has been developed to assess the chemical and quantitative status. The method was tested in four lakes with good chemical and quantitative datasets in Denmark. The test of the stepwise method on both the quantitative chemical effect in all test lakes could be carried out to the steps four or five. The step five of the chemical effect is dominated by an expert assessment. There have been discrepancies in the methods used to determine the percentage of groundwater seepage into lakes smaller than 100 hectares. The development of a simple quantitative method for calculating the diffuse nutrient load of a lake may be needed. In addition, there is a need to develop a tool for assessing when the 50% diffuse nutrient load of a lake has been exceeded.

This study was carried out last year in a collaboration between The Geological Survey of Denmark and Greenland & Aarhus University.

Managing nutrients loads, water levels and wetland ecology: opportunities and sticking points in the upper Lunan Water, Scotland

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Since 2006, the Lunan Water catchment in Eastern Scotland, has been a focus for research and development of monitoring, modelling and mitigation methods for diffuse pollution, supported by Sottish Government research and advisory funding as well as Agency work (Scottish Environment Protection Agency and Scottish Natural Heritage). It is now a priority catchment for diffuse pollution mitigation under the second cycle (2016-21) of WFD River Basin planning. Catchment issues include high groundwater nitrate concentrations, eutrophication of standing waters and associated wetlands linked to sediment, P and N loads and risks of flooding and low flows. We review progress in monitoring, modelling, management and governance of diffuse pollution and water levels in the catchment.

Nutrient load estimation used a combination of routine flow and water quality sampling, modelling and proxy high frequency measures such as turbidity, calibrated using storm event data. Markov switching time series analysis has helped to add value to this data. Downward trends of N and P in the main stem of the Lunan water have been identified. These may partly be due to improved sewage treatment rather than catchment-scale measures. Changes in livestock numbers are also implicated. Approaches to choosing cost-effective mitigation measures have been developed. Novel measures explored include the use of sediment fences, seeding with water cress, harvesting of aquatic vegetation and improved management of flow at hydraulic structures by diverting flow of nutrient-rich water from ecologically sensitive wetlands. Several rural payments-funded measures have been adopted, including sediment bunds, buffer strips, ponds and wetlands.

Stakeholder engagement (through farmer workshops, survey, interviews and a catchment management group) has shown the additional importance of flood risk mitigation (and some concern about low flows) but governance across a range of water ecosystem services remains challenge. Potential for establishment of drainage boards or other community-interest approaches is considered.

Changing mindsets to improve water quality: A new approach for RBMP 2018-2021

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Water quality in Ireland is under pressure; the number of monitored river water bodies and lakes at high or good status declined during the first River Basin Management Plan cycle despite increased regulation and investment in infrastructure designed to protect water quality.

The lessons learned from the first cycle of river basin management planning resulted in a new approach in Ireland's River Basin Management Plan 2018-2021. RBMP 2018-2021 recognises that securing water quality improvements requires effective engagement with and supports for the communities "on-the-ground" and closer co-operation between states agencies at regional and national level.

The Local Authority Waters Programme (LAWPRO) was established to drive the implementation of RBMP 2018-2021. LAWPRO consists of two elements; the waters and communities office and the catchment assessment team. It is focused on assessment of water quality issues to identify the "right measure in the right place" while also supporting communities to get involved in protecting their water resources. LAWPRO is taking a multi-faceted approach and will seek all sectors identified as a significant pressure on water quality to implement corrective measures. A further innovation of RBMP 2018-2021 is a collaboration with the agri-advice and dairy industry and the creation of the Agricultural Sustainability Support and Advice (ASSAP) team of advisors. This is a unique partnership of key sectoral and industry stakeholders and enables wider access to farming communities through a network of experienced agricultural advisors.

RBMP 2018-2021 has prioritised 190 areas nationally; LAWPRO's catchment assessment teams are systematically assessing these areas to identify the activities impacting on water quality and will recommend measures required to bring them into compliance with their WFD objectives. The ASSAP advisors, working closely with the catchment assessment team in the areas where agricultural practices are impacting on water quality, engage with farmers on their farm to identify adaptations to practices, support behavioural change and secure more sustainable farming practices. Embedded in all stages of LAWPRO's process is a recognition of the importance of engagement with the communities affected through public events and by distributing information through crucial local networks.

A Farmers Perspective

Carroll B[1]

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In March 2015 milk quotas were withdrawn by the European Union which, in addition to allowing existing dairy farmers increase milk production, it also opened the door to new entrants to get into dairy farming. Brigid Carroll's change in farm enterprise is typical of many such new entrants, which have contributed to the increase in dairy cow numbers in Ireland from just over one million in 2010 to 1.5 million today.

Brigid farms a 40 hectare grassland block in the townsland of Ballinakill, which is on the banks of the Ounavarra River. She had a suckler beef enterprise, with forty cows selling weanling and yearling cattle. At that time Brigid also had off farm employment as an assistant in a local school. The total farm output in 2014 from the suckler enterprise was €56,000 with a gross margin of €590 per hectare.

In October 2015 fifty dairy heifer calves were bought and the conversion to dairy had begun. Construction of a milking parlour began in November 2016 and the first milk collection was on the 4th of February 2017. Cow numbers have increased from 45 in 2017, to 70 in 2018 and 85 this year. The herd is spring calving and milk production is from grazed grass, with output matching grass growth. It is the intention to milk 100 cows and rear all replacement heifers on the farm. The most significant investments incurred due to the change in enterprise were livestock and farm buildings (slurry storage and milking facilities). These have been funded by borrowings, building grants and the sale of livestock from the beef enterprise. Other significant investments include farm roadways, water drinking facilities and grass reseeding. Over half the farm has been reseeded since the conversion to dairying started. By way of comparison to the beef enterprise, the total farm output in 2018 from the dairy enterprise was €165,000 with a gross margin of €1,400 per hectare.

Grass covers are measured weekly and PastureBase is used to budget grass supply and demand. Nitrates derogation was applied for this year, which may not be required but the plan is to build the herd to 100 cows and remain at that stocking rate. Brigid is also participating in Dairy4 Future, an INTEREG funded project studying dairy farming in the Atlantic regions of Europe.

Using Fuzzy Cognitive Maps and stakeholders' engagement to achieve safe drinking water in Ireland

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Maintaining safe drinking water is of paramount importance for the health of individual consumers and is a policy, regulatory and economic challenge for authorities at local and national scales. In this context, agricultural activities are of great importance as they can be one of the largest sources of diffuse pollution and these have the potential to affect the quality of raw water sources. To enhance measures designed to achieve good water quality in Ireland, there is a need to integrate the views of different stakeholders and actors which are included with water quality issues in different sectors. Based on this objective, for this study stakeholders were categorized into four groups: individuals, policy developers, researchers and regulators. Stakeholder views and opinions were collected through individual interviews and also within a workshop where they were asked to connect and weight (positively or negatively) the relationship among different indicators affecting water quality. Maps from the people of the same group were aggregated in order to compare the ideas of different groups. The designed maps were then imported within Fuzzy Cognitive Maps software (gephi) to analyse and visualize the different ideas. This work is ongoing and results from this study will provide a transparent framework on the perceptions of different stakeholders about the indicators affecting water quality in Ireland and suggest some scenarios to improve the interaction among stakeholders in future.

This work was funded by WaterProtect (Horizon2020 project number 727450).
Keywords: Agricultural activities; safe drinking water; stakeholders; fuzzy cognitive maps

Improving extension services surrounding diffuse water pollution from agriculture: new insights from England

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Agricultural contributions to diffuse water pollution remain significant in many rural areas and are central to ongoing debates surrounding sustainable intensification. Environmental advice is one mechanism for reducing the impact of farming on water quality, alongside targeted regulation and incentivisation. But, against this context, the extension system in England has become increasingly fragmented since a withdrawal of state-funded advice during the 1990s, leading to pluralistic provisioning, with many organisations operating under slightly different remits. Whether farmers find current environmental advice credible, relevant, and legitimate (CRELE) is crucial as they may be unlikely to uptake environmental measures where these attributes are unmet.

An ongoing doctoral research project is therefore reviewing the extension landscape in England and exploring how environmental advice could be improved to meet farmers' CRELE attributes. This interdisciplinary research utilises a mixed methods approach including telephone interviews, focus groups, an online questionnaire survey and sediment source fingerprinting (SF) as an example of empirical evidence on the contribution of farming to water quality problems which could be provided to farmers. Despite the growing application of SF in academic studies, farmer engagement with this type of empirical evidence has not been explored in depth; therefore, how scientists can disseminate such research to farmers and advisors in an engaging, applicable way is being explored, with preliminary findings indicating that farmers find such scientific evidence useful. This research also explored how initiatives such as Catchment Sensitive Farming (England) could provide more targeted advice to reduce environmental externalities arising from farming. Despite a paradigm shift towards co-production and knowledge exchange, current advice provisioning in England often appears to uphold a traditional top-down approach; possible implications of this will also be discussed briefly. This research is relevant within an Irish context due to its wider applicability to agricultural extension services including those delivered by Teagasc.

Poster Session Abstracts 1

Stoichiometric mismatch in macronutrient ratios between source soils and sediments at the landscape scale

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Human-induced changes in both the absolute and relative contents of carbon (C), nitrogen (N) and phosphorus (P) have direct effects on soil C-sequestration and the long-term structure and function of agroecosystems, but also affect freshwater ecosystems indirectly through alteration of the N:P, C:N and C:P ratios in fine-grained sediment. Within a catchment, the stoichiometric ratio of C:N:P, known as the Redfield ratio, differs by land use due to differences in natural and anthropogenic inputs associated with them. Moreover, the fine-grained sediment C:N:P ratio is potentially driven by soil erosion and sediment delivery, deposition and associated oxidation conditions. The objective of this study is to compare the C:N:P stoichiometry of catchment source soils and stream fine-grained sediments with respect to different land use. To do this, we obtained surface soil samples from arable fields, pasture fields, woodlands, damaged road verges and stream banks from the Cocktree sub-catchment (4.5 km^2) in the upper River Taw, South-West of England. The C:N:P ratio comparison between source soils and fine-grained sediment (time-integrated suspended and deposited) samples will help to identify key differences and similarities in source soil and sediment C, N and P ratios, and will offer perspectives on the role of anthropogenic pressures in generating the imbalance of macronutrients between catchment soils and river sediments.

2

Harmonising soil phosphorus index systems: A cross-border challenge

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Currently two soil phosphorus (P) index systems are operated within Ireland. In the Republic of Ireland (ROI) Morgan's extract is the statutory method (10% sodium acetate, pH 4.8). This test is considered optimal for brown earth soils. The ROI system uses four indices (1 to 4), with Index 3 considered optimum for grassland soils. Northern Ireland (NI) uses the Olsen P test (0.5 M sodium bicarbonate, pH 8.5) which more strongly extracts sorbed P and is intended for neutral to calcareous soils. The NI system consists of five indices (0-4), with Index 2+ indicating optimum availability for intensive grassland systems. In both cases, P values above the agronomic optimum are expected to pose the greatest risk to water quality.

The management of cross-border waterbodies requires a harmonised approach and a clear understanding of the P contributions from different soil types. This is masked by inconsistent approaches to soil testing which reflect political jurisdictions rather than soil type. The objective of this study is to quantify the relationship between both index systems. Soil samples (c.1,000) taken from catchments in the border region were assessed using Morgan's and Olsen soil tests. For 33% of samples the NI system assigned a higher index than the ROI system, i.e. assumed a greater agronomic availability of P. Of these samples, 57% indicated a high/excessive index using the NI system, versus an optimal index using the ROI system. The implications are that the farmers using the NI system may attribute greater risk of P loss to watercourses than those using the ROI system for a given soil. Furthermore, 33% of samples indicated optimal P using the NI system but low P content using the ROI system. This may result in over- or under-application of P from an agronomic perspective, depending on soil type.

These are preliminary results and research is ongoing.

3

Mapping soil texture variability of the root zone with a new transient electromagnetic system (tTEM)

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Modelling is often used to acquire information of water and nutrient fluxes in the root zone. The models require detailed information of the texture in order to produce accurate estimations and reduce uncertainty on prediction. Soil texture can vary considerably even on field scale and is cumbersome and expensive to map in details with texture sampling.

This study investigates if a new transient electromagnetic system (tTEM) (Auken et al., 2018) has enough information in its measurement to delineate the soil textural variations of the root zone. The study has focus on the clay fraction of the textural composition, as it is one of the main drivers for water and nutrient movement. Electromagnetic induction (EMI), tTEM and soil textural surveys were carried out on two agricultural fields in Denmark. The geophysical data was processed and inverted. A direct comparison between the two types of geophysics in the close proximity of the textural sampling locations have been made. The two individual geophysical data sets are also compared to the clay content in the texture samples and the quality of the relationship is determined.

The comparisons between the geophysical methods show varying degrees of correlation between the values and the quality of the relationship is dependent on the field. However, interpolation of the geophysical data provides contours with almost identical patterns. The new system was found useful in identifying zones of similar textural composition, but it has difficulties in predicting the exact clay content of the soil.

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4

The influence of lime and phosphorus on soil P pools and soil pH in a controlled incubation experiment across a range of heavy soils

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Soil fertility is a major limiting factor on the output potential of grassland farms, particularly soils with low pH and soil test phosphorus (STP) concentrations. Optimum soil pH increases soil microbiological activity, promotes the release of nutrients and increases the efficiency of organic and chemical fertilisers. Soil pH is a fundamental factor that must be optimised when improving soil fertility as it regulates the availability of macro- and micro-nutrients. Phosphorus (P) is important for the growth, establishment and persistence of productive grassland species, however it can pose an environmental threat with potential impacts on water quality. Over time the soil pH and STP status of the soil changes depending on the intensity of production, fertiliser management, soil physical and chemical characteristics and climate. Limited knowledge exists on the quantity of P required to build-up soil P supply for grass production on high clay textured soils and organic soils and the P loss risks associated with such P fertiliser inputs.

To elucidate the responses of soil P pools (STP and water soluble P (WSP)) to lime and P fertiliser inputs on soils with high levels of clay and, or, high OM levels a controlled soil incubation study was established using 25 soils from farms participating in the heavy soils research programme. Six treatments were imposed on the soil; namely 0, 50 and 150 kg ha^{-1} equivalent of P both with and without the addition of 5 tonne ha-1 equivalent of ground limestone. Soils were incubated at constant temperature, humidity, water filled pore space and bulk density for a total of 140 days with sampling at 35 day intervals. The initial soils were analysed for OM% and total P and metals. The change in soil chemistry (pH & P pools) was assessed over the trial period where at each sampling time the soils were analysed for STP and bioavailable metals, WEP and soil pH. There is a significant effect of soil type ($p<0.0001$) and treatment ($p<0.0001$) on the concentration of WEP. Increasing P fertiliser rate significantly increased WEP across all soils with a mean value of 0.545 mg l^{-1} on mineral soils and 5.349 mg l^{-1} on organic soils for the 150 kg ha^{-1} P fertiliser rate. Overall results indicate that there were higher risk of P loss on organic soils (>20%OM) compared to mineral soils, and that careful P fertiliser management is required on all soils to minimise such losses.

5

The importance of timing of scheduled ploughing and reseeding operations for fine sediment generation from hydrologically - isolated grassland fields in the South West UK

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Grassland represents the largest crop by area in the UK and, under intensive farming, is a major potential diffuse source of fine sediment. Scheduled ploughing and reseeding operations are used to increase pasture yields and quality in lowland landscapes that are dominated by intensive ruminant grazing. The timing of ploughing and harrowing operations strongly affects erosion risk, as soils are of greatest risk of erosion when a seedbed has been prepared but crop cover has not yet developed. Additionally, factors such as rainfall intensity and soil moisture have been shown to affect erosion response to ploughing. Recent work has determined the magnitude of the erosion response of ten grassland field-scale catchments during ploughing and reseeding operations and the factors controlling that response. Sediment loads originating from hydrologically-isolated grassland fields on the North Wyke Farm Platform were compared after 12 reseeding events to determine the effect of rainfall, soil moisture, soil type and field topography.

All fields experienced an increase in suspended sediment concentration for a given flow rate after ploughing; however, the magnitude of the increase was highly variable. Post-plough sediment yields varied from 0.20 to 4.73 t. ha yr^{-1} and rainfall from 306 – 1121 mm. The post-plough periods account for a very high proportion of the total sediment fluxes despite only covering an average of 10.9% of the 5.5 years of monitoring. When rainfall and/or soil moisture were low during summer ploughing operations, as little as 15% of the total sediment flux occurred after ploughing. However, when scheduled ploughing was undertaken in October in two fields, an average of 56% of the total 5.5 year sediment flux took place in the seven month post plough period. When compared to soil moisture and rainfall, catchment characteristics such as slope or soil type show negligible impact on sediment loads. Overall, the findings underscore the high risk associated with undertaking scheduled ploughing regardless of soil moisture status.

6

Key soil characteristics in water quality and runoff formation modelling

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Water quality in the streams from agricultural watersheds is closely related to the runoff regime. It differs naturally in wet and dry conditions not only due to the different discharge levels and related solutes dilution. It depends largely from different activity of their sources and flow paths available to reach the stream. From the hydrological point of view the main question for the dynamics of solutes transport is the runoff formation type – rapid surface (or shallow subsurface) runoff or percolation into the deeper layers and discharging as baseflow.
Which one of these types occurs depends above all on rainfall intensity patterns and topsoil characteristics and conditions. Detailed temporal rainfall patterns were analysed in the Czech Republic using radar and gauging stations rainfall data. Six typical patterns and their spatial distribution with respect to different return periods were designed for the use in water and soil conservation planning. Recently an ongoing project on initial soil conditions has been started as well as assembling the key soil characteristics for the national-wide use. Selected outputs from all these activities are being published via online maps and services. This work was supported by research grants QJ1520265 - Variability of Short-term Precipitation and Runoff in Small Catchments and its Influence on Water Resources Management; QK1910029 - Antecedent saturation and design rainfalls as factors of hydrological response in small catchments; TJ01000270 – ATLAS Hydrology – smart tool for runoff and sediment transport calculation and design of soil conservation measures; TJ02000234 - Physical and hydro-pedological soil properties of the Czech Republic.

7

Development in Nitrogen concentrations and loads in Danish streams

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The diffuse loading of nitrogen (N) to the aquatic environment due to farming activities is a well-known fact. During the last three decades, many measures have been taken in order to reduce this loading and to prevent undesired eutrophication of especially coastal waters. In Denmark, a comprehensive monitoring program of the aquatic environment was established in 1989 and has provided information of the success or lack of success in combatting this agricultural driven diffuse N-load.

The monitoring programme includes 77 near coastal sampling stations with full times series of concentrations and estimated load of total N and nitrate-N (NO_3-N)-N. Unfortunately, in some later years the laboratory analysis of total N has been somewhat biased which complicate the interpretation of the trends of N in recent years. However, the time series of NO_3-N are considered to be reliable and a major reduction in the annual flow-weighted concentration of NO_3-N can be documented during the 30 years of monitoring. The outcome is an overall reduction in the annual flow- weighted NO_3-N concentrations that amount to 46%. Furthermore, the average annual NO_3-N concentrations is found to be strongly and significantly related (R^2=0.88; P<0.0001) to the estimated national N-surplus (field scale) during the period 1990-2017.

A major Danish stream (Odense å) holding measured NO_3-N for the period since mid-1970's shows that the annual flow-weighted concentration of NO_3-N parallels the calculated national N-surplus (farmgate) for this 40 year time series. The relationship shows a steady increase during the 1970-1980's and a decrease during the 1990's and a more or less constant concentration latest five-eight years. However, such a development in N-concentration is not found in all Danish streams as a few streams show marked delays in responses to reduced Nitrogen surplus. This delay can be explained by a catchment specific low reduction capacity in old oxic ground water. Also, for 46 minor streams some delay in the Nitrogen reductions has been seen. Hence, streams receiving relatively older oxic groundwater showed a lesser reduction than the remaining of these 46 streams.

8

Assessing the risk of colloidal phosphorus transfer to groundwater in relation to soil chemical and physical properties

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Colloid-facilitated phosphorus transport is an important mechanism of phosphorus loss from soils to groundwater due to the high sorbing capacity of colloids. In order to better localise critical source areas of colloidal phosphorus loss to groundwater, it is important to better understand the role of soil properties in the transfer pathways of colloidal phosphorus.

For this purpose, soil chemical and physical properties were examined in three Agricultural Catchments Programme sites with contrasting soil properties and land use. The study included ten sites adjacent to long-term groundwater chemistry monitoring wells. Composite soils were analysed to determine their chemical properties such as soil Water Dispersible Colloidal phosphorus and metals fractions, phosphorus sorption properties, degree of phosphorus saturation or soil solution phosphorus. Undisturbed soil cores were also taken to determine soil hydraulic properties through the determination of Soil Water Retention Curves. Physical and hydraulic parameters were then incorporated into Hydrus-1D to model solute transport to groundwater at two targeted sites.

Results showed a strong effect of the soil chemical properties on colloidal phosphorus source and mobilisation in soils. In particular, the labile inorganic iron fraction positively influenced the colloidal phosphorus fraction whereas the soil organic matter correlated negatively with colloidal phosphorus suggesting competition for sorption sites. Mobilisation of colloidal phosphorus was also positively influenced by weak soil sorption properties and a high degree of phosphorus saturation. Soil physical and hydraulic properties also influenced transfer to groundwater. Higher long-term groundwater phosphorus concentrations were measured at a site with a higher soil saturated hydraulic conductivity, total porosity and macroporosity suggesting transport limitation. Lower concentrations were measured at a site with a higher soil bulk density. However, the high spatial variability in soil properties highlight the need for larger scale studies with consideration of below ground colloidal phosphorus transfers.

9

A connectivity risk ranking for phosphorus loss along agricultural drainage ditches

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Agricultural drainage systems comprising both in-field pipe drains and surface ditches are typically installed to remove excess water from agricultural land. These drainage networks can provide connectivity between phosphorus (P) sources and surface waters thereby increasing the risk of P loss to rivers and streams. The objective of this study was to derive a farm-scale drainage ranking that categorises drainage ditches in terms of P loss risk based on connectivity and physic-chemical characteristics. Ten pilot farms were selected to characterise drainage networks through ground survey and, sediment and water sampling. Five drainage ditch categories were derived based on landscape setting and connectivity. Each category recorded soluble and reactive P concentrations above environmental water quality standards.
To assess the risk of surface ditches as a connectivity vector between agricultural P and surface waters ditches were ranked in order of P loss risk by integrating landscape position and sediment P chemistry. Elevated sediment P with high equilibrium P concentration (EPCo) were associated with ditches connected to farm yards, and in sediment sampled at ditch outlets, suggesting P deposition over time indicative of a legacy P source. The greatest risk of P loss was attributed to ditches connecting farm yards to streams, and ditches that connected the drainage network to surface waters, or outlets. The five ditch categories presented provide a connectivity risk ranking for P loss along agricultural drainage ditches and could be included in farm level risk assessment schemes to help target appropriate P loss mitigation measures to the appropriate locations.

10

Integration of geochemical and isotopic biomarker tracers to apportion functionally similar sediment sources at catchment scale

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Sediment source apportionment at catchment scale is often limited by: (1) lack of robust tracers to separate potential sources, and; (2) catchment complexity including that associated with land use rotation. Here, we use integrated tracers (geochemistry and compound-specific stable isotopes) in a source fingerprinting approach to differentiate functionally similar sources in a mixed-land use catchment (4.5 km^2) in the South-West of England. Source sampling targeted arable fields, pasture fields, woodland, damaged road verses and stream banks. All source and sediment (deposited and time-integrated suspended) samples were analysed for geochemistry and isotopic biomarkers (alkanes and fatty acids). An advanced Bayesian Isotope Mixing Model (MixSIAR) was used to integrate the tracers for estimating source apportionment. Land use rotation means that pasture and arable sources are interchangeable over the duration of crop rotations with the result that geochemical tracers alone have limited capability for separating these two sources. Integration of land use-based isotopic biomarkers in the tracer set can significantly improve source differentiation and thereby estimated source apportionment. This study will provide an expanded understanding of tracer utility for source apportionment in lowland agricultural landscapes in the UK and will assist catchment managers in targeting interventions for reducing sediments and associated organic matter or pollutant transfer to the aquatic ecosystem.

11

Targeting Riparian Buffer Strips at Field Scale in the Upper Bann Catchment

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Riparian buffer strips (RBSs) are one of the most widely implemented mitigation measures for addressing nutrient loss in overland flow from agricultural soils. However, there are significant uncertainties in the effectiveness of RBSs due to the impact of inter alia terrain, land use, soil type and hydrological connectivity on their ability to mitigate nutrient loss in overland flow. This study evaluates the effectiveness of four RBS designs: 2m wide grass, 10m wide grass, 2m wide trees, and 10m wide trees, in different topographic and soil scenarios. Basins were first characterised within the Upper Bann catchment (250km^2) in Northern Ireland using flow contributing area and average slope data extracted from a 5m Digital Elevation model to create basin specific topographic profiles. Soil drainage characteristics were then attributed to the riparian agricultural fields using The Ordinance Survey Map of Northern Ireland (OSNI). Using both the topographic profiles and soil characteristics, fields were then grouped into typologies through cluster analysis in R. The RBS designs were then evaluated for each site typology using the Riparian Ecosystem Management Model (REMM) to estimate the change in pollutant loading for each scenario. This approach enabled not only the evaluation of the RBS but also how their effectiveness varies among site specific characteristics in the Upper Bann. We conclude that topography and soil characteristics are of greater importance on nutrient reduction than buffer strip width, and can be used to direct the placement of RBS templates in the landscape. Greater site specific targeting of RBSs in the landscape is required in order to maximise pollutant reduction.

12

Natural water retention measures in agricultural catchments, Ireland

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We introduce a newly funded large-scale Environmental Protection Agency project (2019-2023): SLOWATERS: a Strategic LOok at natural WAter reTention mEasuReS. The research aims to assess the benefits of Natural Water Retention Measures (NWRM) for agricultural catchments in Ireland. We will use GIS-based mapping techniques, topographic indices, hydrological modelling, and full-scale field demonstrations to develop a portfolio of potential approaches and methodologies to reduce flood risk and generate co-benefits including sediment and nutrient attenuation and ecosystem enhancement. Demonstration sites will show how to design, build and instrument NWRM. Scaling up methodologies will use hydro-geomorphic patterns to investigate NWRM in other Irish catchments, at a range of spatial scales. The research will underpin policy by identifying across scale the measures that are most effective at targeting flood flows, providing beneficial ecosystem functions whilst having minimum effect of farm economics. The project outputs will specifically provide recommendations for the management of specific catchment types relevant to the Irish environment by quantifying the magnitude of NWRM required to reduce flood peaks.

Keywords: Flood; NBS; NWRM; Agriculture

13

Right Time, Right Place – Slurry Application Strategies for Reducing Phosphorus loss in Overland Flow

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Slurry application to grasslands remains a high-risk practice in climates with high rainfall frequency and low soil moisture deficit for much of the year. SurPhos is a daily time-step model that simulates surface application of slurry, soil phosphorus cycling and dissolved reactive phosphorus (DRP) loss in overland flow (kg/ha/day) for a range of mitigation strategies, over multiple years, to sites with different antecedent conditions. The model was evaluated under Irish conditions using data from a two-year study of P loss in overland post application (R^2 = 0.74). Subsequently, the model was applied to 4 sites in Ireland & the UK that provided 84 plot-years of data for low (n=27), medium (n=28), and high (n=29) overland flow potential sites to evaluate the impact of application timing, rate, and P content of slurry and soil conditions on DRP loss in overland flow. For example, simulated average DRP loss during the closed period (15th Oct -31st Jan) was 0.4, 1.0 and 1.92 kg P ha^{-1} on low, medium and high runoff sites respectively, compared to average losses of 0.14, 0.2 and 0.45 kg P ha^{-1} during the rest of the year.
On an annual basis, full implementation of the Nitrate Action Programme regulations resulted in 41%, 55% and 63% reduction in DRP export from fields with low, medium and high overland flow potential. Overall, results demonstrate what reductions in P export can be achieved if slurry applications are consistently targeted at the right place and time.

14

Effects of plant diversity on yield in intensively managed grasslands

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Multi-species grasslands mixtures offer an opportunity to increase sustainable production from intensively managed European grasslands. We investigate the effects of mixing species and functional groups with the aim of improving forage yield and yield stability.

A simplex design including six species monocultures and 13 mixtures is sown in 2017 in a field experiment in the south-east of Ireland. Three functional groups are represented: grasses *(Lolium perenne L., Phleum pratens L.); legumes (Trifolium repens L., Trifolium pratense L.)* and herbs *(Cichorium intybus L., Plantago lanceolata L.)* and combined to create monocultures of all six species, as well as 2-, 4-, 5- and 6-species mixtures within 1, 2, and 3 functional groups respectively.

All experimental plots receive 150 kg ha^{-1} of nitrogen fertiliser per annum and a *Lolium perenne* monoculture with 300 kg ha^{-1} of nitrogen included as a comparison, represents standard Irish management. Above-ground biomass is harvested following a simulated grazing protocol. We measure dry matter yield and separate subsamples to identify species proportions. The total annual above-ground yield is compared between each community, and we quantify the effects of species richness, and functional group richness.

15

Classification of riparian delivery points for improved specification of mitigation measures

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Sources and pathways by which macronutrients (nitrogen and phosphorus) and sediment enter watercourses have traditionally been classified as being either point or diffuse, with agricultural sources typically classed as the latter. Increasingly, however, the idea of diffuse pollution is being replaced with the idea of multiple point sources. Whilst previous work has sought to identify the locations of these multiple point sources (to support greater targeting of mitigation measures), little research exists describing or classifying the variety of delivery points.

An element of the Smarter BufferZ project (Irish EPA-funded) aims to classify different morphologies of the delivery pathways by which water crosses from edge of field to stream (e.g. cattle access points, pathways further enlarged by increased water flow, temporary *versus* permanent points) to create a typology of delivery points. This will be achieved (in the initial phases) through *in-situ* assessment by catchment walks (including previously identified delivery points, and unidentified points). In order to increase coverage, it is hoped that a library of typologies will be built with the aid of various stakeholders (e.g. landowners, catchment scientists, agricultural advisors).

It is anticipated that the findings will feed into the creation of easily understood diagnostic tools for farmers and agricultural advisors that can then be used to aid in the choice of appropriate measure to mitigate excess nutrient and sediment runoff.

16

Monitoring of the runoff and sediment transport on arable fields – plot and small catchment scales

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Soil and catchment water balance, runoff processes, sediment and nutrients transport at agricultural areas are important to understand for proper management of the landscape. Nučice experimental catchment was established in 2012 in order to monitor hydrological processes at small headwater agricultural catchment. The catchment is located in the center of the Czech Republic, 30 km to the east from Prague. Agricultural land covers 96.4% of the 50 ha area of the catchment and it consists of three separated fields. Mean slope in the catchment is 3.8 %. Rainfall, discharge, suspended sediment, groundwater level, soil water regime and meteorological variables for evapotranspiration calculation are monitored at the catchment outlet. Nučice catchment is drained by a small water course which is active during winter and wet periods during summer only. Low runoff coefficient (0.2 - 6 %) and relatively short conservation time (0.75 - 3 hours) together with slow ground water level response suggest that the shallow subsurface runoff plays an important role in the runoff generation. The shallow runoff hypothesis has been tested with plot scale artificial rainfall – runoff experiments. Such experiments aim to study how subsoil compaction, surface sealing and agro-technical operations affect runoff and soil erosion. Moreover the temporal variability of the topsoil characteristics as a result of the rainfall kinetic energy and tillage operation has been studied. Results of both the long-term measurement and the artificial experiments are presented in this contribution. The long term monitoring and the experiments have been conducted within a frame of projects GAČR 17-33751L, LTC18030 and TJ01000270.

17

Evaluating Scenarios for Achieving the Water Framework Directive Phosphorus Targets in Small Catchments

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Under the Water Framework Directive (WFD) and its UK implementation programme (UKTAG), freshwaters are required to obtain "Good" chemical status in terms of phosphorus (P) as well as other nutrients. However, numerous catchments in the UK contain river reaches that fail to achieve this status. A modelling study in two sub-catchments will assess the reductions in P export required in order to improve their chemical status, where high temporal resolution bankside sampling has identified the fluctuations in P concentrations at the catchment outlet. The catchments are: (i) The Pow Burn, a 10.5 km^2 sub-catchment of the River Eden, which was selected for the EdenDTC research project *(http://www.edendtc.org.uk/).* It contains numerous point sources within an intensively farmed landscape (mostly livestock) and was classified as "Poor" in terms of P for over 50% of the time in the last WFD assessment; (ii) a 5 km^2 sub-catchment of the Oona Water, a tributary of the Blackwater River in Northern Ireland. This catchment does not contain any significant settlements and point sources, and is almost entirely composed of pastoral farmland and was classified as having "Moderate" ecological status in the last two WFD assessments.

The aim of this study is to identify if the targets of the WFD are achievable given the current high agricultural loadings of P in these catchments and determine whether alternative targets need to be considered. The CRAFT model will be used to model the P dynamics (concentrations and exports) under the existing land use in both catchment. By relating the concentration-duration curve outputs from the model to the concentrations of P that are required for "good" status to be achieved, the percentage reduction in nutrient export required can back-calculated. Several different scenarios of land use management and mitigation (e.g. improving ditches to function as sediment traps) will be investigated in both catchments using the CRAFT model.

18

Changes of organic carbon concentrations in correlation with climate and land use changes - Analysis of river catchments in Northern Finland

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Total Organic Carbon (TOC) has lately shown an increasing trend in boreal regions. The interest in TOC has raised due to the currently observed changes in the climate patterns worldwide. TOC is mostly stored in sediments on the ocean's bottom and in northern latitudes, where the soil may endurance long frozen periods. The disturbances created by the changes in the climate are provoking that these TOC storages gradually become sources of TOC instead.

There are only a few studies on water quality in rivers in northern Finland. TOC concentration in Finland has been observed to be increasing (Lepistö et al., 2008) as well as the estimated annual load in catchments characterized by organic soils (Arvola et al., 2004). A river's carbon content is dependent on hydrological conditions, climate and land use properties of the catchment (Mattsson et al., 2005). Changes in TOC may affect the water chemistry which can have considerable consequences for the aquatic biota (Jarvie, 1991).

In this study, we have investigated river catchments in northern Finland between 2000 and 2018 to find changes in TOC concentrations as well as its link with the alterations of temperature and precipitation patterns. This relationship agrees with our results as we found increasing trends in TOC concentration as well as an increase in temperature and discharge. To try to get a deeper understanding, we have also considered and studied changes in land use in this area and the potential connection with TOC concentration as the northern catchments are sparsely populated and not heavily impacted by agriculture or industrial activities.

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19

Citizen scientist involvement in water quality monitoring in the Upper Liffey and Barrow catchments: a case study

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Over four days in September 2019, almost 600 citizens took part in a project to record and map the water quality of their local freshwater body in Ireland, with a focus on Leinster. The project was part of Earthwatch's Freshwater Watch Waterblitz programme, which in 2019 was rolled out to Dublin, Luxemburg and Paris as well as the Thames catchment in the UK. 202 water samples (53% of the samples) were taken throughout the Liffey Catchment over the four days, and the data fed back to the project leaders in real-time via an app that the participants had downloaded on their smart devices.

The citizen scientists recorded nutrient levels (nitrates and phosphates) as well as conducting a visual survey of the waterbodies. This poster gives an overview of the results of the project for the upper parts of the Liffey and Barrow catchments, and includes information on the effects of a heavy rainfall event on the water quality. It also discusses the importance of allowing local populations input into the collection of water quality data, and the importance of this on informing public perceptions of water quality and water stewardship.

20

Monitoring the impact of cattle access points on river water quality using in in-situ high frequency turbidity

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Cattle with direct access to streams and rivers contribute to deterioration in water quality arising from contamination with faecal matter, increases in suspended sediment and nutrient enrichment. The exact extent and impact of how cattle's behaviour when entering these water bodies affect the quality downstream from cattle access points has not been studied in great detail. In this study, *in-situ* monitoring of water quality was carried out using 2 multi-parameter sondes (temperature (^{o}C), conductivity (mScm^{-1}), turbidity (NTU), optical dissolved oxygen (ODO) (mgL^{-1}) and pH) installed upstream and downstream from the cattle access point. Motion detection cameras were used to capture cattle entry events and to quantify these events in terms of duration/length (min) and magnitude (number of cows). R studio was used to carry out the statistical analyses of the data and event classification.

During the deployment a total of 69 cattle access events were recorded and turbidity data was classified based on event time stamps. Results show there is a positive correlation between the number of cows entering the stream and the resulting impact on turbidity (difference in upstream and downstream turbidity) and between the entry event duration/length (min) and the impact on turbidity. The results identified a site specific threshold corresponding to eight cows and 14 min. When there are more than eight cows present, or the duration of the entry event is higher than 14 min, the impact on turbidity is considerably higher.

Keywords: cattle access points; turbidity; nutrients; agri-environmental and sediment.

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A novel effective, fast and frequent monitoring system for phosphate within a catchment

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Catchment monitoring with an emphasis on water quality is a growing area of critical importance within recent years. [1] Catchments can be extremely complex systems where the quality and quantity of the water is influenced by biological, chemical and physical factors. [2] A catchment area for water is usually defined as the area of land around a lake, river or some form of water body. [3] Catchment monitoring is important as it provides a strong approach to sustainable management of the area, it can also highlight problems or threats concerned with the area. Monitoring systems are put in place to better understand the key drivers influencing the quality of the water bodies and land surrounding the catchment.

The Burrishoole catchment in Newport, Co. Mayo is the focus of this study. Burrishoole is a highly instrumented and monitored catchment. Long-term data sets are widely available that date back to the 1950's. These datasets contain information on water temperature, precipitation pH, and dissolved oxygen. This work aims to demonstrate the need for novel multi-test phosphate sensor that is capable of on-site frequent analysis of phosphate levels in real time throughout the many lakes and rivers within a catchment area.

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22

Ten years of High Temporal Resolution Water Quality Monitoring

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The Agricultural Catchments Programme (ACP) was established in 2008 to include an assessment of the Nitrates directive and water quality in Ireland. The experimental design was based in six catchments on differing soil and drainage types and representative of the predominant farming enterprises.

As river flows generally respond quickly to rainfall in Ireland the ACP commissioned high resolution data monitoring equipment for synchronous measurement of nutrients and river discharges. Instantaneous nutrient concentrations and accurate calculation of loads are measured throughout the year and based on the Hach Phosphax sigma and Nitratax equipment. Supporting data include turbidity, conductivity meteorological parameters and groundwater levels and quality.

Deployment of this instrumentation to help evaluate the Nitrates Directive in Ireland was novel by its nature. It also represented a stepped change in the monitoring of nutrient loss from agricultural catchments over traditional sampling methodologies and strategies.

Challenges encountered included farmer stakeholder buy-in, selection of suitable sites, installation of single phase power supply, ground works including access, commissioning of instrumentation and the requirement for hands on learning approach for Technical and Research staff alike to gain required experiential knowledge of instrumentation.

Ten years of this high temporal resolution water quality monitoring has provided an improved understanding of catchment science dynamics in relation to nutrient source, pathways, delivery and impact – related to farm management under the Nitrates Directive.

The high temporal resolution monitoring sites also act as hubs for education and stakeholder engagement as data can be viewed in real-time or trends presented that are linked to major weather events and periods of the farming calendar.

23

Investigating the occurrence of anticoccidial agrochemicals in Irish groundwaters: preliminary findings

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Due to increased intensification of the food production system, agrochemicals including veterinary pharmaceuticals have become a critical component in animal husbandry. Administration of such compounds can potentially lead to their occurrence in the environment. This work presents investigations of a particular group of agrochemicals called anticoccidials, which are used to control coccidiosis and other protozoan infections in food producing animals. They are licensed in the EU both as veterinary drugs for therapeutic treatment and/ or as feed additives, with primary prophylactic use in poultry production. Excretion in manure and subsequent landspreading provides a potential pathway to groundwater. There is limited information available on the fate and occurrence of these compounds in environmental waters and as a result, these substances are considered to be potential emerging organic contaminants of concern. The aim of this work was to develop a comprehensive method for the determination of commonly used anticoccidials in environmental water samples, in order to investigate the occurrence of these contaminants in an Irish groundwater setting.
A multi-residue method based on Solid Phase Extraction (SPE) with Ultra High Performance Liquid Chromatography Tandem Mass Spectrometry (UHPLC-MS/MS) detection was developed for the quantitative determination of 26 anticoccidials in water. This method was applied in a comprehensive spatial study whereby 109 samples (63 borehole and 46 spring samples), representative of the different karst and fractured aquifer categories in Ireland, were sampled and analysed during November 2018. The preliminary findings of this study are presented here, which show detections of up to 7 different anticoccidial compounds at 24 % of sites sampled (26 of 109).

Keywords: agro-chemical; anticoccidials; emerging organic contaminant; groundwater; karst

24

Pesticide source risk identification - an evaluation of Decision Support Tools in Northern Irish catchments

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The FAIRWAY project *(https://www.fairway-project.eu/)* is a multi-national, EU Horizon 2020 funded project that is evaluating different approaches to drinking water source protection from contamination by pesticides and nitrate. Through analysis of 13 case study catchments across Europe the project seeks to identify and further develop innovative measures, and identify decision support tools (DSTs) and governance approaches for more effective protection in the future.

In Northern Ireland, the herbicide MCPA ((4-Chloro-2-methylphenoxy) acetic acid) is of particular concern for water quality as it is extensively used to control rushes (Juncus effuses) in grassland. MCPA sorbs poorly to soil and concentrations in river water frequently exceed 0.1μg/L. There are significant costs associated with treating contaminated water abstracted for drinking water purposes.

DSTs are often developed for specific climatic and geographic conditions and their transferability to other regions may not be considered. Currently there are no pesticide loss DSTs designed for Northern Ireland and so the transferability of three established DSTs (Farmscoper and SCIMAP (English) and Phytopixal (French)) were evaluated. Farmscoper is an Excel-based model designed to encourage use by individuals with a wide variety of technical backgrounds and is pre-populated with a variety of datasets based on standard British farm practice, climate and soil types. SCIMAP (offline) and Phytopixal DSTs are both GIS-based models that require the operator to provide site-specific data and to follow an analysis protocol. Although the user interface of Farmscoper makes it more suitable for non-specialists to operate, we found that the pre-provided datasets translated poorly to Northern Ireland. The SCIMAP (offline) and Phytopixal DSTs both require a basic level of skill with GIS software, which would be a barrier to adoption at the farm-scale, but they both make use of catchment-specific datasets. In both cases it was possible to generate spatial risk assessment maps at the catchment scale.

25

A novel method to evaluate the hydrochemical interaction between groundwater and surface waters in Denmark

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[3]Aarhus University, Department of Bioscience, Roskilde, DK-4000, Denmark

This study investigates the hydrochemical interaction between groundwater and surface water in order to develop a method to evaluate the chemical impact from aquifers on surface water chemical quality in Denmark. The proposed method involves a catchment analysis for evaluating, whether groundwater aquifers is a significant source of nutrients and hazardous substances. The novel method proposed involves a five tier approach: Tier 1: Assesses whether there are exceedances of the environmental quality requirements and / or significant upward trends for specific nutrients or hazardous substances. Tier 2: Source apportionment of the specific substances identified as problematic in tier 1. Tier 3: Analysis of the potential contact (PC) between the groundwater aquifers and surface water bodies in the catchment based on the National Danish hydrologic model (Troldborg et al, 2014). Tier 4: Quantification of the discharge of relevant substances from sub-surface point sources to surface water bodies Tier 5: Analysis of the potential hydraulic contact (PHC) where the PC is supplemented by the potential hydraulic contact (PHC) calculated by the DK-model. A screening is performed for the occurrence of the substances within a buffer of 250 m and 500 m. A combination of modelled groundwater discharge to the water body, chemical quality of the groundwater aquifer and expert assessment of the substance transport and attenuation, the potential influence of each groundwater aquifer for the chemical status of surface water is quantified and evaluated.

The method was tested in three different pilot catchments in Denmark. The suggested screening method was found to be useful and that missing data made it impossible to complete some of the proposed tiers. Moreover, we concluded that more monitoring data for hazardous substances is needed and that specific knowledge about the fate of hazardous substances between the groundwater aquifer and surface waters is generally poorly established.

References:
Troldborg L, Sørensen BL, Kristensen M, Mielby S. 2014: Afgrænsning af grundvandsforekomster. Tredje revision af grundvandsforekomster i Danmark. GEUS rapport 2014/58

26

Estimating Farmers' economic value for reducing risk to flooding events

Doherty E[1], Mellet S[1], O'Hora D[2], Ryan M[3], on Behalf of the RiskAquaSoil Project

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Climate change has both direct and indirect effects on agricultural productivity, including due to changing rainfall patterns, drought, flooding and the geographical redistribution of pest and diseases. Extreme weather events are projected to increase in the coming decades, however, uncertainties remain in relation to the scale and extent of the impact on farming. Using the discrete choice experiment (DCE) method from a representative sample of Irish farmers', this paper analyses farmers' economic value associated with insurance against extreme weather events, including flooding events. We find that farmers' have a slight but significant preference for index-based insurance and prefer longer insurance contracts. Approximately 30 percent of farmers indicated that they are concerned with flooding events and a larger majority of farmer' are concerned with storm damage. In additional analyses, we find that approximately 40 percent of farmers would be willing to allow some flooding on their land to reduce the risk of downstream flooding to local communities.

This research is part of the RiskAquaoil Project co-financed by the European Regional Development Fund (FEDER) through the cooperation programme Interreg Atlantia Area, with reference EAPA – 272/2016.

27

Specific Management and Robust Targeting of Riparian Buffer Zones

SMARTER_BufferZ

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The pollution of surface and ground waters represents one of the primary environmental problems 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. These areas can provide a variety of environmental and ecological services, including a habitat for biodiversity, enhancing connectivity, alleviating flood threat, greenhouse gas exchanges and aesthetic and recreational services. Despite their widespread implementation, huge uncertainties remain in relation to the optimal design, management and cost-effectiveness of riparian buffer zones as a measure to support the delivery of ecosystem services and to enhance the quality of water-courses, particularly at larger catchment scales.

The SMARTER_BufferZ project aims to ensure optimal targeting and management of riparian buffers for the effective management of Irish rivers. The project will:

- Evaluate the effectiveness of targeted riparian management measures to maintain and enhance water quality in Irish rivers.
- Identify factors and develop tools for risks associated with insufficient and inefficiently sited or designed buffers that do not optimise benefits, particularly for water quality and ecological condition.
- Make recommendations for actions from basic strategies widely implemented, to more specific requirements according to site circumstances, both physical and habitat aspects, at the correct spatial extent (from site-reach-whole catchment).

It is anticipated that information gleaned from this study 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. SMARTER_BufferZ will contribute to environmental policy and to improved management of agricultural and surface water landscapes in Ireland.

28

The Dairy-4-Future Project: Propagating innovations for more resilient dairy farming in the Atlantic Area

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The Altantic area encompasses regions along the Altantic coastline of Europe including the west of Scotland, the entire island of Ireland, Wales and south west England, the west of France, the Northern coastline of Spain and Portugal. This area includes important dairy producing and exporting regions accounting for 20% of EU milk production. The Atlantic Area is well positioned to meet growing global demand for dairy products because of favourable climatic conditions for fodder production, well-educated farmers and efficient dairy processing and manufacturing businesses. Nevertheless, dairy farms face several challenges including economic viability, complying with environmental regulations and future challenges such as climate change. Funded by the Interreg Atlantic Area Program, the Dairy-4-Future project aims to increase the competitiveness, sustainability and resilience of dairy farms in the Atlantic area. The key questions in this project are (i) how sustainable are the farms that produce our milk and (ii) what can be done to improve the sustainability and the sustainable image of these farms. A network of 100 commercial dairy farms has been established including 10 commercial dairy farms in each of the following regions: Scotland, Northern Ireland, southwest England, Ireland, Normandy, Brittany, Pays de Loire, Basque Country, Galicia, Portugal and the Azores Islands (which account for 30% of Portuguese milk production). Many aspects of sustainability are being measured including economic performance, nutrient use efficiency, carbon footprint and ammonia footprint. The goal is to improve the economic performance and environmental footprint of dairy farming by identifying and demonstrating best practices leading to practical recommendations tailored to the socio-economic, climatic and soil conditions in each region. Recommendations will be widely disseminated in the Atlantic Area. The key message for Irish dairy farmers is to continue to focus on low-cost grazed-grass to ensure the economic and environmental sustainability of their farms.

29

RiskAquaSoil - Comprehensive management plan for risks in soil and in water to improve the resilience of the Atlantic rural areas to climate change

Mellet S[1], Doherty E[1], O'Hora D[2] and Ryan M[3] on Behalf of the RiskAquaSoil Project

[1]National University of Ireland, Galway, Whitaker Institute
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The Atlantic Area presents high exposure to climate change. Increased intensity and frequency of storms, drought and flooding, altered hydrological cycles and precipitation variability have implications for the agriculture sector. There are huge uncertainties in the way climate change will affect agricultural and food systems. The purpose of this presentation is to present an overview of the RISKAQUASOIL project. RiskAquaSoil aims to develop a comprehensive management plan for risks in soil and in water to improve the resilience of the Atlantic rural areas. Through transnational cooperation, the project partners will combat the adverse effects of the climate change, especially on agricultural lands. This integral plan will entail three stages linked to the three specific objectives: (i) early warning and diagnosis: testing new low-cost remote techniques to measure and forecast the local impact of different meteorological phenomena. These techniques will provide accurate data that will result in a better early detection system in rural areas. Diagnosis activity will be enlarged with climate scenarios and forecasts and the improvement of climate information services to farmers; (ii) implementation and adaptation: developing several pilot actions in agricultural lands that will permit a better soil and water management taking in to account the risks associated to climate change; (iii) capacity building and dissemination: training and commitment of local communities and farmers for an increasing capacity building, information and cooperation in risk management and damage compensation systems. The project will contribute to a better coordination for the detection, risk management and rehabilitation for rural territories (maritime and terrestrial areas), especially for agricultural purposes, mainly associated to climate change and natural hazards but also to human pressure.

*** This research is part of the RiskAquaoil Project co-financed by the European Regional Development Fund (FEDER) through the cooperation programme Interreg Atlantic Area, with reference EAPA – 272/2016*

30

The utility of mobile phone apps to manage pesticides at field scale: The perspective of Northern Ireland farmers

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The FAIRWAY project *(https://www.fairway-project.eu/)* is a multi-national, EU Horizon 2020 funded project that is evaluating different approaches to drinking water source protection from contamination by pesticides and nitrate. Through analysis of 13 case study catchments across Europe the project seeks to identify and further develop innovative measures, and identify decision support tools and governance approaches for more effective protection in the future.

In Northern Ireland the herbicide MCPA ((4-Chloro-2-methylphenoxy) acetic acid) is of particular concern for water quality as it is extensively used to control rushes (Juncus effuses) in grassland. MCPA sorbs poorly in the soil environment (Koc: 74 ml/g) and concentrations in river water frequently exceed 0.1μg/L. There are significant costs associated with treating contaminated water abstracted for drinking water purposes.

In order to assess farmers' willingness to adopt a mobile phone app to inform field scale management of MCPA, a structured questionnaire was developed. Participants were recruited through visits to markets, agricultural shows and on-farm meetings and through the Ulster Wildlife Grassroots programme. Interim results, based on 81 responses suggest that the majority of respondents do not use online (57%) or mobile app (96%) resources. 77% of respondents owned a smart phone and the majority (70%) were willing to use an app in future. 75% of those willing to adopt were less than 60 years old. Respondents were interested in gaining more information on best practice around pesticide selection and usage (product selection: 75%; Dilution calculations: 56%) and environmental conditions for application (ground conditions: 62%; weather: 60%). Although 38% of respondents requested information on handling and disposal of contaminated packaging, 81% were somewhat or very confident of their knowledge on this issue. This information is informing the development of the prototype mobile app for field scale management of pesticides in drinking water catchments.

31

Validating simplified riparian context models: capturing your views about the importance of different riparian types for water quality management

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This will be an interactive poster demonstration to introduce visual interpretations of a set of simplified models of key field-riparian-channel transition zone contexts in Ireland. The aim of these models is to categorise riparian contexts as a tool to aid the selection of packages of measures for a given place that results in the best effectiveness of water quality and wider benefits. The work is part of the Smarter BufferZ project (Irish EPA-funded) seeking to improve riparian buffer zone management using concepts of 'right measures' for the 'right place'.
This display will introduce:

- The key attributes being represented (water table, soil chemistry and pollutant delivery pathways)
- The groupings sought to differentiate, but simplify representation of, broad differences across the landscape in attributes affecting sediment, N, P delivery pathways and seasonality
- How we may utilise spatial data at different scales to locate model types in Irish catchments
- Basic communication tools associated with the models to convey the pathway and pollutant differences between groupings

The interactive part of this display will ask for validation from different groups of stakeholders as to:

- Whether the models represent the key types of riparian transition zone occurring in Ireland
- The dominance of the different models in either the general landscape of Ireland or areas of their personal and professional familiarity
- Whether they judge certain contexts more or less likely to be associated with pressures on water quality and on good vs degraded riparian condition and why
- The role of such communication tools in linking riparian context-issues and potential management for differing audiences

The interaction with our display will combine discussion in person, free comments and voting tokens and may be made anonymously.

32

Assessing direct cattle access contribution to streambed sediment nutrient and faecal pollution in Irish agricultural catchments

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[3]School of Biology and Environmental Science, Freshwater Ecology Research Group, University College Dublin, Dublin, Republic of Ireland

Agriculture is one of the major causes of water pollution and water quality impairment globally. Although livestock agriculture, particularly the use of farmland watercourses by livestock for drinking water or as crossing points, has been shown to have a negative impact on stream biogeochemical parameters such as bank stability, sedimentation or faecal contamination, the information available in literature regarding its impacts on water quality in a European context is scarce. In this study, bed sediment was collected at sites actively used by cattle in five agricultural catchments across a range of water quality status in Ireland at two times of the annual cattle management cycle. At each study site, the sediment was sampled at the cattle access site and at reaches of the stream not used by cattle. Sediment samples were analysed for organic carbon (OC), total nitrogen (TN), carbon:nitrogen (C:N) ratios, total phosphorus (TP) and Escherichia coli (E. coli) concentrations. Cattle access to watercourses significantly increased sediment TP and E. coli concentrations, whereas OC, TN and C:N ratios did show any significant change as a result of cattle access. These results show that unrestricted cattle access to watercourses can lead to 1) high levels of faecal contaminants in stream sediments, with implications for both human and animal health, and 2) a localised accumulation of TP in sediments at access sites, potentially contributing to a legacy effect in streams that can hinder the effects of mitigation measures, with subsequent implications for water quality and the achievement of WFD objectives.

33

Control of diffuse agricultural pollution and management of trans-boundary waterways: A comparative analysis of the policymaking process in Ireland and Northern Ireland

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Brexit is likely to trigger significant changes in the agri-food sector between Ireland, Northern Ireland and Great Britain, including shifts in market conditions, industrial organisation, and policy. This may have a disproportionately significant impact on the island of Ireland due to its highly integrated agri-food sector and shared ecosystems. Resultant challenges, if not properly addressed, have the potential to negatively affect current provision of ecosystem services in agriculture, and undermine the overall sustainability of the industry.

Many of the island's ecosystems are transboundary in nature, including numerous waterways. New regulatory regimes may result in different standards across a single water catchment area; changes to the management of a catchment in Northern Ireland can exhibit positive or negative externalities in the Ireland, and vice versa. One of the challenges for policy makers and farmers alike will be to determine how to weather upheavals in agri-environmental policy, practice and trade so that farmers on both sides of the border can collaboratively continue to thrive while also sustaining and improving existing land and waterway management practices. In doing so, there must be greater consideration of the factors that affect farmers' decisions around land use management and practice. Farmers are driven not only by market factors and economic incentives but also by a complex mix of social, cultural and political factors, household and individual profile characteristics, and concern for the natural environment. Understanding these is critical to understanding how farmers adapt to policy changes.

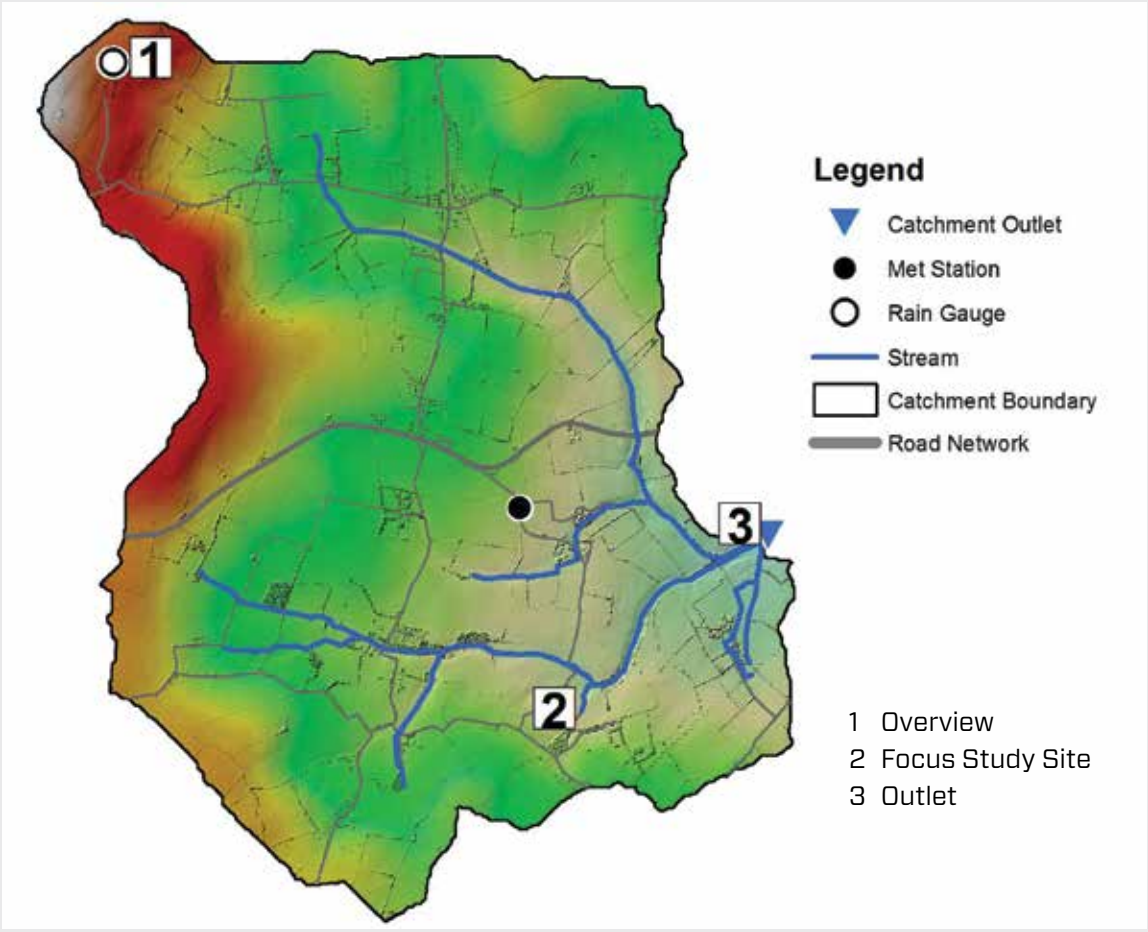
This project considers the potential impact of diverging agri-environmental policy on agricultural land use and trans-boundary waterway management on the island of Ireland. Using a range of qualitative methods (interviews, focus groups and case studies), I am investigating the various factors that affect farmers' land use and waterway management practices in specific trans-boundary water catchment areas in the region, and to what degree these factors are considered in the policymaking process.

Field Trip Information

Field Trip Option 1: Castledockrell Catchment Visit: Data acquisition and analysis

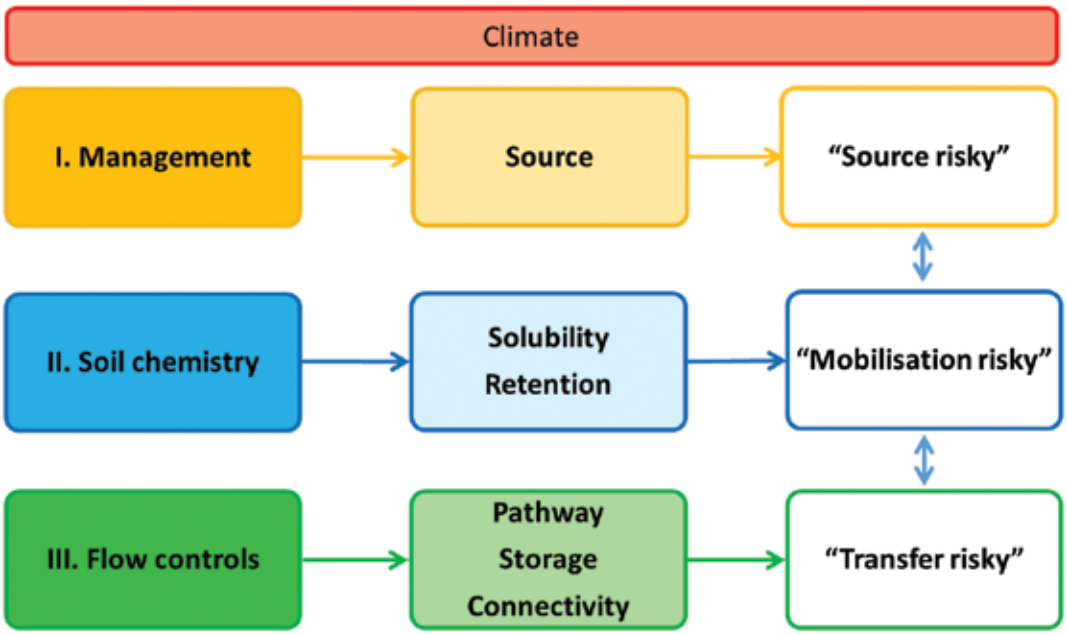
The Castledockrell catchment is situated between Enniscorthy and Bunclody in Co. Wexford. The stream that drains the catchment is a tributary of the Slaney River which drains much of the south-east region. It is 1,117ha in area and in a typical year 54% of the catchment area is used for tillage with 39% in grass and the balance in non-agricultural uses. The type of farming in the catchment is typical of the tillage/drystock mix that is found in much of the south-east and south of Ireland on well-drained soils. Spring barley production is the main tillage enterprise with some other cereals such as winter barley as well as some oil-seed rape and potatoes.

Sheep production is traditional in the area and is still carried on by many farmers as well as beef production. The majority of the land in the catchment has free draining typical brown earth soils, belonging to the Ballylanders and Clonroche Soil Series. These soils which are underlain by slate and shale geology are ideal for spring barley growing. In the low lying areas near the stream there are some poorly-drained groundwater gleys soils most of which are artificially drained. Based on the type of soil and subsoil in this catchment nitrogen is considered to be the main nutrient at risk of loss to water and the main pathway for loss is considered to be leaching through the soil to the groundwater.



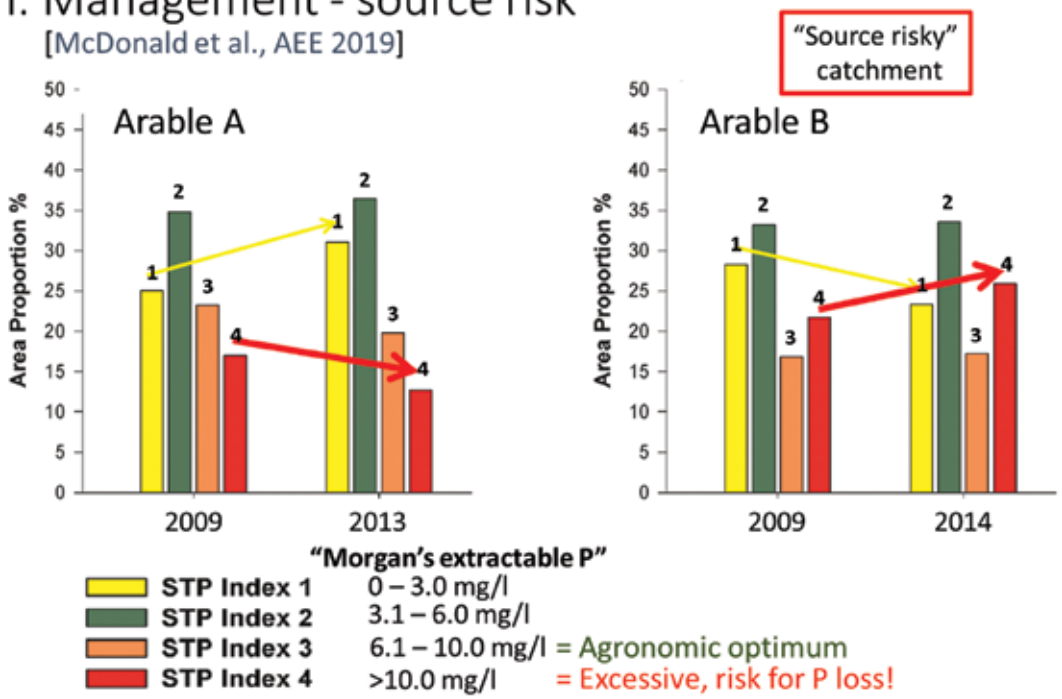
Simplified climate-chemical indicators

[Mellander et al., Sci Rep 2018]



I. Management - source risk

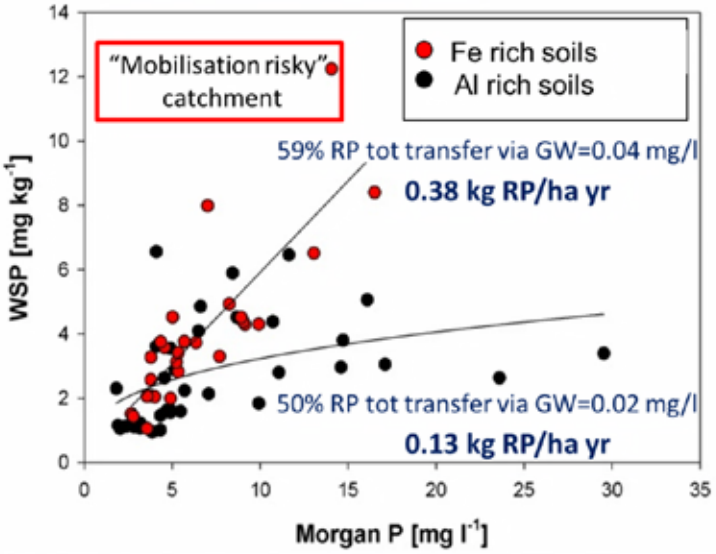
[McDonald et al., AEE 2019]



Good farm-scale nutrient management to improve the spatial distribution of nutrients

II. Soil chemistry - mobilisation risk

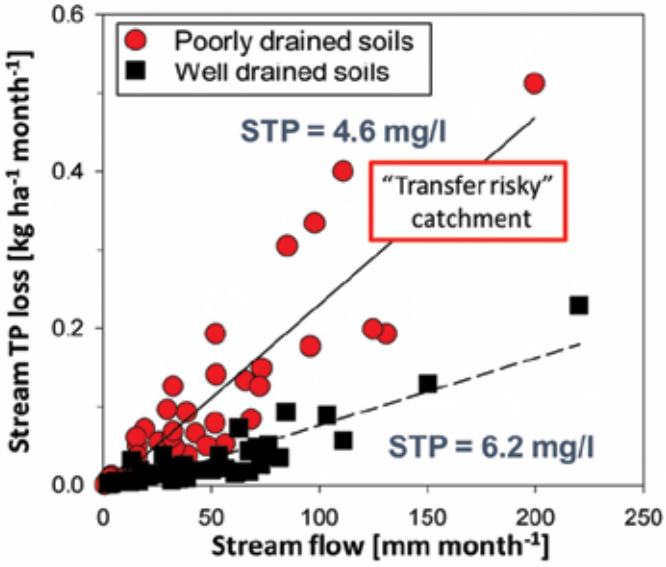
[Mellander et al., STOTEN 2016]



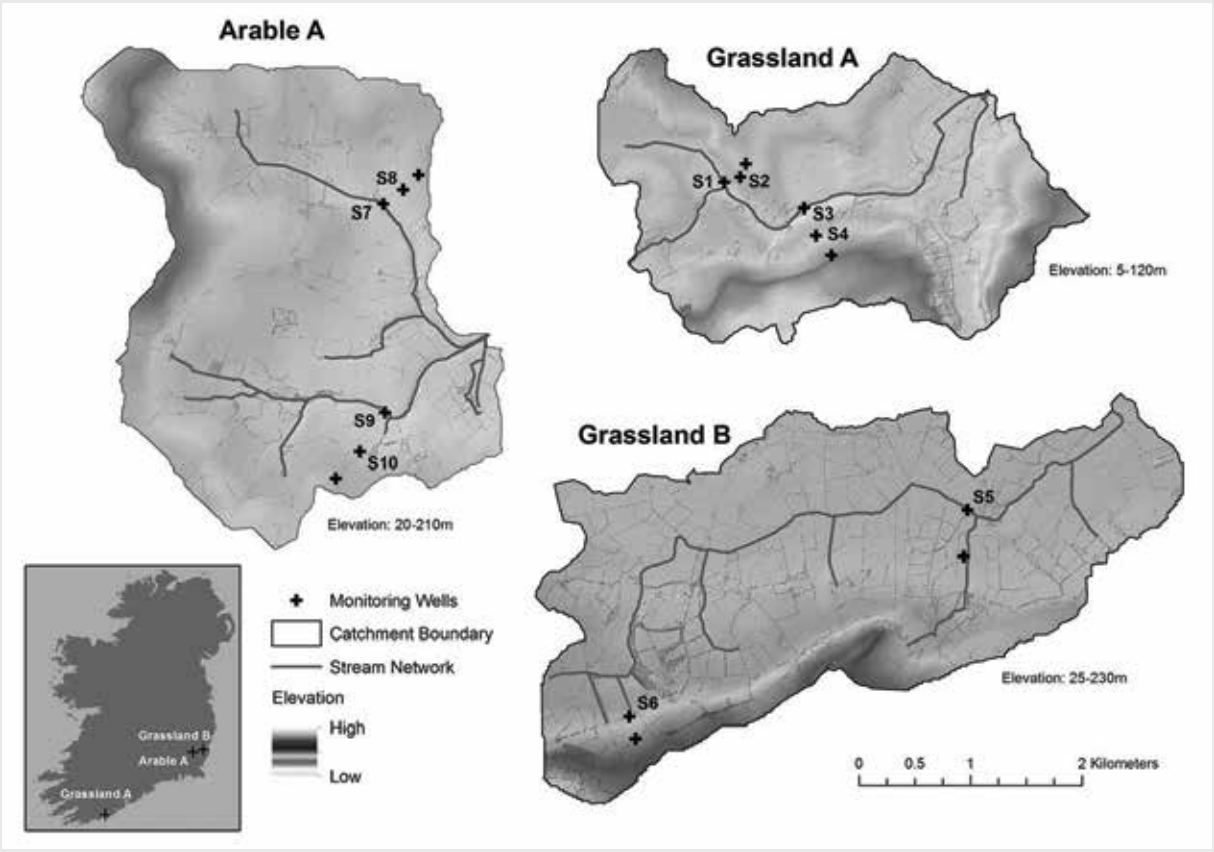
- Phosphorus is more easily leached in iron rich soils
- Influenced P loss at catchment scale

III. Flow controls – transfer risk

[Mellander et al., Hyd Proc 2015]



- Flow controls overrides source pressure
- Larger inter-annual P loss than between catchments


Arable A
S8
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Elevation: 20-210m
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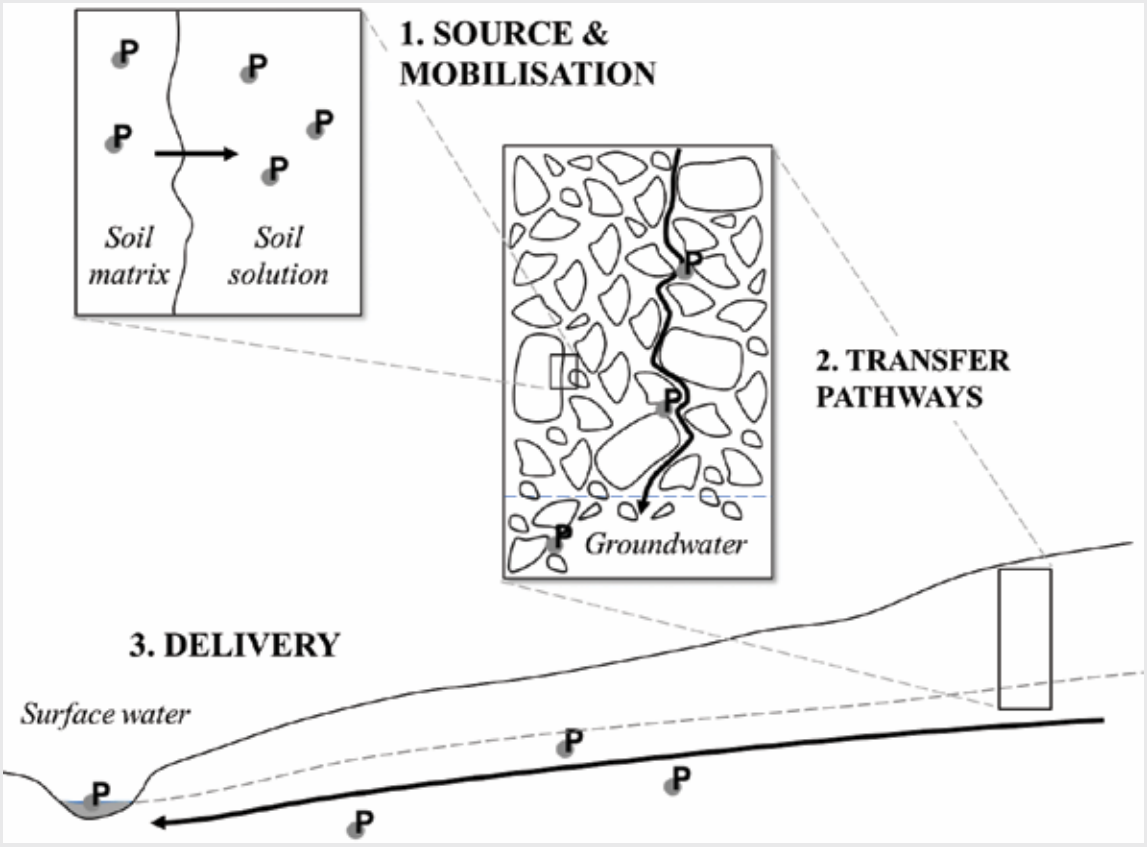
Monitoring Wells
Catchment Boundary
Stream Network
Elevation
High
Low


1. SOURCE & MOBILISATION
Soil matrix
Soil solution
2. TRANSFER PATHWAYS
Groundwater
3. DELIVERY
Surface water
P

Multiparamaters Probe

Low Flow Groundwater Sampler

Stream Autosampler

Free Soil Solution Traps

Stream velocimeter

Kiosk Instrument Summary.
Analytes being measured continuously at (approx.) 10min intervals are:
- Total Phosphorus in mg L^{-1}
- Ortho-Phosphate P in mg L^{-1}
- Total Oxidised Nitrogen in mg L^{-1}
- Turbidity in NTU
- Electrical Conductivity in micro
- Siemens/cm
- Total Organic Carbon in mgL $^{-1}$
- Temperature in degrees Celsius.

Instruments and measurement principles are:
- All instruments are manufactured by Hach
- Our instruments and sample delivery systems were supplied and commissioned by an Irish company, UISCE Technology. Currently we have a service contract with an independent Hacht
- Lange trained technician
- Water is delivered continuously to a header tank in each kiosk via a submersible pump which is anchored to the river bed. All sensors are housed in, or sampled from, the header tank
- All kiosks are supplied with (necessary) mains 230V AC power.

Sigmatax sample preparation and Phosphax Sigma
- Total Phosphorus (TP)
- Ortho-Phosphate P (OP).

The Sigmatax sample preparation unit takes a sample in, mixes it using ultrasonic vibration then the sample is fed to the Phosphax. The equipment analyses unfiltered river water samples for total digested P (TP) and total molybdate-reactive P (TRP) concentrations from 0.01 mg L-1 to 5.00 mg L-1.The method alternates the digestion (using high temperature and acid in the central cuvette) step to give up to 3 TP and up to 3 TRP data-points in each hour. An automated single point calibration and cleaning cycle occurs daily. The equipment is routinely maintained and serviced and the analytical method and quality control of these types of instrument suites are described by Jordan et al., 2007, and Cassidy and Jordan, 2011.

Nitratax
- Total oxidised nitrogen, every 10 minutes (Range 0.1 – 50 mg N L^{-1}).

The Nitratax unit uses spectrophotometry to measure the total oxidized nitrogen (nitrate plus nitrite, where nitrite concentrations are usually very low or zero). Total oxidized nitrogen absorbs light at 210nm wavelength, so a beam of UV light at this wavelength is passed through the sample and the amount of light absorbed is measured. A second beam of light is passed at 350nm to correct for turbidity and organic matter. A calibration equation is use to convert Ultraviolet absorbance into total oxidized nitrogen concentration.

Solitax
- Turbidity (NTU), every 10mins. Range 0 – 2000 NTU.

The Solitax unit also uses spectrophotometry to measure the turbidity of the water. A beam of infrared light is passed through the water sample and two receptors detect the amount of light that is scattered at an angle by the particles in the water.

UVAS plus sc Sensor (Total Organic Carbon)
- Total Organic Carbon, every 10 minutes.

The UVAS unit uses spectrophotometry to measure the total organic carbon of the surface water. Total organic carbon absorbs light at 254nm wavelength. The amount of light absorbed at this wavelength is measured. A calibration equation is used to convert UV absorbance into total organic carbon measured in mg L^{-1}.

Temperature and Conductivity sensor 3400 series
- temperature and the electrical conductivity of the water are measured every 10 minutes.

Flow measurement
Water level (m) is recorded via OTT Orpheus Mini and OTT ecoLog 500 vented-pressure instruments and discharge (m3 s^{-1}) calculated via rating curves developed on non-standard Corbett flat-v weirs using the velocity-area method with OTT Acoustic Doppler Current-meters.

Real-time and historical data for the ecoLog 500 instruments is accessible via OTT HydrometCloud.

Meteorological parameters
Meteorological parameters are recorded by Campbell Scientific BWS-200 weather stations. Final archiving and quality control of hydrochemistry and meteorological data is undertaken in the WISKI-7 (Kisters AG, 2011) database management system.

The Agricultural Catchments Programme weather station data can be viewed remotely from any of its seven stations using the following link https://www.acpmet.ie

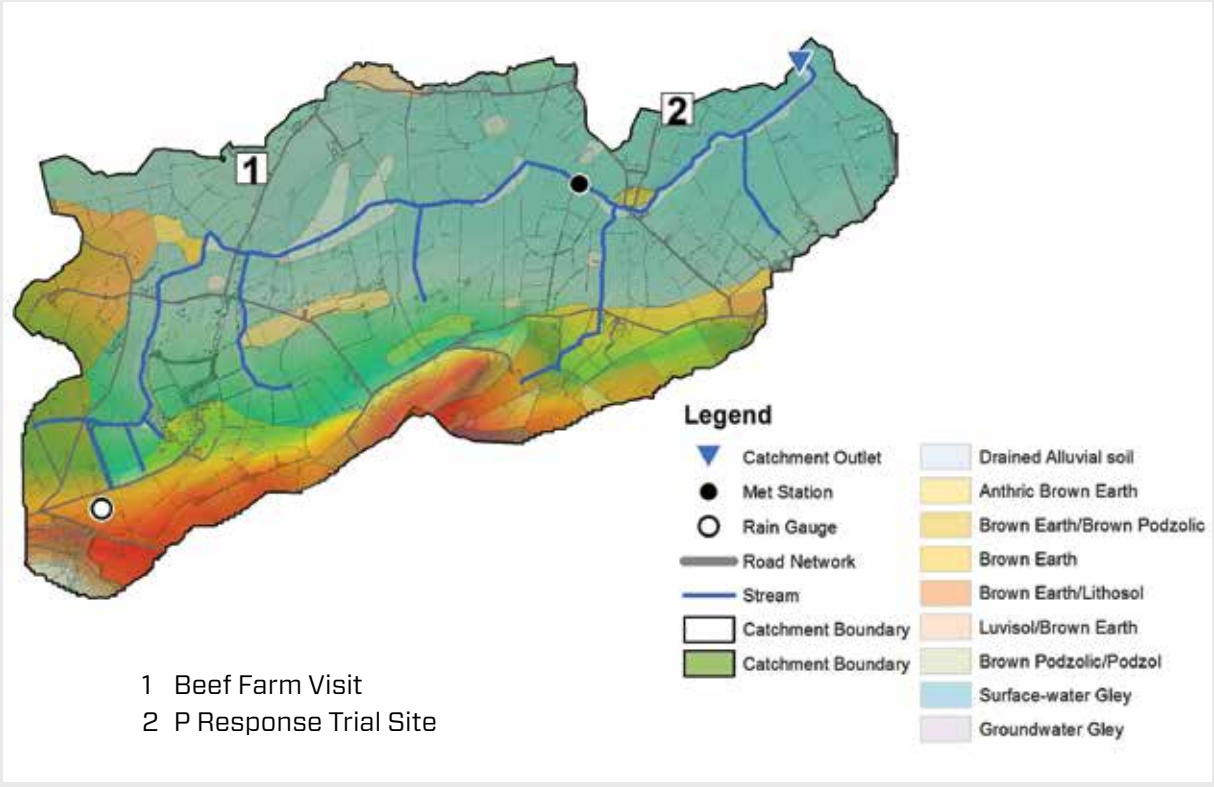
Web-enabled SQL server (Dexdyne Ltd.)
Data are held in an internal logger and also transferred to a Netrix GPRS data-push system to hold on a web-enabled SQL server (Dexdyne Ltd.) for real-time and historic data visualisation.

Castledockrell kiosk *containing High Resolution Water Quality Instrumentation and telemetry.*

Stilling well *with OTT Instrumentation. Stream channel, bridge and V notched weir.*

Field Trip Option 2: Ballycanew Catchment Visit: Agronomy and knowledge transfer

The Ballycanew catchment is located just north of the village of Ballycanew, near Gorey in Co. Wexford. It is 1,191ha in area and grassland makes up approximately 78% of the land-use with 20% in tillage and the balance in woodland and other uses. The main grassland-based farm enterprises are beef production and dairying with some sheep production and sport horses. Spring barley is the main tillage crop with small areas of other cereals. The dominant soils in the lowland of this catchment are surface water gleys, mostly belonging to the Kilrush and Macamore soil series. These soils are derived from endmorainic and marine deposits of heavy muds giving them poor drainage characteristics. The drainage in this area has been improved somewhat by the owners through tile and mole drainage. The soils on the elevated land to the southern catchment boundary are non-calcarious brown earths over slate and shale geology. Tillage in the catchment is limited to this area. With good management the heavy soils in the catchment are well suited to grassland farming and dairying is expanding in the area. Based on the type of soil and subsoil in this catchment phosphorus would be considered to be the main nutrient at risk of loss to water in the heavy lowland soils. The main pathway for loss is through overland flow during heavy rain events.



1 Beef Farm Visit
2 P Response Trial Site

Thomas Doyle – Ballyoughter
Tom Doyle farms 45 hectares in north Co. Wexford with his wife, Alice. The farm is located beside the village of Ballyoughter, where the main enterprise is beef farming, using a grazing grass based production system. Typically, Tom buys in just over 100 yearling or store cattle during the winter months, rears and sells them as finished cattle to the factory when close to two years of age. The farm stocking rate under two livestock units per hectare (135 kg N/Ha.) and no suckler cows are kept on the farm. Usually there is a cereal crop on the farm, with 8 hectares of Winter Barley grown this year.

The soil type on the farm is a surface water gley, with soils that are naturally moderate to poor draining. The soil test results for the farm in 2017 are typical of the area, with low levels for P (average 3.5 mg/l) and medium to high for K (average 120 mg/l). Tom has managed the soil pH well, with an average value of 6.4

Tom has and continues to be a very active member of various farm organisations, of note being chairman of both the IFA's national Farm Business Committee and the Wexford Farmers' Co-operative Society.

Grassland phosphorus plot trial
Phosphorus (P) is an essential nutrient input to agricultural systems for grassland and crop production. Excess P (if lost to waterbodies) can contribute to eutrophication and decline in Water Framework Directive (WFD) status (O'Neil et al., 2012; Dodds and Smith, 2016). In Ireland, 26% of rivers still have an average P concentration over 0.035 mg l^{-1} indicating a failure to achieve good ecological status under the WFD criteria (WFD indicator report, EPA).

Under the Food Wise 2025 plan (2015) Ireland aims to increase the value of primary production by 65% between 2015 and 2025. This will require expansion of the national dairy herd and consequently, will increase the volume of cattle slurry produced. Achieving both of these environmental and agronomic goals requires prioritization of P management including better fundamental understanding of soil and water chemistry, improved utilization of slurry fertilizers on farm, and tailoring of nutrient recommendations to reflect plant requirements and environmental risks.

Considering the increasing availability of manure P resources on Irish farms, the aim of this study was to evaluate agronomic impact and potential losses of P across soil types and fertiliser treatments. The specific objectives were to compare the effects of organic and inorganic fertiliser applications (1) on grass production (2) grass P concentration (3) soil P build-up and (4) to quantify P losses below the root zone across contrasting soil types.

Material and methods:
This study utilizes grassland sites in four contrasting catchments. Presented herein is the Ballycanew catchment; a poorly drained, grassland site in Co. Wexford in the Southeast of Ireland. The experimental design consists of 28 plots per site (Figure 1), receiving treatments of either chemical or cattle slurry P.

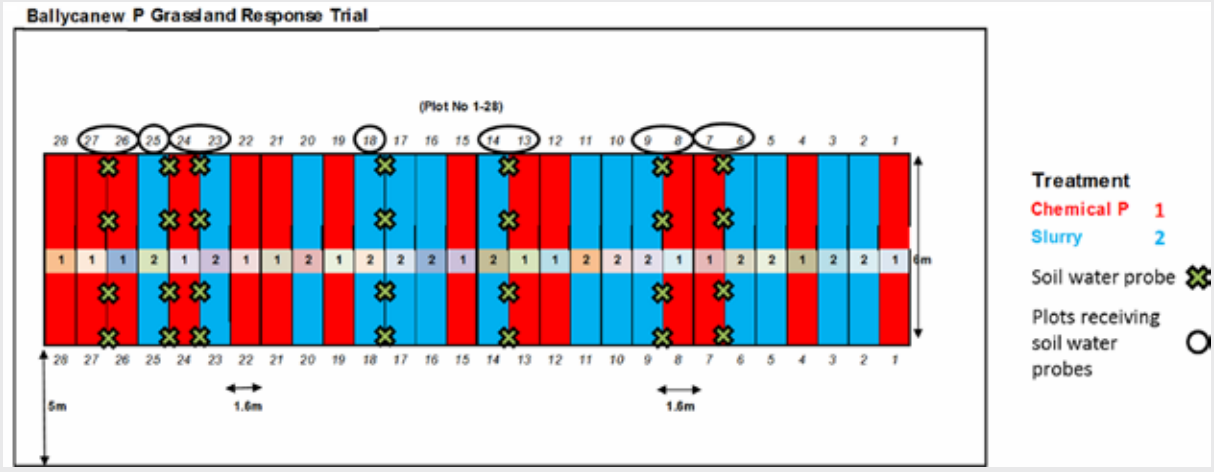


Figure 1: *Ballycanew grassland plot trial experimental design*

Each plot was initially analysed for bioavailable P (Morgan, 1941) to establish the baseline nutrient availability prior to application of treatments. Subsequently, at each site, plots were paired according to their closest soil P levels (14 pairs per site). From each pair, one plot was chosen to receive P in chemical form (Triple Superphosphate) and the other one in organic form (cattle slurry).

Thereafter, 6 plots with low soil P levels (Morgan, 1941) per site were selected (3 receiving chemical P and 3 receiving cattle slurry), as well as 6 plots with high P soil P levels (3 receiving chemical P and 3 receiving cattle slurry). The selected plots were each equipped with 4 soil pore water probes (Figure 2). The probes were inserted below the first soil horizon (approximately 30 cm) directly under each plot. A tube protected by a sewer pipe made the link between the probe and the surface to maintain easy access on the side of the plots. Control probes were placed at 3 different positions around the area of the plots.

Grass samples were harvested on a monthly basis from end of February to November each year. Herbage was harvested across the entire width of each plot with a ride-on mower (Etesia Hydro 124) to a height of 4 cm and was weighed on site using a collection box and a field balance. Total weight was recorded on site and a sub-sample was taken and returned to the lab for analysis. Dry matter (DM %) of the grass was determined by drying and weighing a sub-sample (approx. 100g) at 70°C for one week. Total herbage yield (kg/DM/ha) was calculated by multiplying fresh yield by DM %. The dry sample was then ground and analysed for total N, P, K and S content.

Figure 2: *Soil pore water samplers at the poorly-drained grassland site. Grass harvests*

Treatments
The chemical P was weighed in the lab before application. Cattle slurry was weighed on-site, adjusted for volume using a slurry hydrometer and sub-samples were sent to an accredited laboratory for analysis of N, P, K and DM content. The same rate of P (42 kg/ha) was applied to each plot over the year using a split application of 21 kg/ha in both April and June. This mimicked typical P applications across the growing season for a silage cut based system (Wall and Plunkett, 2016). Supplementary applications of N and K insured equal distribution of nutrients across the plots and prevented nutrient deficiencies from occurring.

Water sampling
To obtain pore water samples, each tube was equipped with a syringe and suction was maintained for 2-3 days. Each sample was then, collected from the plots, bulked, and filtered in the lab (0.45 microns) prior to analysis. The samples were analysed for DRP, TP, $N\text{-}NH_4$ and TON.

Sampling was conducted on a monthly basis throughout the growing season (February to September) of the year 2019, and each probe was sampled once a month, prior to grass harvests. During the initial weeks of the 2018 closed period (October to December), a higher sampling resolution was implemented. In this period, sampling was conducted weekly. During 2019, weekly sampling was conducted over the 3 weeks subsequent to each slurry application (May, July and October), and for the first weeks of the closed period (up to December).

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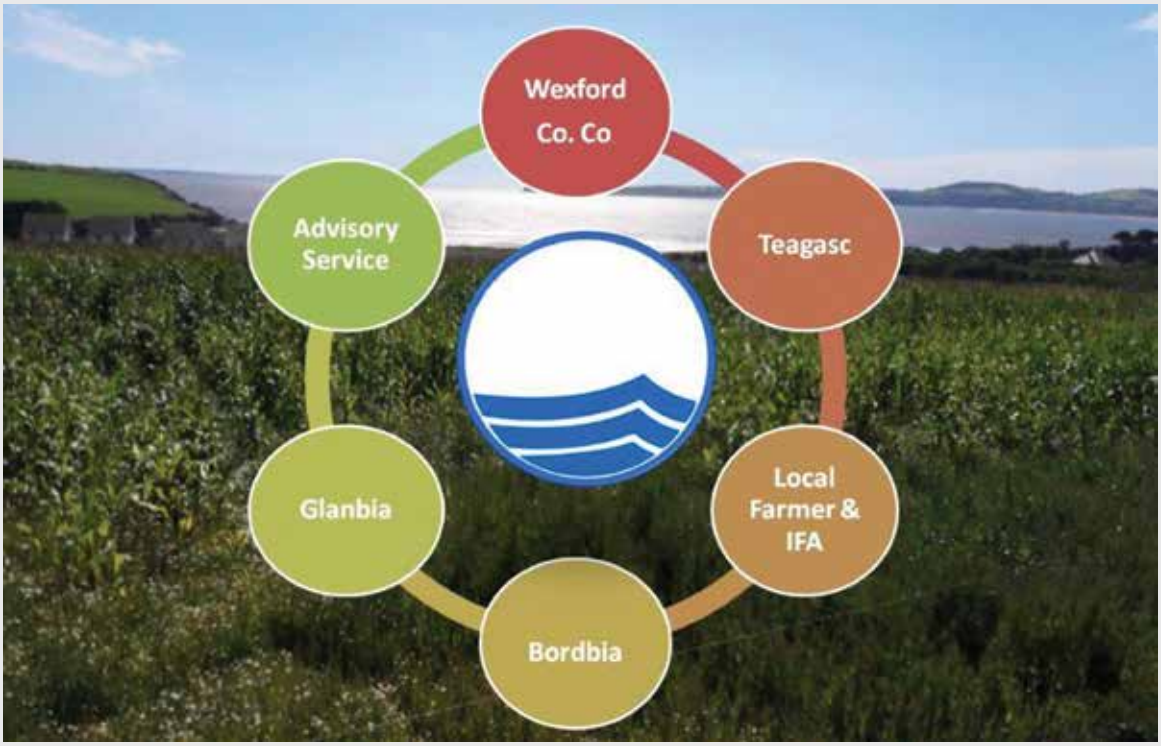
Field Trip Option 3: "The Duncannon Blue Flag Farming and Communities Scheme"



Project Rationale

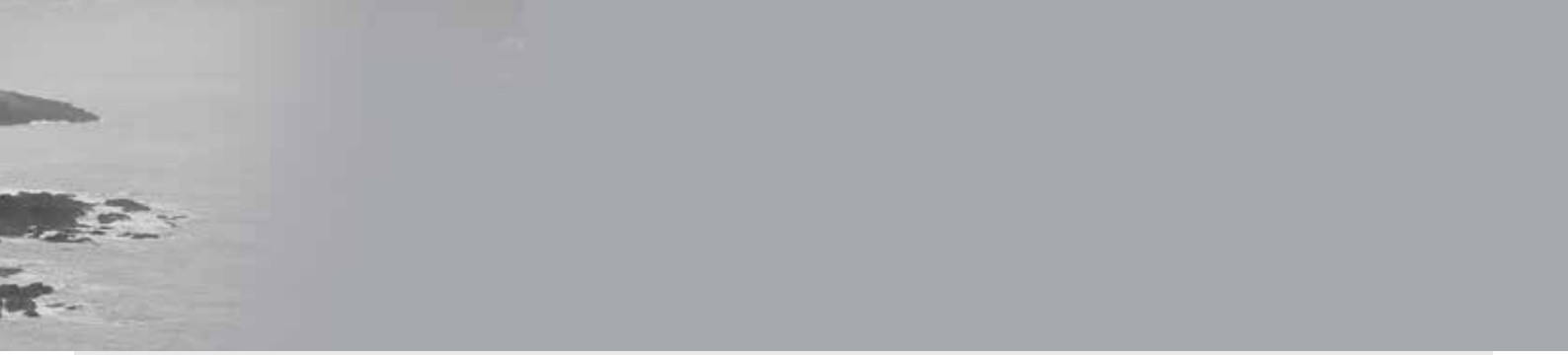
The elevated bacteria levels of bathing water quality at Duncannon beach together with the loss of its 'Blue Flag' status of environmental excellence in 2007 have had a major impact on the tourism potential of the area. For example, bathing prohibition notices had to be enforced as recently as August 2017, during the week of the Hooked KiteFest, due to excessive levels of Intestinal Enterococci (IE) in the bathing water.

Project Aims and Objectives

The project aims to contribute to the recovery and long-term retention of the Blue Flag status at Duncannon beach, Co. Wexford, by improving the bacterial quality of the two coastal streams that flow onto the beach.

To achieve this goal, the project will pursue the following specific objectives within the Water Framework Directive (WFD) Integrated Catchment Management (ICM) approach:

- Sustainably restore, protect and enhance the quality of the bathing and riverine waters at Duncannon by reducing pollution (mainly faecal bacteria but also nutrients and sediments) from rural agricultural and domestic sources whilst also protecting farm incomes;
- Develop an effective model for the future sustainable management of similar catchments;

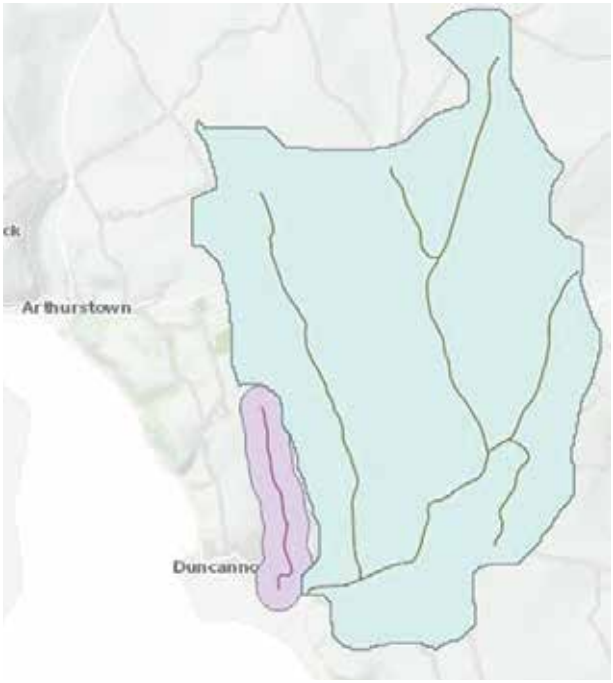


- Foster positive relations between the farmers and householders in the catchment area and the local natural landscape, particularly the water environment and associated biodiversity.

Project Activities

- Create a farm-specific 'Pollution Potential Zone' (PPZ) plan for each farm.
- Provide local farmers with a full-time 'Sustainability Manager' who will help participant farmers achieve the objectives of the project by guiding them through their PPZ plans and by developing and delivering a number of knowledge exchange initiatives.
- Monitor farm practice change and water quality in the wider catchment area.
- Create a local awareness programme for domestic waste water treatment systems.
- Develop community wide engagement with the project with the objective of creating a sense of local ownership, responsibility and appreciation for the local water environment.

- 13km² 1km²
- Intensive agricultural land
- Well-drained soils
- ~ 60 Landowners
- ~ 20 farmyards
- Village of Ramsgrange
- ~ 200 houses
- Several Bussiness's
- Schools
- Elevated N& P levels
- Impact on Ecology



Future engagement/education

- Encourage farm participation in knowledge exchange (KE) initiatives
- Farm Demonstrations- farmer change/ local water-environment
- Maintain 'citizen science' courses
- Carlow IT- Final year student project
- System of communicating water-quality results to farmers/community- local meetings
- 'Text-alert' system
- "Blue Flag Communities Committee" "DWWTS campaign"
- "Expert talks" - Agriculture, water quality
- Fishing competitions, kick sampling
- Social Media- Twitter, website & facebook
- Maintain core location

Simple, Cost effective & innovative

- Cow Path/Fam Roadways
- Segregating Yard/areas diverting cleanwater
- Replace earhen banks for silage pits
- Water Harvesting equipment
- Protection of watercourses
- Creating Riparian/ arable margins
- Soil Sampling
- Nutrient Management Plan (NMP)

Expected Results, Returns & Performance

- Reduction in Bacterial Pollution
- Improvement in Ecological
- Compliance above Nitrates Directive
- Effeciencies on catchment farms
- Reduction in septic tank failures
- Local ownership, responsibility and appreciation for loal water environment

Engagement Education

- 2 'Citizen Science' course in Duncanon for farming/ wider community in 2017 (18 Participants)
- Participants learned how to monitor the water quality of local streams
- Focused SSCS- identyfing & scoring the invertebrates
- Huge interest and enthusiasm particularly for their own farms.

Field Trip Option 4: Workshop (Clayton Whites Hotel):

A Catchment Challenge, an interactive workshop on balancing competing demands on land functions

Functional Land Management (FLM) Workshops – Catchment Challenge

Lilian O'Sullivan[1], Ger Shortle[2] and David Wall[1]
[1]Teagasc, Crops Environment and Land-use Programme, Johnstown Castle, Co Wexford
[2]Teagasc, Advisory, Johnstown Castle, Co Wexford

Functional Land Management

The challenge to meet both food security and environmental sustainability has resulted in a confluence of demands on land within the European Union (EU). Functional Land Management (FLM) offers policy makers a framework support tool that seeks to optimise the agronomic and environmental returns from the land based upon the selective augmentation of specific soil functions. FLM recognises that soils deliver multiple functions simultaneously to society, namely:

1) food production,
2) water purification & regulation,
3) carbon sequestration,
4) the provision of a habitat for biodiversity and
5) the ability to absorb external organic nutrients such as sewage sludge or organic manure.

FLM is an integrative framework that takes a landscape approach thereby allowing agriculture and environmental sustainability to be considered together. Soil quality within FLM is the capacity of the soil to supply these soil functions sustainably, with demand defined by policy drivers. The introduction of the 'demand' concept within FLM therefore allows changes in soil quality to vary through a change in demand. In this way, FLM offers considerable possibility as a policy integrator for sustainability with potential to utilise existing policy instruments for FLM governance. The discrepancies in relation to the supply and demand for soil functions associated with scale described by Schulte et al. (2015) have implications for soil and land management: some soil functions must be managed at local field and farm scale, whilst others may be offset between regions with a view to meeting national or continental targets.

Function Land Management Workshops

A series of participatory FLM workshops have been conducted across a diverse range of stakeholders. The purpose of these workshops is to communicate the FLM concept and to challenge participants to take a holistic approach to the landscape. Furthermore, this provides the opportunity for often diverging stakeholders to work together, to find common solutions to satisfy the growing demands on the land using the FLM concept.

Within these workshops, participants are challenged to design the optimised catchment without constraints to achieve a range of targets in relation to the aforementioned soil functions, for example, to improve water quality in line with Water Framework Directive targets or to increase dairy production by 50%.

Overall, the development of an optimal catchment management scenario is achieved with a high degree of consensus with similar suites of land use change and management options proposed. The second workshop challenge is to consider the existing policy instruments, or gaps in policies that would be necessary for the optimised catchment to become a reality at field and farm level.

A larger degree of divergence typically occurs at this phase of the workshop emphasising the 'think-do gap' (O'Sullivan et al. 2018). However, a general conclusion is that targeting policies towards soil optimisation is appropriate. A mix of "hard" mapping approaches to "soft" approaches around education and knowledge transfer have been considered with increased knowledge transfer cited as essential. The adoption and modification of existing policy tools is generally preferred over the development of new policy instruments.

Functional Land Management Workshops– groups conducting the Catchment Challenge.

The workshops are set around a physical catchment model and this depersonalised setting facilitates enhanced collaboration while allowing a wide range of expertise and value judgements to be considered. Future research through the Horizon 2020 project LANDMARK has applied national case studies to other jurisdictions and will include workshops to understand the priorities of stakeholders based upon the local context.

The outcomes from a series of FLM workshops conducted with multiple stakeholders have been utilised as the basis of a scientific paper as follows;

O'Sullivan L., Wall, D., Creamer, R., Bampa, F., Schulte, R (2018) Functional Land Management: Bridging the Think-Do-Gap using a multi-stakeholder science policy interface. Ambio,47, 216-230. https://doi.org/10.1007/s13280-017-0983-x

Field Trip Option 5: Johnstown Castle: Gardens, Museum and Castle Tour

Johnstown Castle Estate, Museum & Gardens has a long and colourful story stretching over 800 years. Situated outside Wexford town in Ireland's south east, it is not only a significant property of national importance but a place of great romantic charm and tranquility. The spectacular lake walks, walled gardens and sculptures all offer the beautiful setting for the great 19th-century castle.

Johnstown Castle Estate, Museum & Gardens opened in summer 2019 as a brand new '3 in 1' visitor attraction – a significant addition for Irish tourism and Ireland's Ancient East. Conservation and upgrading works on the Gothic-Revival Castle have been undertaken and guided tours are now available for the first time on a daily basis, including the unique servants' tunnel at an incredible 86 metres long.

This new attraction also includes the Irish Agricultural Museum's exhibitions in the castle courtyard building. Visitors can also enjoy the walks in the stunning woodlands around the picturesque castle lakes with Gothic towers and statues. An additional fully accessible 1.5km lower lake walk opens in September for the first time in a hundred years with a new woodland children's play area.

The Irish Heritage Trust, an independent charity, was announced in 2015 as the successful applicant to work with Teagasc – the Agriculture and Food Development Authority & owners of the Johnstown Castle Estate – and the Irish Agricultural Museum, to oversee a capital development programme. The Trust is now the operator of this new and exciting visitor experience to benefit the wider community sustainably over the long term.

This first phase of conservation and development works is thanks to generous funding from the Department of Agriculture, Food & the Marine, and Fáilte Ireland. Much more work remains to be done in the coming years but for now, Johnstown's future is safeguarded. The Irish Heritage Trust plans to continuously reinvest in Johnstown Castle Estate, Museum & Gardens so that visitors and members experiences are constantly improving and changing according to the high standards expected in today's world.

Notes

Catchment Science 2019 is the third scientific conference hosted by the Agricultural Catchments Programme. This event will bring together scientists, regulators and practitioners engaged with water quality in rural catchments.

CATCHMENT SCIENCE 2019

AGRICULTURAL CATCHMENTS PROGRAMME

Achieving quality water in diverse and productive agricultural landscapes under a changing climate

Food production and environmental stewardship continue to be essential considerations from local to global scales. Food production for a growing world population and how this interfaces with the needs of a clean water resource and healthy biodiversity, and in the face of a changing climate is a challenge across the science-policy-producer-industry-consumer spectrum. For agriculture, the key challenge is for sustainable intensification.

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Department of Agriculture, Food and the Marine

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Agriculture and Food Development Authority

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