Institution: Ulster University

Unit of Assessment: Geography and Environmental Studies (14)

Title of case study: Changing the approach of water management across Ireland through the uptake of field-scale diffuse pollution pressure mapping

Period when the underpinning research was undertaken: 2011 - 2017

Details of staff conducting the underpinning research from the submitting unit:

Name(s):	Role(s) (e.g. job title):	Period(s) employed by submitting HEI:
Philip Jordan	Professor of Catchment Science	1999 - present
Paul Dunlop	Senior Lecturer in Remote Sensing and GIS	2004 - present

Period when the claimed impact occurred: 2017 - 2020

Is this case study continued from a case study submitted in 2014? N

1. Summary of the impact

Research from Ulster University (UU) has changed the way that public sector agencies, advisory services and farmers identify diffuse phosphorus pollution pressures on agricultural land in Ireland. Identifying these areas is essential for water management in farmed landscapes. Our innovative approach, which uses geographical information system (GIS)-based tools to detect hotspots of potential pollution within individual farm-fields, has been adopted in both Irish jurisdictions (north and south). This is regarded as a novel and important development for water management, implemented into new farm plans by 1,091 farmers in Northern Ireland [**I1**] and operationalised into a public sector tool for use across all farms (approximately 137,000) in the Republic of Ireland [**I2**].

2. Underpinning research

Eutrophication of freshwater bodies caused by phosphorus (P) loss from agricultural land continues to be a major environmental problem in Northern Ireland and the Republic of Ireland. Agricultural soils are implicated as one of the main P pressures on freshwater quality, but identification of specific P hotspots on farms and in river catchments has been a major challenge. This is because P hotspots occur when high soil P concentrations that are easily mobilised coincide with hydrologically sensitive areas that are prone to surface runoff. These 'critical source areas' (CSA) are diffuse across the landscape but mostly occur at or within individual farm fields. This is a scale where the conditions are difficult to predict due to small field sizes and the influences of micro-topography. However, the individual field is a meaningful scale for farmers to understand the nature of the soil P pressure. Furthermore, developing a tool that can accurately predict where these CSAs are at this small scale is seen as essential to increase farmer participation in managing this problem. It is also the correct scale for farm advisors to engage and advise farmers on a one-to-one basis, and for public sector organisations such as the Department of Agriculture, Environment and Rural Affairs (DAERA) in Northern Ireland and the Irish Environmental Protection Agency (EPA) to target and manage problem areas at regional and national scales.

In collaboration with Teagasc, the Irish Agriculture and Food Development Authority, UU researcher **JORDAN** identified the key challenges in obtaining and combining these CSA hotspot data across the island of Ireland [**R1; R2; R3**] (2011-2014). The data analysis needed

was to: (i) identify and model the influences of micro-topography on surface runoff pathways in an agricultural landscape of small field sizes; (ii) integrate a soil P factor, which is also of primary agronomic importance to farmers, at the scale of single fields; and (iii) isolate the synchronous P concentration and discharge data from seasonal high magnitude diffuse storm events originating from field surfaces. The challenges were subsequently overcome in collaborative work with published papers co-authored by **JORDAN** and **DUNLOP**. First, a spatial risk assessment of hydrologically sensitive areas was developed using high-resolution digital elevation data in four agricultural catchments (an average of 485 fields per sub-catchment) [**R4; R5**]. This research clarified the correct elevation data resolution to use in landscapes dominated by micro-topography and further used these findings to predict small areas prone to surface runoff. Second, areas prone to surface runoff were combined with field-by-field soil P concentration data in a validated geospatial model in the same catchments to map CSAs at the sub-field scale [**R6**] (2016). Crucially, these predictions of CSA risk were validated in [**R6**] using P concentration data captured during diffuse storm events using continuous, high-resolution river sampling approaches from the system designed by **JORDAN** [**R1; R2**]. It is the evolution of these ideas in [**R1**] (2011), [**R2**] (2012) and [**R3**] (2014) and development of the research culminating in outputs [**R4**] (2017), and particularly in [**R5**] and [**R6**] (2016) that has impacted the approach to identifying soil P pollution risk in the agri-environment across the island of Ireland. This has been a key development which means that CSAs of soil P pollution can now be identified effectively at a national scale by lead agencies and by farming communities.

3. References to the research

The following journal outputs have been subject to blind peer review by internationally-based editorial boards with significance, rigour and originality taken into account:

[**R1**] Wall, D., **Jordan, P.**, Melland, A.R., Mellander, P.-E., Buckley, C., Reaney, S.M., and Shortle, G. (2011). Using the nutrient transfer continuum concept to evaluate the European Union Nitrates Directive National Action Programme. *Environmental Science and Policy*, *14*(6), 664-674. https://doi.org/10.1016/j.envsci.2011.05.003

[R2] **Jordan, P**., Melland, A.R., Mellander, P-E., Shortle, G., and Wall, D. (2012). The seasonality of phosphorus transfers from land to water: Implications for trophic impacts and policy evaluation. *Science of the Total Environment* 434, 101-109. https://doi.org/10.1016/j.scitotenv.2011.12.070

[**R3**] Shore, M., **Jordan, P.**, Mellander, P-E., Kelly-Quinn, M., Wall, D. P., Murphy, P.N.C., and Melland, A. R. (2014) Evaluating the critical source area concept of phosphorus loss from soils to water-bodies in agricultural catchments. *Science of the Total Environment*, *490*, 405-415. https://doi.org/10.1016/j.scitotenv.2014.04.122

[**R4**] Thomas, I.A., **Jordan, P.**, Shine, O., Fenton, O., Mellander, P-E., **Dunlop, P.**, and Murphy, P.N.C. (2017). Defining optimal DEM resolutions and point densities for modelling hydrologically sensitive areas in agricultural catchments dominated by microtopography. *International Journal of Applied Earth Observation and Geoinformation, 54*, 38-52. https://doi.org/10.1016/j.jag.2016.08.012

[**R5**] Thomas, I.A., **Jordan, P.**, Mellander, P-E., Fenton, O., Shine, O., Ó hUallacháin, D., Creamer, R., McDonald, N., **Dunlop, P.** and Murphy, P.N.C. (2016). Improving the identification of hydrologically sensitive areas using LiDAR DEMs for the delineation and mitigation of critical source areas of diffuse pollution. *Science of the Total Environment. 556*, 276-290. https://doi.org/10.1016/j.scitotenv.2016.02.183

[**R6**] Thomas, I.A., Mellander, P-E., Murphy, P.N.C., Fenton, O., Shine, O., Djodjic, F., **Dunlop, P.** and **Jordan, P.** (2016). A sub-field scale critical source area index for legacy phosphorus management using high resolution data. *Agriculture, Ecosystems and Environment*, *233*, 238-252. https://doi.org/10.1016/j.agee.2016.09.012

4. Details of the impact

The development of research in [**R1**], [**R2**] and [**R3**], culminating in [**R4**], [**R5**] and [**R6**] has resulted in two national impacts on understanding, participation, and delivery of public services across both Irish jurisdictions. First, in Northern Ireland, our research has been used by DAERA to provide innovative field-scale mapped instructions on soil P management for 1,091 individual farmers in large river catchments [**I1**]. Second, applied as a public sector tool by the EPA in the Republic of Ireland, the research has influenced how agricultural land is now assessed and mapped for soil P pollution pressures in 190 priority catchments and across the Republic of Ireland as a whole (approximately 137,000 farms), and also how farmers are advised regarding mitigation approaches [**I2**]. This is the first time this type of field scale soil P CSA mapping approach has been adopted on a national scale in Europe. It has been used by the lead agencies across Ireland to significantly increase awareness and understanding among the farming sector of soil P pollution at meaningful spatial scales, improving the ability to make informed decisions by engaging farmers and farm advisors; and the technologies have been adopted into public services.

[I1] Bespoke critical source area farm plans in Northern Ireland

Water quality in Northern Ireland is affected by P from agricultural sources and the soil P pressure is recognised as particularly problematic by DAERA but difficult to identify within individual farms. UU's CSA mapping approach [**R4**], [**R5**] and [**R6**] was implemented by the Agri-Food Biosciences Institute (an executive non-departmental public body, sponsored by DAERA) in partnership with the Ulster Farmers' Union using EU Exceptional Aid Adjustment funding to assess the distribution of field scale soil P fertility and CSA risk **[C1].** Between 2017 and 2018, individual soil fertility and CSA maps were produced for 513 farmers and 7,700 fields and followed up with a further 578 farmers managing 9,600 fields **[C1].** The CSA maps indicated for the first time where P was at risk of runoff following fertiliser additions [directly from **R4**, **R5**] and where excessively fertilised soils were at risk [directly from **R6**]. The maps also indicated where specific points should be managed adjacent to watercourses and these were supplied as bespoke risk assessments for each farmer. An independent behavioural study commissioned by DAERA evidenced that 91.5% of farmers who adopted the mapping approach used the maps to specifically identify fields where there may be risk of nutrient runoff into a watercourse; this helped farmers adjust nutrient applications and stopped the application of slurry in high-risk areas **[C2].** The report also states that 77.6% of farmers used the runoff risk maps to decide where to establish a buffer strip. The report concludes that the P runoff maps "improved awareness and induced behavioural changes" among farmers; qualitative data from farmers stated that the "maps had made them conscious of land mineral content"; making them "less careless", and is helping them "move away from traditional ways". Prior to using the maps, they paid little attention to important conditions that could trigger nutrient runoff (e.g., weather conditions and high nutrient status). However, following use of the maps and the knowledge subsequently gained, they now "look at weather conditions, wet trampled ground etc." before applying nutrients [**C2**]. The research was recognised by DAERA's Deputy Secretary, Environment, Marine and Fisheries Group [**C1**] as providing "a new benchmark for soil P management across Northern Ireland", described as "strategic capacity building for NI" and has "provided a strong justification for implementing the methods across NI". For individual farmers, the Ulster Farmers' Union's Senior Policy Officer [**C3**] considered the CSA maps "a step-change in capability to help farmers understand and meet the challenge of managing our important rivers and lakes" and "one of the most important environmental resources…in recent years".

[I2] Critical source area operationalised tool for Irish river catchments

In the Republic of Ireland eutrophication of water bodies caused by P inputs from agricultural land is considered one of the more difficult pressures to manage. Further agricultural pressures have been reported in recent years and the Irish EPA has questioned the efficacy of one-size-fits-all regulatory approaches. As part of the EU Water Framework Directive Second Planning Cycle (2018-2021) in Ireland, the EPA proposed that a more spatially targeted approach to diffuse P pollution risk assessment and mitigation was required. A national network comprising a Local Authority Waters Programme (LAWPRO) of catchment scientists and an Agricultural Sustainability Support and Advice Programme (ASSAP) of advisors was established to take the targeted approach forward for both assessment and advice, respectively. Prior to UU research in [**R5**] and [**R6**], this targeting was limited to comparing sub-catchment assessments with water quality and could not be used to differentiate risk at the farm- and field-scale due to a coarse spatial resolution. Subsequently, the EPA "drew heavily on" the CSA research in [**R5**] and [**R6**] and it was "operationalized into a public sector GIS-based tool" between 2018 and 2020 for both LAWPRO and ASSAP personnel for sub-farm scale diffuse P risk assessment and mitigation advice. This is confirmed by the EPA's lead of the Catchment Science and Management Unit **[C4]**. This tool has been developed by the EPA for the whole Republic of Ireland and is being targeted in 190 priority river catchments. It has had a "critical influence on how Ireland now defines and manages diffuse nutrient pollution from agricultural land" and has "transformed our capability to manage this environmental pressure nationally" **[C4].** The research has influenced Teagasc's training provision for LAWPRO and ASSAP advisors on the identification of diffuse P pollution on the ground**.** The ASSAP Programme Manager for Teagasc has confirmed in **[C5]** that the "risk maps produced by the EPA using this (UU) research are a game changer for our work enabling us to target specific parcels of land over large catchment areas". At the level of the individual farmer, the maps have been utilised to inform and improve farm water management planning and practice, as captured by one such farmer **[C6]** thus: "it has been very useful to me as I have started to make plans as to how I can make changes on my farm that… impact on water quality and avoid the need for more regulation". This impact is confirmed at national level by the Chair of the Irish Farmers' Association Environment and Rural Affairs Committee **[C7]**: "We finally have a mapping tool that is of benefit to all farmers operating to produce food sustainably and that provides targeted on the ground advice for opportunities to manage water quality. This is of great benefit to the priority catchments where ASSAP focuses advice and also reaching more than 137,000 farmers nationally"**.**

5. Sources to corroborate the impact

[**C1**] Letter from the Deputy Secretary (Environment, Marine and Fisheries Group) Department of Agriculture, Environmental and Rural Affairs, Northern Ireland

[**C2**] Report "Behavioural impacts of Northern Ireland's Funded Soil Sampling and Training Evaluation report" prepared for the Department of Agriculture, Environment and Rural Affairs, Northern Ireland. Okumah et al. (2019) – section 3.2.7

[**C3**] Letter from the Senior Policy Officer Ulster Farmers' Union, Northern Ireland

[**C4**] Letter from the lead of the Catchment Science and Management Unit, Environmental Protection Agency, Republic of Ireland

[**C5**] Letter from ASSAP Programme Manager, Teagasc (Agriculture and Food Development Authority) Republic of Ireland

[C6] Email from individual farmer in the Republic of Ireland on the benefits for his farm water management planning and practice of utilising the EPA-produced risk map.

[C7] Letter from the Chair of the Irish Farmers' Association Environment and Rural Affairs Committee