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Agricultural Catchments Programme - nutrient pathways

Key external stakeholders:

Policy makers including Department of Agriculture, Food and the Marine, Department of the Environment and Local Government, Environmental Protection Agency and Teagasc research and advisory colleagues.

Practical implications for stakeholders:

This project contributes with information that will help policy makers to target mitigation measures.

Main results:

- Hydrological connectivity by surface (overland) or near-surface flow might not be as important in nitrogen (N) and phosphorus (P) transfer from land to water as is often assumed in some catchments of high permeability soils and aquifers.
- There are likely to be significant lag-times between implementation of a source measure and impact on water quality due to long time-scales that can be involved in below-ground nutrient transfers.
- Current Nitrates Action Programme (NAP) measures targeted at nutrient sources (soil nutrient status and nutrient inputs) may provide a more effective mitigation of nutrient loss over time in landscapes of high permeability, than supplementary measures such as buffer strips which target overland flow pathways (notwithstanding the multi-functional nature of such features).
- A method of quantifying N and P transfer to streams was developed using high-resolution hydro-chemistry data.
- Higher P exports were attributed to lower soil permeability, leading to flashier runoff (and P mobilisation into fast pathways), more so than to land use or the magnitude of the P source (soil P status).
- Between 29% and 40% of the P exports from two grassland and two arable catchments occurred during the closed period for slurry spreading, supporting the utility of the closed period to avoid incidental losses.
- Emerging high P concentrations during sensitive low flow Summer periods were attributed to loss of dilution of rural point sources.
- In a karst spring zone of contribution high P source (soil P status) and aquifer vulnerability did not elevate P in the emergent groundwater.
- Definitions of risk and vulnerability for P delivery in karst systems need further evaluation.

Opportunity / Benefit:

The output from this project contributes to the scientific evaluation of the effectiveness of the measures through an improved understanding of the nutrient pathways and will also provide a basis for any modifications to the measures.

Collaborating Institutions:

None

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1. Project background:

The Agricultural Catchment Programme (ACP) evaluates the impacts of European Union (EU) Nitrates Directive measures. The NAP in Ireland constrains the magnitude of the nutrient source pressure (through limits on livestock numbers and fertiliser use, for example) and minimises mobilisation potential (through closed periods for nutrient application and ploughing and slurry/manure handling and storage requirements, for example). This closed period takes account of the fact that diffuse nutrient mobilisation and transport is more prevalent in times of greatest hydrological action. Within the ACP pathway project we aim to provide information on when, where and how much of the nutrient is transferred to groundwater and stream water.

There are uncertainties in the definition of N and P transfer pathways within agricultural river catchments due to spatiotemporal variations such as water recharge and the farming calendar, or catchment soil and hydrogeological properties. A holistic insight into processes and spatiotemporal variability is thus required when estimating nutrient transfer pathways in catchments.

In Ireland many karst aquifers are classified as having poor status; contributing to the eutrophication of receiving waters and this status had been identified by the EU Commission and other authorities as being of particular concern. Therefore, to evaluate the efficacy of the NAP measures, a karst spring zone of contribution was included in the ACP.

2. Questions addressed by the project:

- When and where are nutrients (N and P) mobilised and transferred from source to ground water and surface water?
- How do nutrient pathways respond to different land management, soil, geology and season?
- Can we define the risks and vulnerability of P delivery in a karst spring zone of contribution?
- How can we target and improve mitigation strategies with our insight to nutrient pathways?

3. The experimental studies:

This study combined site specific pathway studies on focused study sites with catchment integrated studies in the catchment outlets in order to characterise N and P transfer pathways from four agricultural river catchments (two grassland and two arable) with different land management, soil drainage and geology as well as from a karst spring zone of contribution.

Data from four ACP river catchments were used to compare the magnitude and seasonality of N and P transfers using data from the catchment outlets where synchronous chemistry and hydrology data were

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gathered at high resolution (sub-hourly time scales). Monthly sampling of groundwater chemistry and high resolution monitoring of groundwater hydraulic gradients (gathered from representative focussed study sites), together with onsite weather data, allowed a coupling of surface and ground water.

In a karst spring zone of contribution the soil P source and pathway components of the nutrient transfer continuum were defined at a high spatial resolution and the inferred risk of P transfer was evaluated using observed P delivery to the primary emergent spring at a high temporal resolution. This was achieved by surveying soil P status in fields as well as mapping of all surface karst features and depth to bedrock, by sub-hourly monitoring of P concentrations and water discharge in the emergent spring, and by monitoring weather within the zone.

The approach involved monitoring, surveying, data analysis and modelling. The challenges are the complexities of scale involved that arise from the spatial variability of soil physical/chemical properties that determine the pathway, the temporal variability of rainfall and the nutrient transformations that occur in the soil.

4. Main results:

For a major Summer flow event in two river catchments with well drained soils, below-ground delivery pathways of N represented up to 97% of the total load, and up to 63% of the total reactive P and total P load. In these catchments, hydrological quick flow pathways were only 2–8% of total event flow but were efficient in delivering P to the stream. In two other catchments, with poor to moderately drained soils, up to 55% of the hydrological pathways were quick flow during a Summer storm flow event. This quick flow delivered up to 88% of the event flow P load. Background ground water flows were apparently mixed with point source inputs.

Even though quick-flow P transfer pathways (largely surface and shallow subsurface or artificial drain flow) appeared to dominate catchments with poorly drained soils and below-ground N transfer pathways dominated in catchments with permeable soils, a substantial P loss below-ground was found in the catchments with permeable soils. There was some evidence for N loss via ephemeral surface ditches in catchments with predominantly moderate to poorly drained soils.

Annual total phosphorus exports were low to moderate and not defined by land use as is usual in models which use export coefficients. For example, the two grassland catchments exported 0.541 kg/ha/yr and 0.701 kg/ha/yr and the two arable catchments exported 0.175 kg/ha/yr and 0.785 kg/ha/yr.

Assuming that P exports during the closed period for slurry spreading comprise mostly of residual soil P (*i.e.* not incidental losses from recently applied P), the proportion of annual P exported in this period was mostly related to the hydrological flashiness of the catchments. As these exports represented 29% to 40% of the annual exports (in approximately 25% of the time), the results support the utility of a closed period for avoiding incidental losses – or avoiding spreading times of higher runoff risk.

The data also show that the runoff flashiness is synonymous with soil permeability – a factor not accounted for in the regulations as a limitation to nutrient mobilisation and fast runoff flowpaths.

In a karst spring zone of contribution with a moderate to intensive grassland agriculture, a high proportion of soil P Index 4 fields (considered agronomically and environmentally excessive) and a high karstic connectivity potential, P concentrations in the emergent ground water were low and indicative of being insufficient to increase the P status of receiving surface waters.

Episodic P transfers *via* the karst conduit system did increase the P concentrations in the Spring during storm events but not above 0.035 mg total reactive P/L. This process is similar to other catchments where the predominant transfer is *via* episodic, surface flow pathways, but here the high buffering potential of the karst system delayed and attenuated the infiltrated runoff. Spring hydrographs indicated a large proportion of small fissure flow within the limestone bedrock, thus inferring a high potential for P attenuation.

In a karst spring zone of contribution, capture of conduit flows in datasets of intermittent water quality assessment may over-emphasise the influence of conduit flows on the overall status of the groundwater body.

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Current definitions of risk and vulnerability for P delivery to receiving surface waters should be re-evaluated as high source risk (soil P status) need not necessarily result in a water quality impact due to the nature of transport pathways and attenuation processes.

5. Opportunity/Benefit:

The principle stakeholders for this research are policy makers in the Republic of Ireland. This includes officials within government (DAFM, DEHLG), state organisations such as the EPA as well as farm and agri-food industry representatives and colleagues within Teagasc research and advisory directorates. The research conducted is helping informed policy debate on the review of the EU Nitrates Directive based regulations and a changed risk assessment.

6. Dissemination:

Main publications:

Mellander P-E., Melland A.R., Jordan P., Wall D.P., Murphy P.N.C. and Shortle G. (2012). Quantifying nutrient transfer pathways in agricultural catchments using high temporal resolution data. *Environmental Science and Policy*, 24, 44-57.
Jordan P., Melland A.R., Mellander P-E., Shortle G. and Wall D.P. (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.
Mellander P-E., Wall D.P., Jordan P., Melland A.R., Meehan R., Kelly C. and Shortle G. (2012). Delivery and impact bypass in a karst aquifer with high phosphorus source and pathway potential. *Water Research*, 46, 2225-2236.

Popular publications:

Melland A. and Mellander P-E. (2011). Everyone wins by reducing nutrient loss. *Today's Farm*, Jan/Feb, 2011.
Jordan P., Mellander P-E. and Melland A. (2011). Considerations of nutrient status in river systems. Geological Survey of Ireland, *Groundwater Newsletter* No. 49, 2011, ISSN-0790-7753.
Jordan P., Melland A., Mellander P-E., Wall D., Murphy P., Buckley C., Mechan S. and Shine O. (2011). Nutrient loads from agri-catchments: environmental risk or economic write-off? *TResearch*, 4(6), 12-13.

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