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Harmony High status waterbodies: managing and optimizing nutrients.

Key external stakeholders:
Policy makers, nutrient management planning, advisors, farmers.

Practical implications for stakeholders:

There is an urgent need to stem the degradation of high status sites because of the unique ecosystem services these areas deliver and their significance in supporting aquatic species (e.g. freshwater pearl mussel). Most of these sites are located in upland areas characterised by extensively farmed land, however relatively low intensity activities can become a significant pressure and have a disproportionate impact on high status sites relative to the same pressure on other sites. The outcome/technology or information/recommendation is that nutrient application to these soils requires a different management strategy compared to mineral soils due to the high potential for P transfer to water. Soil testing should include % organic matter to discriminate organic and mineral soils. A 'little and often' approach to P applications on high organic matter soils will avoid losses of P to water, and reduce financial losses due to over-applications. Nutrient management measures applied to soils will have lag times, which has implication for design of measures and monitoring effectiveness at farm, and catchment scale.

Main results:
A survey of farms in high status catchment showed P surpluses were common on extensive farm enterprises despite a lower P requirement and level of intensity. At field level, soils with high organic matter contents received applications of P in excess of recommended rates and when managed as mineral soils, the risk of P transfer from the soil to the surrounding waters greatly increases as added P tends to remain, to a greater extent, in the soil solution. Frequent but smaller P applications on organic soils significantly reduced the P loss in overland flow when rainfall events occurred shortly after P application.
Field by field Nutrient management strategies applied to soils will have lag times. The rate of soil P decline to environmentally sustainable levels varied at field scale, which has implication for design of measures and monitoring effectiveness at farm, and catchment scale.

Opportunity / Benefit:
Despite higher costs in the first years of correcting deficiencies in all nutrients (P, N and K), balancing soil pH on all fields, and avoiding P applications on high soil P fields and high organic matter fields, this is cost-effective and environmentally sustainable in the long term.

Collaborating Institutions:
NUIG, UU, AFBI.

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1. Project background:
There is an urgent need to stem the degradation of high status sites, not least because Ireland is in breach of a European Directive, but because of the unique ecosystem services these areas deliver and their significance in supporting aquatic species (e.g. freshwater pearl mussel) and overall catchment biodiversity. It is generally accepted that most of these sites are located in upland areas characterised by extensively farmed land, however relatively low intensity activities can become a significant pressure and a have a disproportionate impact on high status sites relative to the same pressure on an already degraded system. The predominant soils in these areas are peat soils and soils classed as peaty gleys and peaty podzols which previous studies have identified as vulnerable to phosphorus (P) loss due to their poor P retention capacities. Farmer preference for measures and their cost-effectiveness were considered, and whilst most famers preferred measures that required low labour input, some preferred measures that included soil analysis and nutrient management planning. This project will integrate research-based strategies with a comprehensive socio-economic evaluation of farmer acceptance and preference for measures

2. Questions addressed by the project:
- What are the current nutrient management and farm practices from participating farmers in high status catchments?
- Can we provide new knowledge to improve nutrient efficiency and management, for productive agricultural systems in sensitive catchments?
- What are the most effective measures from the perspective of cost-effectiveness and likelihood of adoption?

3. The experimental studies:
Farm Survey & Risk Assessment
The research combined fundamental research hypotheses in soil and catchment science across different scales with applied socio-economic methods to deliver the project objectives. The platform for this research was a number of case-study catchments selected using spatial analysis of high status sites described land use, soil type, soil drainage and livestock density in these catchments. This also provided the basis for an initial farm survey to assess the current nutrient management and farm practice in these areas. Three case-study areas were chosen for farm survey and these were the River Urrin, Co. Wexford, the River Allow, Co. Cork, and the River Black Co. Galway/Mayo. Within these catchments, a farm survey and soil sampling campaign was undertaken to obtain a realistic appraisal of farm practice and nutrient management in these areas, and assess the risks of P loss.

Fate of applied P to high organic matter soils on yield, P fractions and losses.
Six soil types, namely four organic and two mineral soils were collected, based on organic matter content and P status. The research compared and evaluated grass yield response to fertiliser P in a growth chamber study with % organic matter ranging from 8 to 76. Fertiliser P rates from 0 to 145 kg/ha were applied and dry matter yield of perennial ryegrass measured after a 4 month period. The distribution of P fractions in organic matter-rich soils was examined to determine whether build-up of P can occur. These soils have low sorption capacities for phosphorus (P), and may pose a risk of P loss to water if P applications to these soils coincide with runoff events. Little is known about the magnitude of exports of P in overland flow following application of P fertiliser onto these soils. Superphosphate (16 % P) was applied in single (equivalent to 30 and 55 kg P ha^{-1} applied at day 0) and split (equivalent to 15 and 27.5 kg P ha^{-1} applied in two doses at days 0 and 55) applications to an organic soil inclined at a slope of 6 % in a rainfall simulator experiment. The surface runoff of dissolved reactive phosphorus (DRP) was measured in controlled 30-min rainfall simulations conducted intermittently over an 85-day period.

Socio-economic evaluation of measures for high status waterbodies
Successful implementation of agri-environmental policies can prove challenging when faced with uncertainties and diverging opinions due to the variety of actors involved. This study explored a participatory

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approach including stakeholders with conflicting interests in the decision making for the P transfer mitigation policies. Farm data from a river catchment that recently lost its high status was used to provide of a list of targeted P transfer mitigation options by various stakeholder groups. The process involved the individual and group ranking of 15 P transfer mitigation options, specific for the catchment under study, by a group of experts, groups of farmers and through simulation modelling.
A wider survey of 1,000 Irish farms was conducted to examine the influence of both socio-economic (e.g. farmer age, education and farm size) and a range of socio-psychological factors on farmer intention to implement two separate NMP practices: 1) apply fertiliser on the basis of soil test results and, 2) follow a formally developed nutrient management plan. The research problem was framed using a conceptual framework based on the social-psychology theory of planned behaviour.
The cost of implementing a field-by-filed nutrient management measure was assessed using two case study farms, with different systems and intensity. A simulation was applied to evaluate the costs and time taken for an integrated measure to be effective. In this measure, P applications were avoided on excessively fertilised fields and soil fertility (N, P, K, pH) was optimised across all fields.

4. Main results:

Farm Survey & Risk Assessment

Data from 39 farms showed P surpluses were common on extensive farm enterprises despite a lower P requirement and level of intensity. At field scale, data from 520 fields showed that Histic topsoils with elevated organic matter contents had low P reserves due to poor sorption capacities, and received applications of P in excess of recommended rates. On this soil type 67 % of fields recorded a field P surplus of between 1 and 31 kg ha^{-1}, accounting for 46 % of fields surveyed across 10 farms in a pressured high status catchment. A P risk assessment combined nutrient management, soil biogeochemical and hydrological data at field scale, across 3 catchments and the relative risks of P transfer were highest when fertilizer quantities that exceeded current recommendations on soils with a high risk of mobilization and high risk of transport. This situation occurred on 21 % of fields surveyed in the least intensively managed catchment with no on-farm nutrient management planning and soil testing. In contrast, the two intensively managed catchments presented a risk of P transfer in only 3 % and 1 % of fields surveyed across 29 farms. Future agri-environmental measures should be administered at field scale, not farm scale, and based on soil analysis that is inclusive of OM values on a field-by-field basis.

Fate of applied P to high organic matter soils on yield, P fractions and losses.

When organic soils are managed as mineral soils, the risk of P transfer from the soil to the surrounding waters greatly increases as added P tends to remain, to a greater extent, in the soil solution. Fertilisation of organic soils should be tailored to meet plant requirements during the growing year in order to avoid over-fertilisation, which may result in an increased risk of environmental damage and additional economical costs for the landowners. From an environmental point of view, frequent but smaller P fertiliser applications in organic soils can have two positive implications: (1) it significantly reduces the P loads generated in overland flow when a rainfall event occurs shortly after P application and (2) plants have better access to soluble P throughout the year, resulting in higher herbage P concentrations for ruminants and enhanced grass yield as the P limitations for plant growth are overcome.

Socio-economic evaluation of measures for high status waterbodies

Significant disparities between perceived effectiveness were evident among groups of experts and farmers, with experts prioritizing problems related to connectivity issues, while farmers to soil compaction and erosion. The study highlighted the importance of knowledge transfer between interested actors and the need for integration of conflicting opinions in policy design.
The wider attitudinal survey of 1000 farms results reveal that attitudes, social norms, behavioural control and resource based issues significantly and positively influence intention to apply a detailed farm nutrient management plan. The results suggest that such initiatives must pay attention to demonstrating the benefits of NMP to enforce positive attitudes, Furthermore, providing technical assistance regarding implementing NMP and continuing to provide resources to implement NMP through agri-environmental schemes to farmers may also help to improve implementation levels.

In the simulation study, the nutrient management measure simulated on two case study farms was assumed effective when excessive soil P declined to a value where soil P can match the crop demand, and the time taken for this to occur ranged from 1 to 8 years. This varied spatially across each farm, from field-to-field, based on land use, initial available P and total P reserves. A policy implication of this study is the significance of measuring costs and effectiveness in the long term. Effectiveness in this study took up to 9

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years to be realised at field scale and informing farmers of the long term benefits of applying this measure, despite additional costs at the start, is key for the successful implementation and adoption of measures into the future. In order to increase adoption and implementation of sustainable agricultural practices, policies need to be equally focused on farm profitability and environmental quality. The recommendations arising from this work are as follows:

- Measures applied to soils will have lag times, which has implication for design of measures and monitoring effectiveness at farm, and catchment scale.
- Spatial variation in soil P showed that cost for soils testing and advisory services on a field-by-field basis is expensive in the first 2 years of implementing the measure but cost effective over the longer term.

5. Opportunity/Benefit:

Despite higher costs in the first years of implementation, correcting deficiencies in P, N and K and balancing soil pH on all fields, and avoiding P applications on high soil P fields and high organic matter fields is proven cost-effective in the long term.

6. Dissemination:

Main publications:

Evgenia Micha, William Roberts, Mary Ryan, Cathal O'Donoghue, Karen Daly. (2018). A participatory approach for comparing stakeholders' evaluation of P loss mitigation options in a high ecological status river catchment. Environmental Science and Policy. 84. 41-51.

Daxini, A., O'Donoghue, C., Ryan, M., Buckley, C., Barnes, A., Daly,K. (2018). Which factors influence farmers' intentions to adopt nutrient management planning? J. Environ. Manag. 224, 350-360.

Daly, K. Breuil, M. Buckley, C. O' Donoghue, C. Ryan M. and Seale C. (2017). A review of water quality policies in relation to public good benefits and community engagement in rural Ireland. European Countryside. 1. 99-115. DOI: 10.1515/euco-2017-0006

Roberts, W., Doody, D., Gonzalez, J, Jordan, P. and Daly, K. (2017). Assessing the risk of phosphorus transfer to high ecological status rivers: Integration of nutrient management with soil geochemical and hydrological conditions. Science of the Total Environment. 589, 25-35.

Roberts, W., Fealy, R., Doody, D., Jordan, P. and Daly K. (2016) Estimating the effects of land use and environmental characteristics on high ecological status in Irish rivers at different scales. Science of the Total Environment. 618-625

Gonzalez Jimenez, J. L., Healy, M. G., Roberts, W. M. and Daly, K. (2018). Contrasting yield responses to phosphorus applications on mineral and organic soils from extensively managed grasslands: Implications for P management in high ecological status catchments. J. Plant Nutr. Soil Sci. 1-9.

González Jiménez, J. L., Healy, M. G., and Daly, K. (2019). Effects of fertiliser on phosphorus pools in soils with contrasting organic matter content: A fractionation and path analysis study. Geoderma 338, 128-135

González Jiménez, J. L., Daly, K., Roberts W.M., and Healy, M. G. (2019). Split phosphorus fertiliser applications as a strategy to reduce incidental phosphorus losses in surface runoff. J.Environ.Mang. 242, 114-120.

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Bragina, L., Micha E., Roberts W.M., O'Connell, K., O'Donoghue C., Ryan, M. and Daly, K. (2019). Spatial and temporal variability in costs and effectiveness in phosphorus loss mitigation at farm scale: A scenario analysis. J. Environ. Manag. 245. 330-337.

Popular publications:

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