FROM SOURCE TO IMPACT: MEASURING THE NUTRIENT CASCADE RESPONSE TO EU POLICIES IN IRISH AGRICULTURAL CATCHMENTS

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Food production for a growing global population is a primary justification for intensive agriculture. However, maximising agricultural productivity with consideration of minimising environmental impacts is the central principle of sustainable intensification objectives. Environmental impacts from agricultural activities can include impairment of water resources, which includes losses of nitrogen (N) and phosphorus (P) from land to water and resulting declines in water quality through eutrophication. There are many examples across the developed and developing world where this has been observed as a result of increased use of agricultural nutrients as intensity increases. These impacts can also be delayed in some environments by significant lag times where the pressure increases and the impact might not occur until years or decades later. This is largely due to biophysical (largely hydrogeological and pedological) dynamics.

In the European Union (EU), the risk of nutrient pollution to water resources from agricultural land is managed through a range of voluntary schemes and mandatory measures. Voluntary schemes include, for example, stewardship schemes, administered by national government departments, and promotion through bottom-up education programmes and awareness training by rivers trusts. Mandatory measures usually fall under the EU Nitrates Directive regulations either in distinct zones or as whole-territory regulations. In the Republic of Ireland, mandatory regulations through the Nitrates Directive are on a whole-territory basis, linked by cross-compliance to farm subsidies. Similar to some other EU countries, Ireland regulates to manage both nitrogen (N) and phosphorus (P) use under this directive to offset eutrophication risks to fresh and near shore waters where P risk is considered to be more important in the eutrophication process.

Within a structure of other directives to manage water resources (for example, the Urban Waste Water Treatment Directive; the Bathing Water Directive), the Nitrates Directive is the main tool to manage the risk of agricultural nutrient pollution risk under the over-arching EU Water Framework Directive. In summary, the Irish regulations limit the timing and magnitude of N and P application and, to a certain extent, the modes of mobilisation from land to water. Farm-yards must comply with strict regulations on the management of point sources (and where significant grant aiding was made available from the Irish government) and nutrient application ‘closed periods’ during defined winter periods limit the exposure of incidental mobilisation in rainfall-runoff events. From an agronomic perspective, fertiliser nutrient use is limited to the specific requirements of crop types and, for P, the existing nutrient status of the soil. Organic nutrients are constrained through a limit on livestock intensity which is typically 170 kg organic N yr^{-1} (approximate to 2cows ha^{-1} in Ireland). Derogation to farm at a higher rate of up to 250 kg organic N yr^{-1} (approximate to 2.9cows ha^{-}

[1] in Ireland) is granted under a licence that includes tighter auditing of nutrient use and contingent on more detailed environmental inspections. Soil available P for agronomy is monitored using the Morgan P method and assessed in an index system where indices 1 and 2 require P build-up. Index 3 is considered optimum where P is added as replacement, and index 4 is considered excessive, indicative of no further crop response and so out of balance if further P is added. This principle is embedded in the Irish Nitrates Directive regulations where index 4 fields have to be managed to decline to index 3. Non-derogation farms are not required to soil test but in the absence of a test can only assume index 3 and so limit P application to replacement rates. Derogation farms must have a detailed soil P record of the holding and P fertiliser is applied according to the principles of build-up, replacement and decline, as appropriate the field bocks. These derogation plans are updated annually.

Ireland's mandate to use the Nitrates Directive as a programme of measures within the EU Water Framework Directive is conditional on a robust catchments based monitoring programme. To achieve this, exemplar catchments (c.10km^2) were chosen in an Agricultural Catchments Programme using a geo-spatial multi-criteria method that represented the most intensive agricultural enterprises across different soil and geological settings (www.teagasc.ie/agcatchments). Six were eventually chosen (Fig. 1) from a ranked list of fifty grassland and fifty arable catchments that isolated agricultural landuse away from other landuses (Fealy et al., 2010).

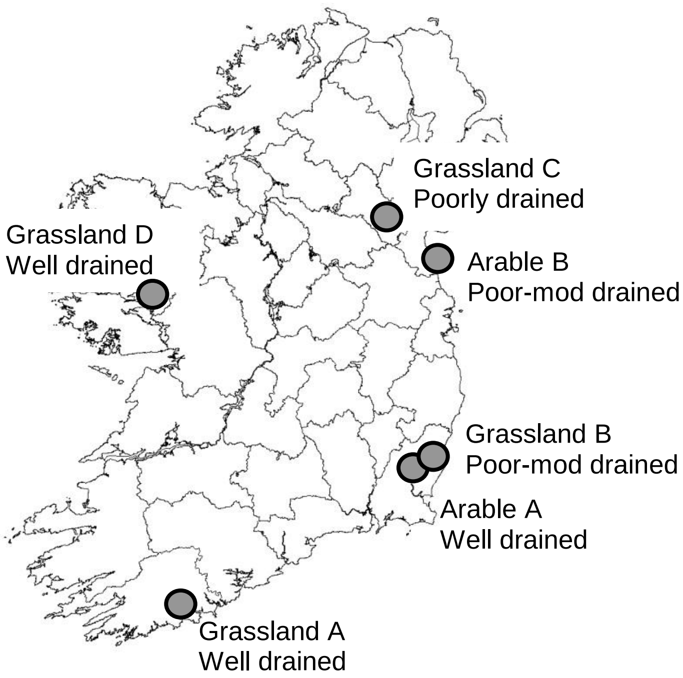

Figure 1. Map of Ireland showing the location and drainage characteristics of six experimental agricultural catchments.

Four of the catchments were grassland, reflecting the dominance of grassland agriculture in Ireland. An experimental design was devised that uses an intensive monitoring method to audit nutrient sources and mobilised nutrients in hydrological pathways that are delivered to catchment rivers. The emphasis of the experimental design was on a high resolution empirical approach to provide definitions of N and P use and status, understanding of pathways between land and water and definitions of risk and impact in catchment water bodies. At either end of this ‘nutrient transfer continuum’, for example, nutrient use and status was recorded at sub-field 2ha block scales and nutrient transfers in rivers at sub-hourly resolution using bankside analysers (Fig. 2). Both aquatic ecological status and farm economic metrics were also included in the experimental design as the two perceived impacts to nutrient source regulations (Wall et al., 2011). Cross-cutting the experimental design was a specialised advisory service to provide farm advice, collect nutrient management records and act as a technical and extension focus between the farming and science community.

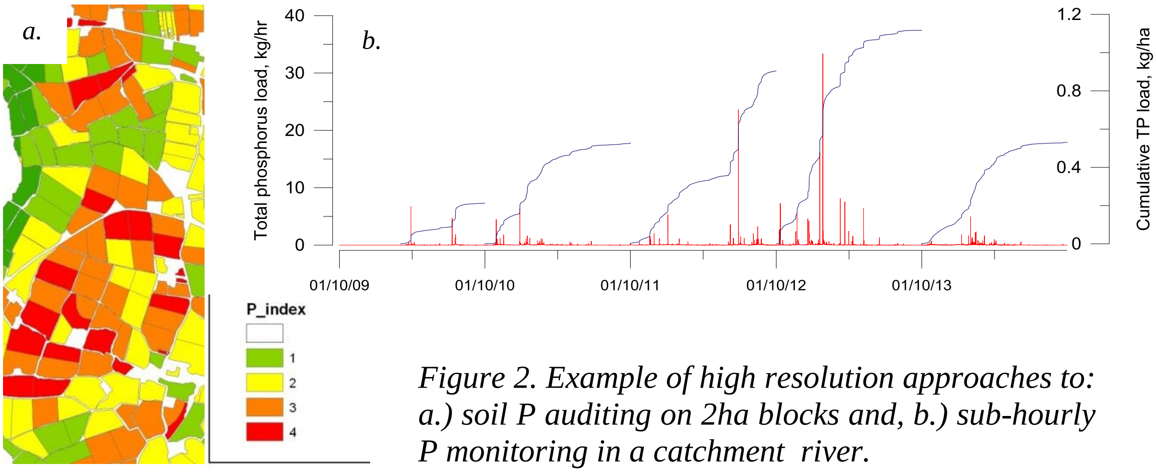

Figure 2. Example of high resolution approaches to: a.) soil P auditing on 2ha blocks and, b.) sub-hourly P monitoring in a catchment river.

Following several years of monitoring the nutrient cascade from source to impact, several important results and principles are emerging. Firstly, nutrient source use has changed and is evidenced by timing practice and soil nutrient status changes. For example, measured declines in excessively high soil P status largely follow modelled predictions for reduced P inputs although, in some catchments, this decline may be increasing the occurrence of fields with below optimal soil fertility.

Secondly, over the short-medium term, the changes in nutrient transfer to rivers as a response to changed nutrient use is more readily interpreted by investigating subtle changes in the nutrient status of hydrological pathways. Mass nutrient fluxes are always influenced by inter-annual hydroclimate variations and changes in rivers from catchment management will be slower to observe – longer term datasets will be important in this regard (Jordan et al., 2012). Aquatic ecological impact also appears to reflect this. Thirdly, In terms of economic impact, where excessive soil P was shown to decline in an exemplar dairy catchment, gross margins were not impacted and were comparable to the top 10% of performing dairy farms nationally. This finding adds to others showing that there may be an emerging decoupling between nutrient source use and impact.

Finally, it is becoming clear that the development and management of critical source areas, where the emphasis is on managing the hydrological mobilisation potential of nutrients, will be important to reduce the asynchronous response of catchments to changes in nutrient use and status at the field scale (Shore et al., 2013). The principle of this last point is gathering pace as an urgent consideration that includes both the role of source pressure risk and the mobilisation risk of nutrients, especially P, in individual field blocks.

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