ENVIRONMENTAL SCIENCE & POLICY 14 (2011) 664–674

available at www.sciencedirect.com

ScienceDirect

journal homepage: www.elsevier.com/locate/envsci

Using the nutrient transfer continuum concept to evaluate the European Union Nitrates Directive National Action Programme

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ARTICLE INFO

Published on line 28 May 2011

Keywords:
Catchments
Phosphorus
Nitrogen
Nitrates Directive

ABSTRACT

Agricultural catchments are where farm and landscape management interact with policy and science; especially with regard to the implementation and evaluation of agri-environmental regulation. The Nitrates Directive constrains nitrogen and phosphorus use and management on agricultural land across all EU member states and is one of the programmes of measures to mitigate eutrophication of water resources under the Water Framework Directive. All policies require a robust evaluation tool and for the potential diffuse transfer of nutrients from land to water, the nutrient transfer continuum concept is applied here as an example framework in small (6–30 km^2) catchments. The experimental design, methods and some early results are presented: auditing nutrient sources to established levels of compliance is the first stage and considers nutrient use and soil status. Studying pathways provides an understanding of linkages between the land sources and delivery in catchment rivers. This delivery is generally associated with episodic, high magnitude transfers and may not necessarily be the only or even primary ecological impact in rivers. Critiquing existing delivery/impact metrics and defining appropriate standards for identifying trajectories associated with diffuse nutrient transfer will be important in ensuring that agri-environmental policies are given a fair and thorough evaluation over a suitable time period.

1. Introduction

Agriculture in the EU contributes 40–80% of the nitrogen (N) and 20–40% of the phosphorus (P) entering surface waters (OECD, 2001) and the sector has a major challenge to curtail these losses in order to reach the EU target of good ecological status and protect potable water supplies in all surface waters by 2015. The European Union (EU) Nitrates Directive (ND) (OJEC, 1991) is a legislation that limits the use of agricultural fertilisers to agronomic optima and aims to minimise surplus nitrogen (N) and phosphorus (P) losses to the aquatic environment. In each member state, the ND is included as part of a suite of Programmes of Measures (PoMs) in the Water Framework Directive (WFD; OJEC, 2000). The Republic of Ireland and some other EU member states have chosen to implement the PoM on a whole territory basis whereas others have designated specific nitrate vulnerable zones (NVZs) and tailored measures for these areas. Where NVZs have been

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1462-9011/$ – see front matter
doi:10.1016/j.envsci.2011.05.003

designated and/or derogations from EU-wide constraints have been granted (the latter applies to Ireland), EU member states are required to monitor the effectiveness of their PoMs (Collins and McGonigle, 2008; OJEC, 1991 – article 5(6)). The regulation of land application, storage and management of nitrogenous compounds in fertilisers and animal manures in order to minimise losses to water bodies is central to the ND PoM in all EU states. However the ND has evolved to additionally include specific measures to address the management of P in some countries.

Methods for monitoring the effectiveness of the ND PoMs were reviewed by 12 EU member states with comparable climate and crops in 2009 (Austria, Belgium (Flemish and Walloon), Czech Republic, Denmark, France, Germany, Ireland, Luxembourg, the Netherlands, Slovak Republic, Sweden and the United Kingdom). Monitoring N in both surface water and groundwater was common to all territories; however, the sampling frequency and resolution was shown to vary largely. In the Flemish region of Belgium where N leaching to groundwater is a high risk, a network of monitoring wells is sampled twice per annum. This is done at a resolution of one well per 200 ha in the most vulnerable areas in conjunction with measurements of root-zone nitrate (NO_3^-) concentrations, measured at 90 cm depth from 2 ha land parcels in the autumn each year (Eppinger et al., 2009). The high density of the Flemish monitoring network allows the water quality data to be interpolated to predict the impacts of agricultural management on water quality across the whole of Flanders.

In Denmark monitoring strategies include sampling of vulnerable groundwater bodies, water supply wells (~6200) and five agricultural catchments (5–15 km^2). Nitrate concentration in root-zone water (1 m below the soil surface) is sampled 30 times per year at 32 sites and NO_3^- concentration in the upper groundwater (1.5–5.0 m) is measured 6 times per annum at 100 sites across these five catchments (Grant and Thorling, 2009). Data from plot/field-scale NO_3^- leaching studies, conducted in the agricultural catchments in conjunction with farm, soil and meteorological data from national archives, are used in N leaching process models (e.g. 'Daisy') to predict N losses from other catchments across Denmark.

In Germany groundwater is monitored at an average of one sampling point per 450 km^2 and sampling frequency varies (monthly to once per annum) according to the perceived NO_3^- leaching risks. Nitrogen balance data from ca. 50 farms are used for modelling soil NO_3^- surpluses and residence times in both the unsaturated zone and groundwater (Wolter et al., 2009).

Further to these examples of N monitoring, surface water monitoring approaches are being employed for evaluation of P loss mitigation policies. In Denmark P transfers in surface and subsurface flows are monitored from the five agricultural catchments and a 20 year time series has been used to demonstrate trends in stream concentrations and to model P loads (Kronvang et al., 2009). In Sweden P transfer in surface and groundwater are being continuously monitored using a combination of 13 instrumented fields (4–34 ha) and 27 small agricultural catchments, some of which were set up in the late 1980 s (Kyllmar et al., 2006). A conclusion from these studies was that many years of monitoring in each catchment were necessary to fully evaluate the relationship between changes in agricultural field activities and nutrient loads (Kyllmar et al., 2006).

In Ireland agriculture comprises 56% of the landuse by area (Central Statistics Office, 2009) and accounts for 8.6% of Gross Domestic Product (Richards et al., 2009). The main enterprises are grassland-based dairy and mixed livestock which comprise 90% of utilised agricultural area. Arable agriculture is limited to some free draining soils, especially in the east and south and primarily for mixed cereals and potatoes. According to the WFD prescribed ecological status assessment procedure, during 2007–2009, 84.7% of groundwater bodies, 52% of river sites, 47.3% of lakes and 46% of transitional and coastal water bodies that were monitored were of at least good status (McGarrigle et al., 2010). Agriculture was deemed the main reason for pollution in 47% of the impacted river sites with P asserted as the primary cause for eutrophication. Only 0.3% of groundwater bodies, one lake, and 3 coastal waters breached N standards from 2007 to 2009.

Phosphorus from both agricultural and non-agricultural sources is delivered to surface water body receptors via direct discharges, surface and near surface pathways and/or via groundwater discharge (Arnscheidt et al., 2007; Douglas et al., 2007; Daly, 2009). For most parts the Irish landscape has rolling topography and is highly dissected with rivers, streams and drainage ditches which are usually directly bordered by agricultural fields. The high drainage density, high annual rainfall (750–1250 mm in an east–west gradient, and exceeding 2000 mm in the mountainous areas) and relatively low annual potential evapotranspiration (20–50% of rainfall), facilitates the hydrological pathways for transfers of P, whereas N has a greater potential to be the major contributor to the failure of water quality standards via leaching in the well-drained intensive agricultural landscapes.

The Irish ND PoM and associated Good Agricultural Practise (GAP) regulations (SI 378, 2006 – updated to SI 101, 2009, Statutory Office 2006 and 2009) limit the magnitude, application timing, rates, storage and placement of inorganic fertilisers and organic manures. Farms can avail of derogation from the organic N loading cap of 170 kg organic N ha^{-1} to an upper limit of 250 kg ha^{-1} (Humphreys, 2008; Coulter and Lalor, 2008; Fealy et al., 2010) but the winter closed period for applications remains the same. An implementation period for the GAP regulations was 2006–2009 and this has been complemented with socio-economic and biophysical evaluation via an Agricultural Catchments Programme (ACP) to monitor the effectiveness of the policy and to inform a review of the National Action Programme in 2013. In the context of Irish landuse and landscape settings and the need to provide evidence of nutrient transfer trajectories from changed policies, this paper provides a description of the experimental design applied as an evaluation method and also discusses the implications of some first results.

2. Methodological design

2.1. *Source to impact concept*

The inception of the ACP as an evaluation process following the establishment of the GAP regulations meant that no prior