Extended Abstract

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Paper/Poster Title	Agricultural Non-Point Source Pollution Control – Synergies between Spatial Targeting and Precision Agriculture

Abstract prepared for presentation at the 98th Annual Conference of The Agricultural Economics Society will be held at The University of Edinburgh, UK, 18th - 20th March 2024.

Abstract	***200 words max***

This paper investigates the cost-effectiveness of agricultural non-point source (NPS) pollution control policies through a biophysical-economic model for the Eden catchment (N-W England). In the context of current UK agricultural reforms and recent technological progress in agricultural technology, policy recommendations are drawn from a purpose-built biophysical-economic model covering six key NPS pollutants (nitrogen and phosphorus to the river and groundwater, sediment, and carbon emissions). The model is characterised by a novel level of biophysical detail in the literature, including six farm types, six livestock types, 10 hydrological connectivity levels, five soil types, four slope types, 45 years of observed weather data, and 25 crops selected from 24 crop rotations.

Incentive-based fertiliser input taxes are found to be the most cost-effective policy mechanism. Notably, the presented results confirm previous findings in the literature of inelastic fertiliser demand. Consequently, high levels of taxation are required to achieve NPS pollution abatement. The novel assessment of Precision agriculture (PA) in the context of a catchment-scale biophysical-economic model highlights the synergies in necessary preconditions for PA and spatial targeting to be cost-effective. Policymakers should ensure sufficient heterogeneity in biophysical characteristics and land cover to safeguard successful spatial targeting and PA.

Keywords	Precision Agriculture, Non-Point Source Pollution, Non-Linear Optimisation
JEL Code	Q52, Q16 see: www.aeaweb.org/jel/guide/jel.php?class=Q)

Introduction	***100 – 250 words***

Over the last three decades, non-point source (NPS) pollution from agriculture has been recognised as a key factor in the significant water quality degradation observed in the EU and across the world (Spofford, Krupnick and Wood, 1986; Buckley and Carney, 2013; Casado et al., 2019). Economic research to support agricultural NPS pollution control efforts, has focussed particularly on biophysical-economic modelling. The current once-in-a-generation reform of UK agri-environmental policy following Brexit calls for up-to-date economic evidence on cost-effective agricultural NPS pollution control options. Further, the progressive use of information technology in agriculture has influenced yield and pollution outcomes as well as extended possibilities on agri-environmental policy. This paper contributes to this need for evidence by addressing the following gaps in the literature: (1) assessing Precision Agriculture (PA) and its synergies with spatially targeted policies and (2) extending previous work by explicitly considering hydrological connectivity levels and modelling a novel combination of crop rotations, weather data, soil-, and slope-types in ranking NPS pollution control options.

Methodology	*100 – 250 words*

The papers' theoretical structure relies on cost-effectiveness. Therefore, the objective of the policymaker is to minimise the cost of achieving a chosen level of pollution abatement given by the difference in catchment gross margins between the unrestricted and policy-restricted scenarios. Representative farms within the catchment are assumed to maximise their gross margin through their choice variables (crop choice, fertiliser application levels, and livestock choice) subject to the constraints of their exogenously given land endowment and production requirements (e.g.: feeding needs and labour requirements).

The biophysical-economic model is implemented in a non-linear programme and solved in GAMS. Yield and pollution data simulated through the Environmental Policy Integrated Climate (EPIC) model (Williams, 1990) using 45 years of observed weather data was fitted to Mitscherlich-Baule and polynomial functions respectively. Pollution functions account for hydrological connectivity in a framework based on SCIMAP outputs(Reaney and Wells (2014)). The assessment of PA focuses specifically on Variable Rate Nitrogen Application (VRNA) and assumes that through improved information, farmers adopting PA shift from within the production possibility frontier (PPF) onto the PPF. Following Colaço & Bramley (2018)'s comprehensive review of agronomic evidence, VRNA is modelled as an efficiency factor applied to the yield functions ranging from 5%-45%.

Model baseline results on cropland allocations, crop-, livestock-, and pollution-output are compared to levels observed for the catchment and in the literature. Overall baseline outputs are shown to match observed levels and expectations.

Results	*100 – 250 words*

Generally, policies' abatement behaviours are similar across the modelled pollutants. Policies largely show similar high cost-effectiveness levels up to around 20% abatement, which is achieved at a maximum social cost of around 5% of the catchment gross margin.

Overall, a combined Nitrogen (N) & Phosphorus (P) tax and an individual N tax provide the most cost-effective abatement for mid- to low-level regulatory targets across pollutants. Demand for fertiliser is found to be relatively price inelastic, as high levels of N taxation (~800% tax) are required to achieve reductions in N application (~10% consumption reduction).

An individual set-aside policy generally does not present the most cost-effective option. A mixed policy combining set-aside with N taxation is generally found to outperform an individual set-aside policy and shows the highest maximum-abatement-potential of the modelled policies across most pollutants.

Up to around 25-30% of baseline pollution abatement, spatially targeting (ST) the set-aside policy to the highest pollution risk slope-type 4, provides modest improvements to cost-effectiveness.

PA provides between 2% and 20% pollution reduction (efficiency factors 5%-45%) at a social cost between 4% and 3%. PA does not individually represent the most cost-effective approach to pollution abatement amongst the modelled policies.

For both ST policies and PA the below expectation cost-effectiveness may be explained by the lack of heterogeneity in the characteristics of the Eden catchment across (1) the distribution of soils and hydrological connectivity, (2) the soil-type compositions, and (3) the dominance of grassland as a land cover (78%).

Discussion and Conclusion	***100 – 250 words***

The findings of a high-performing N tax and very price inelastic demand align with economic rationale (Shortle and Dunn, 1986) and empirical findings (Schmidt et al. (2017)) respectively. Moreover, the higher cost-effectiveness of mixed policies at higher abatement targets mirrors results by Aftab, Hanley and Baiocchi (2010). Similarly, set-aside policies' lower cost-effectiveness for higher regulatory targets aligns with Kampas and White (2004).

The lower-than-expected cost-effectiveness of spatially targeted policies contrasts the significant abatement cost reduction Hasler et al. (2019) found for spatial targeting in the Danish Limfjorden catchment. Notably, the catchment displays high variation in N retention (0-100%, average 65%) and the authors stress the lower impact spatial targeting would have in catchments with lower heterogeneity levels in hydrological connectivity variables.

For PA the results contrast to Schieffer and Dillon (2015) who find PA produces increase in N consumption. This paper provides a more detailed bio-physical representation and shows a reduction in N consumption and increase in outputs. However, PA adoption is not found to be cost-effective which could be explained by the Eden catchment characteristics and farm size being held constant.

Key Policy Recommendations:

- A general reference point for policymakers: across pollutants and policies, cost-effectiveness is higher at mid-to-low regulatory targets
- Strategic implications of a very high N tax required to achieve abatement
- For ST and PA: heterogeneity in catchment characteristics (land cover, biophysical characteristics, etc.) is a necessary pre-condition for successful application
- PA is not individually cost-effective and further work needed on its benefits