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Integrating the economic and environmental performance of agricultural systems: A demonstration using Farm Business Survey data and Farmscoper

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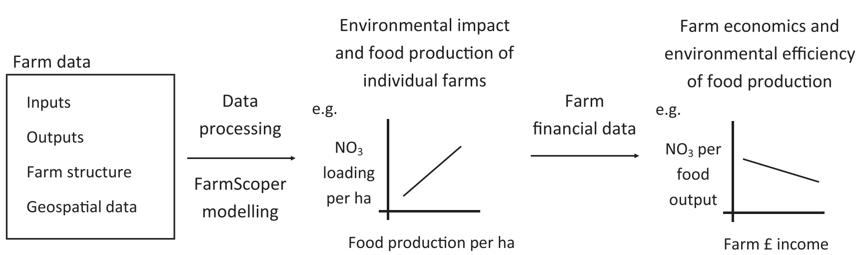
HIGHLIGHTS

- Sample data from an existing, economically rich, dataset were augmented to provide farm-level environmental indicators
- Nitrate loading, ammonia and greenhouse gas emissions were positively correlated with food energy production per hectare
- Greenhouse gas emissions and nitrate loading efficiency were positively correlated with profitability on cereal farms
- No environmental efficiency measures were positively correlated with profitability on dairy farms
- Scaling to the Farm Accountancy Data Network allows economic and environmental performance of farms to be tracked over time

GRAPHICAL ABSTRACT



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ABSTRACT

There is a continued need to monitor the environmental impacts of agricultural systems while also ensuring sufficient agricultural production. However, it can be difficult to collect relevant environmental data on a large enough number of farms and studies that do so often neglect to consider the financial drivers that ultimately determine many aspects of farm management and performance. This paper outlines a methodology for generating environmental indicators from the Farm Business Survey (FBS), an extensive annual economic survey of representative farms in England and Wales. Data were extracted from the FBS for a sample of East Anglian cereal farms and south western dairy farms and converted where necessary to use as inputs in 'Farmscoper'; farm-level estimates of nitrate, phosphorus and sediment loadings and ammonia and greenhouse gas emissions were generated using the Farmscoper model. Nitrate losses to water, ammonia and greenhouse gas emissions were positively correlated with food energy production per unit area for both farm types; phosphorus loading was also correlated with food energy on the dairy farms. Environmental efficiency indicators, as measured by either total food energy or financial output per unit of negative environmental effect, were calculated; greenhouse gas emission efficiency (using either measure of agricultural output) and nitrate loading efficiency (using financial output) were positively correlated with profitability on cereal farms. No other environmental efficiency measures

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were significantly associated with farm profitability and none were significant on the dairy farms. These findings suggest that an improvement in economic performance can also improve environmental efficiency, but that this depends on the farm type and negative environmental externality in question. In a wider context, the augmentation of FBS-type data to generate additional environmental indicators can provide useful insights into ongoing research and policy issues around sustainable agricultural production.

1. Introduction

Contemporary agricultural production systems face a significant challenge if an acceptable balance between production and environmental impact is to be achieved (Foley et al., 2011). To gain some sort of level of acceptable 'food security', agriculture needs to provide for both a growing and increasingly affluent global population (Godfray et al., 2010). However, security of food supply is increasingly threatened by environmental challenges and competition for resources, particularly land for non-food uses such as biomass for fuel (Tilman et al., 2011). These production challenges must therefore be met at the same time as managing the environmental impacts of farming. The significant negative environmental effects of agriculture, such as greenhouse gas emissions and nutrient loss to water, must be limited to some extent (Balmford et al., 2012), while provision of beneficial ecosystem services, for example supporting and regulating services such as soil formation and pollination, must be enhanced (Firbank, 2009).

Addressing these challenges requires consideration of multiple effects that act on multiple components of complex agricultural systems: systems that also involve people – farmers, advisors and other stakeholders – who have economic and other objectives that they wish to fulfil. In order to assess these integrated impacts and appraise changes in agricultural practices or policy interventions, quantitative metrics or indicators are needed, for all outcomes of interest - for example, greenhouse gas emissions as a measure of environmental impact. Direct on-farm measurement on a sufficient number of farms would require significant financial and technological investment in monitoring equipment and is especially difficult for non-point source environmental pollutants, such as those associated with agricultural inputs like nitrogen (nitrous oxide, nitrate, ammonia). To overcome these difficulties, mechanistic modelling of agricultural systems can be used to estimate values of important pollutant loads from available farm information. In the UK, the decision support tool 'Farmscoper' (Farm SCale Optimisation of Pollutant Emission Reductions) uses farm structure and physical input information to estimate production of a range of pollutants at individual farm level from a range of mechanistic models (Gooday and Anthony, 2010).

The mechanistic modelling approach is dependent on the quality and availability of direct (on-farm), or secondary information sources. Collection of on-farm information through surveys or other approaches tailored to specific model requirements will generate a richer dataset for modelling (Firbank et al., 2013), but can be time consuming for the assessor and/or farmer and presents challenges in ensuring sufficient scope in farm types and farm locations visited. Furthermore, it is difficult to collect realistic and comprehensive economic information without access to – what are from the farmer's perspective – sensitive farm financial records. As noted above, agents involved in agriculture, most notably farmers, will have economic (and social objectives) that will influence their willingness to adopt practices that have the potential to enhance or mitigate the positive and negative effects of agriculture on the environment. Thus, the environmental enhancement of an existing, economically rich data set is an attractive option.

The Farm Accountancy Data Network (FADN) was launched in 1965, following EU Council Regulation 79/65, to provide business information on European agricultural holdings and assess the effects of the Common Agricultural Policy (CAP) on farm incomes: of the five original objectives of the CAP, the main social objective was and in practice continues to be "to ensure a fair standard of living for farmers" (European Parliament, 2017). To these ends, FADN data are collected at the individual farm level and are primarily composed of accountancy records, but some physical information and details of farm structure are also available. FADN now represents a large resource of agricultural information, with almost 50 years of economic data. The consistency of the FADN dataset allows assessment over time and between different EU member states. Data collection is handled by liaison agencies within each state. In the United Kingdom this organisation is the Department for Environment, Food and Rural Affairs, and in England and Wales FADN data is collected through the Farm Business Survey (FBS). The FBS surveys circa 2300 farms every year, covering a representative sample of farm types and sizes, providing an excellent agricultural data resource.

A great advantage of generating environmental indicators using the FBS and more widely, FADN or other accounting data, is that it enables both economic and environmental performance to be measured. This is particularly helpful as it helps to operationalise concepts such as 'Sustainable Intensification' (SI). SI has been interpreted in different ways, but a useful definition from the perspective of potential users of the concept – most obviously farmers and extension agents - is given by the RISE Foundation: "Sustainable Intensification means simultaneously improving the productivity and environmental management of agricultural land" (Buckwell, 2014). Although measurement of productivity is in principle straightforward – the change over time in output per unit of agricultural resources used to produce that output – in agriculture this is quite difficult to achieve in practice. Indeed, the fundamental concept driving FADN is the difficult task of relating inputs to their specific outputs on farms with mixed enterprises and production periods that span months, in the case of poultry, or years, in the case of more extensive beef production systems. Measurement of the effect of environmental management - across a wide enough range of environmental impacts - is more difficult without some form of modelling approach. Therefore, it would be attractive if the mechanistic modelling described above could be used to enhance or 'augment' the quality of the environmental information available for individual farms within the FADN and FBS databases and this is the approach that we use here, using the Farmscoper tool as an example. If the resulting information is sufficiently reliable, farmers, extension agents or other stakeholders can assess the extent to which performance is improving across both environmental and economic performance measures.

Most farmers in the UK are familiar with the idea of benchmarking performance through what are termed 'unit costs of production' – cost per tonne of wheat or litre of milk for example. Expressing environmental impact per unit of output is thus an attractive way of presenting environmental information to farmers. This also captures the spirit of SI as described by Buckwell (2014): an improvement in SI can be achieved through either an increase in output for a given environmental impact; or a reduction in environmental impact for a given output. Furthermore, by comparing these environmental efficiency indicators with farm structural information, economic performance or social factors such as membership of buying groups or level of education, we can begin to grasp why some farms may perform better than others, in order to highlight the ways in which SI might be improved, through policy instruments or knowledge exchange programmes.